BANCA D'ITALIA
EUROSISTEMA

Temi di Discussione

(Working Papers)

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Number 1162

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The purpose of the Temi di discussione *series is to promote the circulation of working papers prepared within the Bank of Italy or presented in Bank seminars by outside economists with the aim of stimulating comments and suggestions.*

ISSN 1594-7939 (print)
ISSN 2281-3950 (online)

Printed by the Printing and Publishing Division of the Bank of Italy

REAL EXCHANGE RATE MISALIGNMENTS IN THE EURO AREA

by Michael Fidora,[*] Claire Giordano[†] and Martin Schmitz*

Abstract

Building upon a behavioural equilibrium exchange rate (BEER) model, estimated at a quarterly frequency since 1999 on a broad sample of 57 countries, this paper assesses whether both the size and persistence of real effective exchange rate misalignments from the levels implied by economic fundamentals have been affected by the adoption of a single currency. A comparison of real misalignments across different country groupings (euro area, non-euro area, advanced and emerging economies), shows they are smaller in the euro area than in its main trading partners. However, in the euro area real disequilibria are also more persistent, although after the global financial crisis the reactivity of real exchange rates to past misalignments increased, and therefore the persistence decreased. In the absence of the nominal adjustment channel, an improvement in the quality of regulation and institutions is found to reduce the persistence of real exchange rate misalignments, plausibly by removing real rigidities.

JEL Classification: E24, E30, F00.
Keywords: real effective exchange rate, equilibrium exchange rate, monetary union, regulation.

Contents

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1 Introduction[1]

An economy's price or cost competitiveness is commonly measured by the real effective exchange rate (REER). For euro area countries the ECB (Schmitz et al., 2012) calculates and publishes Harmonised Competitiveness Indicators (HCIs), which are conceptually equivalent to REERs. The REER is calculated as a weighted geometric average of the nominal exchange rates of a country vis-à-vis the currencies of its main trading partners, deflated by relative prices or costs. These deflators are expressed as indices rather than as levels, providing information solely on price competitiveness *dynamics*. In order to appraise a country's competitiveness position it is therefore preferable to assess the REER's distance from its benchmark, or equilibrium, *level*. The challenge is to construct a suitable yardstick against which to appraise a country's price-competitiveness performance.

Based on a behavioural equilibrium exchange rate (BEER) model, in the spirit of Clark and MacDonald (1998), we specifically account for the structural determinants of real exchange rates (RERs). In particular, we estimate a reduced-form relationship between RERs and key macroeconomic fundamentals since 1999 at a quarterly frequency for 57 euro and non-euro area countries, a vast sample when compared with the existing literature. This allows us to derive RER and REER equilibrium values, as well as to compute the corresponding misalignments. Previous contributions to this strand of the literature, amongst many applications, include Maeso-Fernandez, Osbat and Schnatz (2001; 2004), Schnatz, Vijselaar and Osbat (2003), Lane and Milesi-Ferretti (2004), Ricci, Milesi-Ferretti and Lee (2013) and Bussière et al. (2010).

In the medium run, REERs should move in the direction of their equilibrium, thereby annulling any misalignment, although significant deviations from the equilibrium may persist if there are nominal or structural rigidities which hinder adjustment. Persistent deviations from purchasing power parity (PPP) signal international competitiveness issues. We indeed find evidence of significant REER misalignments in the countries under study. In particular, by comparing real misalignments across different country groupings, we assess whether the adoption of a single currency in the euro area, via the introduction of a nominal rigidity in the form of fixed exchange rates, has spurred these disequilibria. Thereby, this paper contributes to the open debate on the effect of flexible vs. fixed exchange rate regimes on the size and persistence of real currency misalignments, kicked off by Friedman (1953), as well as to the literature on inflation differentials and the persistence of inflation within the euro area (see, e.g., Altissimo, Ehrmann and Smets, 2006; Angeloni and Ehrmann, 2007;

[1] We are grateful to Christoph Ellermann for excellent research assistance. We thank two anonymous referees, Nektarios Aslanidis, Mariarosaria Comunale, Riccardo De Bonis, Valerio Della Corte, Juan Luis Diaz del Hoyo, Ettore Dorrucci, Silvia Fabiani, Stefano Federico, Alberto Felettigh, Jorgo Georgiadis, Federic Holm-Hadulla, Pavlos Karadeloglou, Hans-Joachim Klöckers, Klaus Masuch, Giacomo Oddo, Chiara Osbat, Peter Praet, Frank Smets, Livio Stracca, Roberto Tedeschi, Cédric Tille and Bernhard Winkler, as well as participants at ECB seminars and at the 2017 ICMAIF 2017 conference, 2017 INFINITI conference XXIV Villa Mondragone International Economic Seminar and the 32nd EEA congress for highly valuable suggestions and comments. Any error is the responsibility of the authors. The views expressed herein are those of the authors and not of their institutions. An earlier version of this paper has been published as Fidora, Giordano and Schmitz (2017).

de Haan, 2010). Moreover, this paper explores the link between institutions and real exchange rate adjustment, contributing to the surprisingly scanty literature on the topic (see, amongst others, Nouira and Sekkat, 2015).

Our main findings are the following. First, misalignments within the euro area are found to be smaller than those of other advanced countries and of emerging economies, suggesting that the suppression of the nominal adjustment channel is not necessarily conducive to larger misalignments. This result is in line with findings in Berka, Devereux and Engel (2014) and in Bergin, Glick e Wu (2017). Second, the reactivity of REERs to past misalignments within the euro area has been smaller than in other countries, suggesting more persistent misalignments (as in Huang and Yang, 2015), but only in the period prior to 2009. Since 2009 the persistence of misalignments in the euro area has indeed decreased. Third, we find that better-quality regulation and institutions increase the sensitivity of REERs to past disequilibria, thus reducing their persistence, plausibly by lowering both the degree of "tolerance" towards REER disequilibria and the extent of real rigidities in the economy.

The structure of the paper is the following. Section 2 briefly outlines the theoretical and empirical literature on the links between a country's exchange rate arrangement, on the one hand, and the nature of real exchange rate misalignments, on the other. Section 3 describes the specification of the BEER model, as well as the dataset employed; next, it reviews the estimation technique and provides estimation results. Section 4 first examines the magnitude of estimated REER misalignments for various country groupings under different nominal exchange rate regimes. It then compares the persistence of REERs within the euro area to that of the other countries, and explores the role of regulation and institutional quality in REER adjustment. Section 5 draws up some conclusions.

2 Exchange rate regimes, institutions and real exchange rate misalignments

From a theoretical standpoint, the relationship between exchange rate regimes and real currency disequilibria is ambiguous. According to Friedman (1953), flexible exchange rates promote cross-country price convergence when prices of goods are sticky and impair the adjustment of the economy in the face of shocks.[2] On the other hand, fixed exchange rates or the adoption of a common currency, by removing exchange rate uncertainty and lowering transaction costs (in particular, currency conversion costs), increase the transparency of price differentials that could be arbitraged away, foster cross-border trade in the goods market and hence induce faster international price convergence

[2] This claim holds under at least two strong assumptions. First, final users of imported goods, in particular consumers, face prices that are fully flexible in their own currency and adjust instantaneously to changes in nominal exchange rates, vis-à-vis sticky prices in the exporter's currency (i.e. the currency in which exports are invoiced). Second, capital is immobile across countries so that demand for foreign currency only arises to pay for imported goods. As discussed by Berka, Devereux and Engel (2012), these assumptions are not realistic. Indeed there is evidence in the trade literature that there is pricing to market and that prices are rigid in the local (destination) currency, such that there is low pass-through from changes in the exchange rate. The latter do not therefore affect export prices in destination countries and hence do not induce changes in the demand for exports, so that the exchange rate does not play the allocative role in adjustment envisaged by Milton Friedman (Devereux and Engel, 1998; Engel, 2000). Moreover, international capital flows are far from negligible in today's words.

(Mundell, 1961).[3] Furthermore, since capital markets are open in most countries, the price of foreign exchange is not only the price that balances supply and demand for traded goods, but also an asset price which reflects expectations of future fundamentals and risk premia. In this respect, Flood and Rose (1999) develop a theoretical model that assumes that exchange rates are more volatile than macroeconomic fundamentals and regards asset market shocks as the dominant factor driving volatile exchange rate fluctuations when exchange rates are flexible. The elimination of flexibility in the nominal exchange rate might therefore remove a source of destabilising financial or non-fundamental shocks which lead to large and persistent relative price deviations when nominal prices adjust more slowly than the nominal exchange rates (Engel and Rogers, 2004; Berka, Devereux and Engel, 2014; Bergin, Glick and Wu, 2017). Related to this point, Mundell (1961) moreover emphasised that a broader currency area reduces the scope for speculation and hence volatility in foreign exchange markets since, in thicker markets, single speculators are less likely to affect exchange rates.

In the empirical literature no consensus on which type of exchange rate regime is more conducive to smaller real misalignments has been reached either. Some analyses confirm that REERs can be largely misaligned, irrespective of the exchange rate regime (see, e.g., Coudert, Couharde and Mignon, 2013). Dubas (2009) instead points to larger misalignments under flexible exchange rate regimes in emerging economies, whereas Coudert and Couharde (2009) and Holtemöller and Mallick (2013) show that misalignments are larger when the currencies of emerging economies are pegged.[4]

The empirical evidence is ambiguous not only concerning the size, but also the persistence of misalignments. Indeed, the speed of mean-reversion of REERs to their equilibria has been found to be faster, comparable or slower in fixed vs. flexible nominal exchange rate regimes, with no dominant result. The empirical strategies adopted to analyse the issue of persistence have been mainly two-fold. On the one hand, historical regime-switching events have been exploited to account for differences in the speed of adjustment of REERs: studies have focused on a sample of advanced economies in the pre- and post-Bretton Woods periods (Bergin, Glick and Wu, 2014) or on a number of euro area countries before and after the introduction of the single currency (Huang and Yang, 2015; Bergin, Glick and Wu, 2017). An alternative empirical approach has been to explore the persistence of misalignments in a panel of countries with different exchange rate arrangements within the same sample period, as in Mussa (1986), Parsley and Popper (2001), Bissoondeeal (2008) and Berka, Devereux and Engel (2012). Owing to the time-span considered in this paper (focused on the post-

[3] Some scholars have argued that currency unions go far beyond the elimination of exchange-rate variability and that there should be a large discontinuity in estimated trade gains going from small variability to the certain and committed absence of exchange-rate fluctuations that a currency union implies (Frankel and Rose, 2002). Rose (2000) presented the first systematic attempt to quantify the effects of the currency union on trade and famously found, later confirmed in Frankel and Rose (2002), that a currency union triples bilateral trade between currency union members and that every 1 percent increase in a country's overall trade (relative to GDP) raises income per capita by at least one-third of a percentage point. More recent estimates, discussed later on, however significantly downplayed the trade gains from the adoption of the euro.

[4] This macroeconomic literature, to which our paper relates has been complemented by studies that use disaggregated data on goods, such as Berka and Devereux (2010) and Berka, Devereux and Engel (2012).

1999 period, due to data availability), compensated by the vast country sample underlying our model, which includes both euro and non-euro area countries, we mainly adopt this second empirical strategy and assess differences in the size and persistence of misalignments between euro area countries, on the one side, and the remaining countries in our sample, on the other side.

One disadvantage of this approach is that country heterogeneity usually has important implications not only on the exchange rate arrangement adopted but also on the speed of correction, and failure to take account of these conditions will result in a spurious relationship between the exchange rate regime and the speed of exchange rate adjustment (Huang and Yang, 2015). By controlling for country-specific changes in economic fundamentals as well as for country fixed effects, we partially overcome this drawback. Moreover, we test for the role of regulation and institutions in affecting the sensitivity of REER movements to past misalignments, so as to investigate alternative channels of adjustment other than the nominal exchange rate.

Institutions may indeed affect REER adjustments via at least two channels. The first relates to the political economy of sustained REER misalignments. Firms and economic agents in general have different attitudes towards real exchange rates: exporters are likely to be against overvalued currencies, whereas importers are penalised by undervalued currencies; similarly, firms operating in tradable sectors are more prone to suffer from positive REER misalignments than enterprises active in the non-tradable sector (documented on firm-level survey data by Broz, Freiden and Weymouth, 2008). Rodrik (2008) argues that weak institutions exert "taxes" on both the tradable and the non-tradable sectors, yet to a larger extent on the former, leading to a misallocation of the economy's resources, an under-sized tradable sector and sub-optimal growth. Under these circumstances real undervaluation can promote economic growth. On the other hand, as discussed in Christiansen et al. (2009), in countries with better institutions the political process may be less likely to favour certain groups of interest with respect to others and are therefore less keen on tolerating misaligned real exchange rates and more active in correcting existing disequilibria. In particular, Nouira and Sekkat (2015) find a significant, negative relationship between democratic accountability and real currency misalignments in a panel of emerging economies. Accountability indeed exposes policymakers to the sanction of voters and therefore leads to more active corrections of currency misalignments.

The second channel through which regulatory and institutional quality can affect the degree of persistence of REER misalignments concerns the extent of structural rigidities in the economy. Countries need to be flexible to allow relative prices to adjust to shocks (see, for example, Franks et al., 2017; Culiuc and Kyobe, 2017). Prices and wages, and therefore REERs, can adjust more quickly in the absence of frictions. The latter may however be present due, amongst other factors, to strict product and labour market regulation, an inefficient judicial system, a corrupt environment, all factors which distort the efficient allocation of production factors across firms (on the presence of input misallocation in the EU explained by these factors see Gamberoni et al., 2016 and Gamberoni, Giordano and Lopez-Garcia, 2016).

Finally, an extensive literature has explored the effect of REER misalignments on export performance and/or economic growth. This literature too is not at all clear-cut (see Eichengreen, 2008 for an overview) and presents significant endogeneity issues. In principle, REER disequilibria can negatively affect export performance, in that, on the one hand, real overvaluation implies a loss in a country's price competitiveness and a misallocation of resources towards the non-tradable sector (e.g. Edwards, 2000). On the other hand, a persistent real undervaluation could result in an economic overheating and higher import prices, thereby exerting an upward pressure on domestic prices and generating an expected currency appreciation, which in turn could hamper export performance (e.g. Jongwanich, 2008). Moreover, undervalued REERs can bring about "beggar-my-neighbour" effects. However, a strand of the relevant empirical literature has also found an asymmetric effect of REER misalignments on economic development: in the presence of weak institutions and market failures, an undervalued real currency may promote economic growth, whereas overvaluation is generally linked to low-growth episodes (Rodrik, 2008). For a panel of EU countries Comunale (2017), however, finds a significant negative long-run relationship between REER misalignments (whatever their sign) and GDP growth. According to Habib, Mileva and Stracca (2016), there is a significant positive (negative) effect of real depreciation (appreciation) on real per capita growth in emerging economies, but no effect in advanced countries. The present paper is silent on the REER misalignment-growth nexus, which is left for future research.[5]

3 A behavioural equilibrium exchange rate (BEER) model

3.1 The structure of the BEER model

Abstracting from transaction costs, foreign trade and arbitrage in integrated and perfect-competition goods markets should ensure that the law of one price (i.e. absolute PPP) holds for any good *i* so that the latter should be the same across countries when converted into a common currency. In a reduced-form setting, bilateral real exchange rates should therefore be equal to zero in logarithms:

(1) $p_{t,i} = p^*_{t,i} + e_t \Rightarrow rer_{t,i} = p_{t,i} - p^*_{t,i} - e_t = 0$

where, at time *t*, $p_{t,i}$ ($p^*_{t,i}$) is the log of the domestic-currency (foreign-currency) price of good *i*, e_t is the log of the nominal exchange rate (here expressed as units of domestic currency per unit of foreign currency) and $rer_{t,i}$ is the log of the real exchange rate of the domestic currency vis-à-vis the foreign currency referring to good *i*.

If absolute PPP holds for individual goods, it holds also for any basket of goods, as long as it is identical across countries. However, if countries have different consumption baskets with weights and

[5] Nor does this paper examine the welfare implications of REER misalignments and of exchange rate arrangements. Among other things, the mapping between welfare and exchange rates depends on whether financial markets are complete and prices are flexible and whether exporters predominantly follow "local" or "producer currency pricing". Our goal is more limited, in that we seek to determine in a statistical sense whether larger REER misalignments and a less rapid adjustment occur in the euro area currency union with respect to the "rest of the world". Given the large attention that external imbalances have received in recent years, this research question should still be relevant for economic policy making.

mixes of goods varying across economies, then PPP no longer holds. In order to allow for a constant price differential between baskets, the empirical literature has thus generally focused on relative PPP, that is:

(2) $p_t = p_t^* + e_t + \theta \Rightarrow rer_t = p_t - p_t^* - e_t = \theta$

where e_t is as previously defined, p_t (p_t^*) is the log of the domestic-currency (foreign-currency) price of a basket of goods, rer_t is the real exchange rate of the domestic currency vis-à-vis the foreign currency, such that an increase implies a real appreciation of the domestic currency against the foreign currency, and θ is a constant that reflects the differences in consumption-basket composition across the two countries. The notion of relative PPP thus assumes that real exchange rates are stationary, i.e. mean-reverting. Empirically, however, there is ample evidence of systematic deviations from both absolute and relative PPP (see, e.g., Imbs et al., 2002; Kilian and Zha, 2002; Taylor and Taylor, 2004; Taylor, 2006), leading to the well-known "PPP puzzle" (Rogoff, 1996). The traditional findings of Meese and Rogoff (1983a) on the unpredictability of exchange rates at short horizons are generally undisputed, and thus the empirical literature has converged toward explaining the behaviour of real exchange rates at medium or long-term horizons.

Amongst various empirical approaches briefly discussed in Annex A, BEER models attempt to explain the documented time-varying long-run deviations from PPP by modelling RERs or REERs as a function of economic fundamentals. In particular, this set of models determines equilibrium RERs empirically, based on the hypotheses of mean reversion in the long run and on several different assumptions concerning the long-run drivers of these equilibria.

We estimate a BEER model in which the dependent variable (rer_t) is the bilateral RER of each currency vis-à-vis a numéraire currency, for which we choose the euro, defined in such way that an increase corresponds to a real appreciation of the domestic currency vis-à-vis the euro.[6] The estimated elasticities to fundamentals are then employed to derive the equilibrium rates as fitted values, against which actual bilateral RERs may be appraised. Finally, we aggregate (equilibrium and actual) bilateral RERs into (equilibrium and actual) REERs based on the trade weights used by the ECB to compute its official REERs and HCIs (Schmitz et al., 2012; ECB, 2015).[7]

[6] Using bilateral exchange rates as the dependent variable, instead of REERs as in some of the literature, has the advantage that the former capture relative prices in a cleaner fashion in that they are unaffected by changes in trade weights (Adler and Grisse, 2014). At the same time, the approach ensures the multilateral consistency of estimated misalignments given that the effective misalignment of each currency can be calculated as a weighted average of its bilateral exchange rate misalignments.

[7] The most updated ECB trade weights, which we use in this paper, are available at: https://www.ecb.europa.eu/stats/pdf/exchange/updatedtradeweights201708.pdf?8c1ede593e3bfaf5b2b42f0dad342832. As in Turner and Van't dack (1993) and Felettigh et al. (2016) and according to current best practices, the ECB trade weights are given by a weighted average of import weights and double export weights. Import weights are given by the relative importance of each trading partner in a country's total imports. Double export weights measure both the direct competition between exporters and domestic producers in a particular export market and the competition between exporters of two different countries in a third market. The "cost" of these comprehensive trade weights is the limitation of the number of trading partners for which the necessary data are available. We confirm that our country sample is vast, given these data constraints (see, e.g., Couharde et al., 2017 on the topic).

Similarly to Clark and MacDonald (1998), our starting point is the basic concept of arbitrage condition, which holds under perfect capital mobility, free trade and rational expectations of uncovered real interest parity (that is, neglecting risk premia):

(3) $E_t(rer_{t+1}) - rer_t = -(r_t - r_t^*) \Rightarrow rer_t = E_t(rer_{t+1}) + (r_t - r_t^*)$

where r_t and r_t^* are the domestic and foreign real interest rates and E_t denotes the expected value at time *t*. By rearranging the terms in equation (3), the observed RER in time *t* is thus a positive function of the expected value of the next-period RER (or "equilibrium" RER in the absence of any further shocks to the domestic and foreign economies) and of the current real interest rate differential. If domestic interest rates are above foreign interest rates, then the domestic exchange rate should depreciate against the foreign exchange rate in order for investors to be indifferent between holding domestic and foreign assets. Clark and MacDonald (1998) assume that the unobservable expected value of the RER is determined by a vector of economic fundamentals, so the actual RER ultimately depends both on these drivers and on the real interest rate differential.

Table C1 in Annex C provides an overview of the explanatory variables employed in recent BEER-model studies. In order to select the relevant economic fundamentals, we adopt Hendry's general-to-specific approach by sequential elimination of the statistically insignificant variables suggested by the literature at a 10 percent confidence level in most specifications (which, as we shall see, differ according to the cost/price index used to deflate the dependent variable, the bilateral RER). In such an exercise, as in all BEER models, the economic fundamental variables cannot be interpreted to exhibit a causal effect on RERs. Nonetheless, this approach can help determine the extent to which RERs diverge from their historical link with economic fundamentals.

One of the most popular explanations of the deviations from (absolute) PPP is due to Balassa (1964) and Samuelson (1964). The two scholars posited that relative prices of non-traded and traded goods are inversely related to the relative productivity in the two sectors, assuming free labour mobility across sectors and tradable goods prices that are determined in the global market. In particular, a rise in productivity in the tradable sector entails an increase in wages in the tradable sector, yet also bids up wages in the non-tradable sector, without however a corresponding rise in productivity. This leads to a higher general price level, which in turn implies a real appreciation in the currency. By controlling for the Balassa-Samuelson effect in the BEER model, one can assess whether the real exchange rate of a country is in line with its stage of economic development.

In order to empirically investigate the Balassa-Samuelson effect, sector-specific productivities should be employed.[8] However, when productivity growth in the non-tradable sector is constant across

[8] Ricci, Milesi-Ferretti and Lee (2013) for example construct measures of labour productivity in tradables and non-tradables for 48 countries over the period from 1980 to 2004. However, as noted by Schnatz, Vijselaar and Osbat (2003), in an era of globalisation, the boundary between tradable and non-tradable sectors is becoming ever more blurred; many traded goods embody large non-traded components and the dividing line is often endogenous (Obstfeld and Rogoff, 2001). The arbitrariness of the split between the tradable and non-tradable sector is indeed recognised also by Ricci, Milesi-Ferretti and Lee (2013).

countries, which is a reasonable approximation as discussed in Annex B, aggregate labour productivity measures may be employed, as shown in the simplified formalization of the Balassa-Samuelson model in Annex B. Since the BEER model is estimated at a quarterly frequency for a large set of countries, owing to data availability, we are constrained to employ aggregate, as opposed to sectorial, measures. Using GDP per capita as a proxy of productivity to measure the Balassa-Samuelson hypothesis – as is often done in the literature for a dearth of data on employment – implies introducing an additional strong assumption of a stable labour participation rate, absent in the case of using actual productivity measures. We therefore adopt two alternative measures of total-economy productivity differentials, either relative productivity per employee or relative GDP per capita (which in both cases we will refer to as *relprod*), in order to investigate any significant differences across the two measures. In this respect, we follow Schnatz, Vijselaar and Osbat (2003) and Bénassy-Queré, Béreau and Mignon (2009), which are the few studies that, to our knowledge, have similarly tested for alternative proxies of the Balassa-Samuelson effect.

Whereas the Balassa-Samuelson model assumes that the REER depends entirely on supply factors, demand-side variables that may impinge on the equilibrium exchange rate through time are also typically considered in BEER models, based on the observation that, in contrast to the assumptions underlying the Balassa-Samuelson model, labour is not necessarily mobile across sectors in the short run. First, openness to trade (*relopen*), i.e. the sum of exports and imports as a share of GDP, is used, as is standard in the literature, as a proxy of the intensity of trade restrictions, which may have an effect on real exchange rates since higher trade barriers and lower openness to trade lead to a rise in domestically produced goods' prices and thereby to an appreciation (Goldfajn and Valdes, 1999; Ricci, Milesi-Ferretti and Lee, 2013).

Second, an improvement in relative terms of trade (*reltot*), e.g. an increase in overall export prices, should, on the one hand, lead to a positive income or wealth effect in the domestic economy. The ensuing rise in domestic demand will indeed increase domestic prices and therefore lead to a real exchange rate appreciation (Neary, 1988). Moreover, a rise in export prices implies a substitution effect, with domestic producers increasing their tradable production. The ensuing increase in wages in the tradable sector expands to the non-tradable sector, leading to a rise in the general price level and to an appreciation of the real exchange rate (Melecký and Komárek, 2007). On the other hand, however, given the increase in the relative price of exports to imports, domestic agents could shift their demand towards imported goods and the domestic currency would have to depreciate to restore the external equilibrium. Empirically, however, it has been documented that the negative effect of the terms of trade is outweighed by the positive effect, owing to the fact that imports and domestic goods are imperfect substitutes (De Gregorio and Wolf, 1994; Couharde et al. 2017), thereby explaining the positive sign generally associated to this variable (again see Table C1 of Annex C).

Third, fiscal policy, here captured by final government expenditure relative to GDP (*relgov*), can affect the real exchange rate through a composition effect in a multi-good economy even in the presence of Ricardian equivalence (Froot and Rogoff, 1992; Obstfeld and Rogoff, 1996). Indeed, higher government consumption, which is generally biased towards the non-tradable sector, could affect the real exchange rate positively via a higher demand for non-traded goods and a rise in their prices (see also Hinkle and Montiel, 1999). On the other hand, however, excessive government spending may cast doubt on the sustainability of fiscal policy and undermine the confidence in a country's currency, leading to a depreciation (Melecký and Komárek, 2007).[9]

Finally, as discussed above referring to Clark and MacDonald (1998), an increase in real interest rate differentials (*relishort*) should be associated with capital inflows and therefore an appreciation. The full specification of our model is the following:[10]

$$(4) \quad rer_{i,t} = \beta_{1i} relprod_{i,t} + \beta_{2i} relopen_{i,t} + \beta_{3i} reltot_{i,t} + \beta_{4i} relgov_{i,t} + \beta_{5i} relishort_{i,t} + \mathrm{FE} + \varepsilon_{i,t}$$

where *i* indicates the country, *t* a quarter in the period1999Q1-2016Q3,[11] FE are fixed effects[12] and $\varepsilon_{i,t}$ is a random error.

As shown in equation (1), RERs are a function of both the nominal exchange rate of country *i* and of relative prices, in our case represented by one of the following indices or deflators: i) consumer price

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[9] A recent paper (Miyamoto, Nguyen and Sheremitov, 2017) finds a positive relationship in emerging economies and a negative link in advanced economies.

[10] For variables expressed as percentage shares, differences relative to the euro area were taken, otherwise log differences relative to the euro area were employed. Relative explanatory variables are indeed needed since the RER is a bilateral concept which cannot be determined only by a country's own characteristics, but must also reflect "foreign" characteristics (Phillips et al., 2013). While a number of authors find that the choice of the numéraire currency does not significantly affect the computation of REER equilibrium levels and misalignments (see, e.g., Bénassy-Queré, Béreau and Mignon, 2009), Housklova and Osbat (2009) argue that – although in a bilateral estimation set-up the choice of the numéraire will not qualitatively affect the coefficient estimates – the aggregation of bilateral misalignments into effective misalignments will lead to estimates that are affected by the effective misalignment of the numéraire currency at all points in time. The authors suggest using time fixed effects in order to control for the effective misalignment of the numéraire, whereas in this work controlling for cross-sectional dependence by adding cross-section averages of both the dependent and independent variables, as discussed in Section 3.2, should at least partly account for this potential bias. In fact, it turns out that there is no qualitative difference in the estimated real effective misalignments when using the US dollar, the Swiss franc or the Japanese yen as a numéraire currency, for which results are not reported but available upon request.

[11] For monitoring and analysis purposes and in line with Maeso-Fernandez, Osbat and Schnatz (2001) and Hossfeld (2010; see Table C1 in Annex C), we chose to estimate our BEER model on quarterly, as opposed to annual, data in order to have timely REER misalignment estimates. The increase in the number of observations relative to an annual dataset also improves the efficiency in the BEER model estimation. As also discussed in Bussière et al. (2010), the main drawback of adopting high frequency data is thinner data availability, and therefore in our case the restriction of the estimation window to the most recent years (since 1999).

[12] These include both country fixed effects and cross-section means of both the dependent and explanatory variables. The inclusion of country fixed effects is necessary because the RERs employed in this paper are (mainly) index numbers. However, with fixed effects the predicted and thus equilibrium RERs are by construction on average equal to the long-run real exchange rate mean, or in other terms each country's regression residuals are forced to average to zero over the sample period. This implies that equilibrium estimates may be heavily influenced by past actual RER levels. Results are thus less reliable, and tend to underestimate the extent of misalignments, for countries with a short sample span or which have experienced structural breaks over the period considered (Phillips et al., 2013). We, however, partially overcome this shortcoming by adopting (quarterly) data since 1999, which is a relatively long time-span if compared to the existing empirical literature (see Table C1). Moreover, one of the deflators we consider (the PPP) is an actual price level; when it is employed, country fixed effects may be in principle dropped from the estimation of regression (4), although also the explanatory variables expressed as index numbers, such as terms of trade, need to be excluded in this case to obtain reliable estimates. Moreover, PPPs suffer from large measurement issues, such as the aggregation bias of items' prices, items' representativity and quality matching (ICP, 2007; Deaton and Heston, 2010). This confirms the usefulness of comparing results based on all five available deflators in our analysis. Whereas it is not possible to compare actual REER indices or their estimated equilibrium values across countries, it is instead indeed possible to compare REER misalignments, expressed as the percentage-point deviation of REERs from their equilibria, across countries. Finally, the inclusion of cross-section averages is discussed in Section 3.2, to which we refer.

index (CPI), ii) PPP deflator, iii) producer price index (PPI), iv) GDP deflator, v) unit labour costs in the total economy (ULCT). In spite of the ongoing debate on the topic, there is indeed no consensus on the optimal price index to employ in the construction of RERs and REERs (Chinn, 2006; Christodoulopoulou and Tkačevs, 2014; Giordano and Zollino, 2016; Ahn, Mano and Zhou, 2017), which makes it necessary to provide a range of misalignment estimates based on alternative indices. As seen in Table C1 of Annex C, however, BEER models have mainly been estimated based on CPIs or PPPs. To our knowledge, this is the first attempt to consider such a wide range of deflators.[13]

The countries considered include both advanced and emerging countries, accounted for around 91 per cent of global GDP (expressed in US dollars) in 2016 and coincide with the 57 countries employed in the construction of the ECB's official effective exchange rates and HCIs (see Table C2 of Annex C for the full list).[14] In comparison with the studies reported in Table C1, the sample coverage is very large. Since our model is estimated at a quarterly frequency, seasonally adjusted quarterly data are used when available; in the absence of the latter, yearly data are linearly interpolated. The following hierarchy of sources for national account data is followed: Eurostat, the International Data Cooperation dataset of the European Commission, IMF and OECD, IMF International Financial Statistics, IMF World Economic Outlook. The latter dataset is also used for the data related to PPPs and the terms of trade. Nominal exchange rates and price/cost indices are sourced from the ECB.[15] CPIs, PPP and GDP deflators are available for all 57 countries in the sample (the so-called "broad sample"), whereas PPIs are available only for 39, mainly advanced, economies and ULCT deflators for 38 (the so-called "narrow sample"). Nominal three-month money market rates were deflated with the CPI to obtain real interest rates.

3.2 A review of the panel cointegration tools employed

The empirical literature has mainly employed reduced-form models in which a long-run, cointegrating relationship between RERs and economic fundamentals is estimated. Our estimations are run in a panel cointegration setting, which has the advantage of exploiting both the time and cross-section dimension, thereby in principle achieving more significant and robust estimates. As discussed in Housklova and Osbat (2009), Hossfeld (2010) and Bussière et al. (2010), however, panel regressions, as opposed to single-country estimations, give rise to at least two technical issues concerning a)

[13] An exception is the study by Ruscher and Wolff (2009), which assesses the determinants of differently deflated REERs, although not in order to construct REER equilibrium values, but rather to gauge the role of the non-tradable sector in a country's external adjustment.

[14] In turn, these are countries for which data are of sufficient good quality and availability. As discussed in section 3.2., the estimation procedure adopted, which allows for heterogeneous elasticities across countries, helps tackle the disadvantage of using a large panel linked to the vast country heterogeneity it features (see section 3.2 of this paper and Adler and Grisse, 2014 for a discussion of this topic).

[15] In particular we take quarterly averages of the nominal exchange rates. We employ official exchange rates, even though in emerging economies these can greatly differ from the rates actually used in transactions. This does not appear to be an issue for our sample of countries, in that it does not include economies in which black market exchange rates are known to apply and because, as Reinhart and Rogoff (2004) argue, multiple exchange rate arrangements generally applied only until the 1980s.

country heterogeneity and b) cross-section dependence. We believe that the choice of the estimation procedure employed in this paper satisfactorily tackles these two issues, as discussed more in detail further on. Far from being a fully-fledged review of panel cointegration techniques, this section outlines the rationale of the estimation tools employed to estimate our BEER model.

As the empirical literature finds that real exchange rates and their underlying fundamentals are mostly integrated of order one, panel unit root tests are first implemented to explore the stationarity properties of the selected variables. Amongst the most common procedures to test for unit roots in the panel setting we consider two different tests. The traditional Im-Pesaran-Shin (IPS) unit root test allows for heterogeneous autoregressive parameters across units. It tests the null hypothesis that all variables follow a unit root process, i.e. H_0: $\rho_i = 0$ for all units *i* against the alternative hypothesis of stationarity H_A : $\rho_i < 0$. Under the alternative hypothesis, some (but not all) of the countries may have unit roots. The IPS test statistic is constructed as the mean of individual Dickey-Fuller t-statistics of each unit in the panel. The IPS test works, however, under the strong assumption of cross-sectional independence. Pesaran's (2007) cross-sectionally augmented IPS (CIPS) test not only allows the autoregressive parameters to be heterogeneous across countries, but also has the advantage that it accounts for country interdependence. Cross-sectional correlation in residuals may be the result of common shocks and unobserved components that are included in the error term. Given the economic and financial integration of the countries in our panel, strong interdependencies between cross-sectional units are likely to occur and if cross-sectional dependence is neglected imprecise estimates and, at worst, a serious identification problem can occur. To account for this cross-section dependence and thus for unobserved common factors, augmented Dickey-Fuller regressions are further augmented to include the cross-section means of the lagged dependent variable and of its first differences. The null hypothesis of non-stationarity of the CIPS test is then tested against the alternative hypothesis that a fraction (not necessarily all) series are stationary.

Once having tested for non-stationarity, the next step is to test for cointegration. Pedroni (1999) provides seven tests for cointegration under a null of no cointegration, which run Augmented Dickey Fuller tests on the residuals of a static fixed effects model with one or more non-stationary regressors, allowing for panel heterogeneity. These include four panel cointegration tests based on the within-dimension of the panel and three group-mean panel cointegration tests based on the between-dimension. Because we do not wish to impose cross-country restrictions on coefficients, we use the Pedroni group-test-statistics, which rely on the assumption of different unit-root processes in the individual countries. The test statistics are constructed using the residuals from the following estimated cointegration regressions:

(5) $y_{it} = \alpha_i + \delta_i t + \beta_{1i}\, x_{1i,t} + \beta_{2i}\, x_{2i,t} + \dots + \beta_{Mi}\, x_{Mi,t} + e_{i,t}$

where M is the number of regressors and the slope coefficients β_{Mi} are allowed to vary across countries.[16] Allowing for heterogeneous slopes, and therefore for different relationships between RERs and economic fundamentals across countries, is particularly important given that our sample covers a vast number of (heterogeneous) countries. The residuals of the original cointegrating regression $\hat{e}_{i,t}$ are then used to estimate the appropriate autoregression regressions of the residuals themselves, with error term $\hat{u}_{i,t}$. The residuals of this autoregressive regression are then used to compute the long-run variance of $\hat{u}_{i,t}$. Together with the simple variance of $\hat{u}_{i,t}$ the test statistics are then constructed and appropriate mean and variance adjustment terms applied.

To estimate the long-run relationship among integrated variables in a heterogeneous panel framework, a standard estimator is the panel dynamic OLS (DOLS) procedure, proposed by Stock and Watson (1993) and further developed by Kao and Chiang (2000) in a panel setting. As seen in Table B1, this estimation procedure is often employed in the BEER model literature and it involves a parametric adjustment to the errors of the cointegration equation (5). In particular, it consists in adding to equation (5) lags and leads of the explanatory variables in order to absorb endogenous feedback effects from the dependent variable to the regressors.[17] A DOLS regression is conducted for each unit and the results are then combined with a group mean approach. We will use this estimator, however, only as a robustness check.

In our baseline regressions indeed we employ the common correlated effects mean group (CCEMG) estimator developed by Pesaran (2006) and Kapetanios, Pesaran and Yamagata (2006), which, as discussed in Bussière et al. (2010), is robust both to heterogeneous slopes across countries and to cross-section dependence. Following Eberhardt (2012), the empirical setup can be formulated as follows:

(6) $y_{it} = \beta_i x_{it} + u_{it}$

where $u_{it} = \alpha_{1i} + \lambda_i f_t + \varepsilon_{it}$, $x_{it} = \alpha_{2i} + \lambda_i f_t + \gamma_i g_t + e_{it}$, x_{it} and y_{it} are observables, β_i are country-specific slopes on the observable regressors and u_{it} contains the unobservable terms and the error terms ε_{it}. The unobservables are made up of group fixed effects α_{1i}, which capture time-invariant heterogeneity across countries, as well as an unobserved common factor f_t with heterogeneous factor loadings λ_i, which can account for time-variant heterogeneity and cross-section dependence. The factor g_t is included to show that the observables x_{it} are also driven by factors other than f_t. Both f_t and g_t may be nonlinear and non-stationary. In the case of the CCEMG estimator, the country-

[16] A set of common time dummies θ_t can be included to capture common disturbances and ensure that the remaining disturbances are independent across individual countries. By including fixed effects, individual-specific deterministic trends and potentially different error variances, the formulation of the estimated long-run relationship between the variables allows for heterogeneity and some dependence across countries. After normalization, all tests follow a standard normal distribution.

[17] In particular, the correction is achieved by assuming that there is a relationship between the residuals from the regression (5) and first differences of the leads, lags and contemporaneous values of the regressors in first differences: $\mathrm{e}_{\mathrm{i,t}} = \sum_{\mathrm{j=-q}}^{\mathrm{q}} \mathrm{c}_{\mathrm{i,j}} \Delta \mathrm{x}_{\mathrm{i,t-j}} + \mathrm{e}_{\mathrm{i,t}}^{*}$. By plugging this expression into equation (5), a simple OLS regression provides superconsistent estimates of the long-run parameters. The t-statistic is based on the long-run variance of the residuals instead of the contemporaneous variance.

specific equation is augmented to include the cross-section averages of the dependent and independent variables, which are observable proxies for the common effects of the panel. The intuition behind the CCEMG estimator is that it “cleans” the estimates of the effect of cross-section dependence, bypassing the issue of estimating unobservable factors. Next, as this is a mean group procedure, the parameters are estimated country-by-country and then averaged across countries.[18]

3.3 Estimation results

As a first step, we investigate the time-series properties of our panel variables. Test results for the two panel unit root tests put forth respectively by Im, Pesaran and Shin (1995) and Pesaran (2007) are summarised in Table C3 of Annex C.[19] The null hypothesis of non-stationarity cannot be rejected for all dependent and explanatory variables at a 10 per cent confidence level according to the IPS test, with the exception of the relative interest rates and the relative openness variable. This is consistent with the literature which generally finds that real interest rate differentials are stationary (Bénassy-Queré, Béreau and Mignon, 2009 and the articles cited therein). Most importantly, all RERs are found to be non-stationary suggesting that both absolute and relative PPP do not hold and thereby rationalising the use of a BEER model to explain persistent deviations from PPP.[20] Next, we conduct Pedroni’s (1999) group-mean cointegration tests. The null hypothesis of no cointegration is rejected in most cases, suggesting that indeed the various dependent variables are cointegrated with the set of selected explanatory variables (Table C4 of Annex C). A cointegration analysis is thus warranted.

We perform the estimation of the BEER model by adopting the CCEMG estimator. The outlier-robust means of parameter coefficients across countries obtained from estimating equation (4) are reported in Table 1, where each column refers to a differently deflated dependent variable. The top half of the table refers to estimates based on relative GDP per capita as a proxy of the Balassa-Samuelson effect, the bottom half on relative labour productivity. The coefficients of the cross-section averages, which control for common shocks across the countries in our sample, have no economic meaning in our analysis, and are therefore not reported.

The first finding is that the Balassa-Samuelson effect is statistically significant and correctly signed in most specifications, in particular in the “broad sample” of countries (i.e. columns 1 to 3); the magnitude of the coefficient is in line with that reported in the BEER model literature (see, e.g. Couharde et al. 2017). This result points to the importance of sample size in order to find empirical evidence of the Balassa-Samuelson effect in the long run, at least when total-economy measures are employed to proxy for it (on this issue, see also Rogoff, 1996 and Couharde et al., 2017). Second, the sign and significance of the Balassa-Samuelson effect does not appear to be systematically related to

[18] We chose a simple unweighted averaging procedure to avoid affecting our results with the choice of an arbitrary weighting scheme.

[19] In line with the existing literature (Taylor, 2002; Papell and Prodan, 2006; Bergin, Glick and Wu, 2017), we include a deterministic time trend in the tests.

[20] These results are broadly confirmed by the CIPS test. Pesaran (2007) indicates that the power of the CIPS test is low when the sample size is not large, which may explain the slightly less clear-cut results when using this second test.

the choice of the measure employed to proxy for it, although the relative GDP per capita variable is more frequently statistically significant than the actual labour productivity measure. This could be due to the fact that labour productivity is more affected by cyclical conditions, such as episodes of labour hoarding/shedding, which do not affect the GDP per capita measure. The latter proxy thus possibly better captures structural changes in the economies under study. However, given that neither of the Balassa-Samuelson measure outperforms the other, we employ both variables alternately to construct our baseline REER equilibrium and misalignment estimates, as discussed further on.

Table 1. BEER estimation results

	Dependent variable				
	1	*2*	*3*	*4*	*5*
	Relative CPI	Relative GDP deflator	Relative PPP deflator	Relative PPI	Relative ULCT
A.					
Relative GDP per capita	0.2329*	0.3826***	0.3731***	0.1499	0.5541***
	(0.1330)	(0.1217)	(0.1289)	(0.1272)	(0.1652)
Relative openness	-0.4464***	-0.5426***	-0.4920***	-0.1978***	-0.3447***
	(0.0755)	(0.0940)	(0.0861)	(0.0605)	(0.1027)
Relative terms of trade	0.2542**	0.4647***	0.5632***	0.3036*	0.3567**
	(0.1009)	(0.0957)	(0.1111)	(0.1642)	(0.1693)
Relative government expenditure	0.2028	0.2465	0.5134**	0.4004	2.4326***
	(0.2212)	(0.2373)	(0.2285)	(0.3266)	(0.3662)
Relative short-term interest rates	0.0014**	0.0023***	0.0029***	0.0037***	0.0030**
	(0.0007)	(0.0008)	(0.0008)	(0.0011)	(0.0015)
Number of countries	*57*	*57*	*57*	*39*	*38*
Number of observations	*4,045*	*4,047*	*4,047*	*2,769*	*2,698*
B.					
Relative labour productivity	0.2661***	0.1432	0.2068*	0.2150**	-0.0297
	(0.0964)	(0.1054)	(0.1102)	(0.1093)	(0.1468)
Relative openness	-0.3866***	-0.4992***	-0.4710***	-0.1597***	-0.3696***
	(0.0783)	(0.0909)	(0.0876)	(0.0598)	(0.0964)
Relative terms of trade	0.2619***	0.4957***	0.5881***	0.2669**	0.4108***
	(0.0927)	(0.1039)	(0.1143)	(0.1311)	(0.1585)
Relative government expenditure	0.2216	-0.1089	0.1364	0.1430	1.5290***
	(0.3333)	(0.3185)	(0.2714)	(0.3082)	(0.4212)
Relative short-term interest rates	0.0029***	0.0027***	0.0034***	0.0024**	0.0013
	(0.0010)	(0.0010)	(0.0010)	(0.0012)	(0.0017)
Number of countries	*57*	*57*	*57*	*39*	*38*
Number of observations	*4,016*	*4,016*	*4,016*	*2,769*	*2,698*

Notes: Standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Outlier-robust estimates obtained with a common correlated effects mean group (CCEMG) estimator on the period 199Q1-2016Q3. The specification includes country fixed effects and cross-section means, here not reported.

All other results reported are consistent with the expected signs and with the existing empirical literature. In particular, an increase in relative openness is associated with a real depreciation, a result which is strongly significant across all specifications, while an increase in the terms of trade is associated with an appreciation of the real exchange rate. When it is statistically significant, the coefficient of relative government expenditure is positive, thereby confirming the compositional bias of public spending towards the non-tradable sector.[21] Finally, real interest rate differentials are significantly and positively correlated with RERs, as expected, in all but one specification.

3.4 Robustness checks

A first sensitivity check analyses the robustness of the estimated relationships to changes in the time coverage of the sample employed. The time-span considered in this paper covers the recent double recessionary phase for many euro area countries which could have affected the significance and size of the link between RERs and economic fundamentals. In order to test for this, we estimate the BEER model only until 2008 to remove the potential effects of the recessionary period. As shown in Table C5 of Annex C, the baseline results are confirmed.[22]

As a second set of robustness checks, we further explore the correct representation of the Balassa-Samuelson effect. First, we investigate the importance of panel sample size for finding statistical evidence of the Balassa-Samelson mechanism. When restricting also relative CPIs, GDP and PPP deflators to the narrow sample of countries, both relative GDP per capita and relative labour productivity are not statistically significant in four cases out of six (Table C6 of Annex C) against one out of six in the baseline Table 1.

Next, we consider an alternative proxy of relative productivity in the traded-goods sector, which is a country's CPI-to-PPI ratio, as used, for example, in Alberola et al. (2002) and Bénassy-Queré, Béreau and Mignon (2009; 2010), as usual expressed relative to the euro area. The intuition is that, unlike the CPI which includes e.g. services and housing, the PPI broadly covers only tradable goods and therefore this alternative measure proxies the non-tradable vs. tradable price ratio. Relative to our two baseline indicators of the Balassa-Samuelson effect, this proxy has the advantage of considering relative sectorial developments. However, this ratio is an imperfect measure of the non-tradable vs. tradable price ratio (Engel, 1999; Chinn, 2006). Moreover, it may be driven by factors that are totally unrelated to productivity differentials, such as relative demand effects, tax changes or the nominal exchange rate itself. Results reported in Table C7 of Annex C indeed point to a significant positive correlation between this proxy and bilateral RERs however deflated, confirming the existence of the Balassa-Samuelson mechanism.[23] Owing to the fact that PPIs are available only for the narrow sample

[21] This variable is significant, and with a large coefficient, in the case of ULCT-deflated real exchange rates. This is consistent with the fact that government expenditure is directed more towards the non-tradable sector and affects RERs by pushing up wages that are fully reflected in rises in the ULCT, which in contrast to the other deflators is not contaminated by developments in other cost components. See also Ruscher and Wolff (2009), which finds that government expenditure only affects broad (i.e. total-economy) measures of the REER and not narrow measures, limited to the tradable sector.

[22] The Balassa-Samuelson effect is less pronounced in this shorter sample, pointing to the evidence that both large panel and time series dimensions are required to observe this mechanism in the data. This fact is further explored in the second set of robustness checks.

[23] We dropped the CPI- and PPI-deflated real exchange rates as dependent variables for this robustness check.

of countries, we prefer however not to include this alternative Balassa-Samuelson measure in our baseline regressions.

Finally, Kravis, Heston and Summers (1978) and, more recently, studies by Kessler and Subramanian (2014) and Hassan (2016) uncover non-linearities in the relationship between PPP-deflated real exchange rates and relative GDP per capita levels over long time-spans. In particular, they find that the Balassa-Samuelson effect holds only for middle- and high-income countries, whereas the relationship is negative for low-income countries.[24] We therefore augment our main specification (4) with second-order terms of the two alternative baseline Balassa-Samuelson measures. The quadratic term however does not appear to be significant in our sample (Table C8 of Annex C). This could be due both to the time-span considered and to the sample of countries used in this paper. Both studies by Berger, Glick and Taylor (2006) and by Hassan (2016) indeed find that in more recent years an increasing and linear Balassa-Samuelson effect is observed.[25] Moreover, the low-income economies considered by Hassan (2016) are not included in our sample of countries. A linear specification for the Balassa-Samuelson effect therefore is confirmed to be appropriate for the sample of countries and time-span under consideration in this paper.

As recalled in Section 3.1, when selecting the right-hand side variables in the BEER model we excluded from our baseline specification those regressors which were not statistically significant at the 10 per cent level across any of the specifications.[26] In Table C8 of Annex C we also report these other excluded explanatory variables, all expressed in relative terms to the euro area.[27] In particular, first we examined the role of demographics in determining the real exchange rate, a link first explored by Rose, Supaat and Braude (2009) and later taken up by Christiansen et al. (2009). In particular, we introduced three alternative indicators of demographics in our model (the labour participation rate; the total dependency rate, computed as the share of young and old persons as a ratio of total population;[28] the aging structure of the economy, given by the change in the total dependency rate twenty years

[24] In particular, Hassan (2016) suggests this non-linearity reflects the fact that increases in productivity in agriculture lead to decreases in the relative price of agriculture and, in turn, of the aggregate price level in low-income countries, as their share of agriculture in total labour is high. Only above a certain income threshold, productivity in manufacturing relative to services becomes the main driver of the aggregate price level and the standard Balassa-Samuelson effect is confirmed.

[25] According to Hassan (2016), this is possibly due to the fact that structural changes in the economy, and in particular labour-shedding from agriculture to industry and services, were more relevant in the post-war period than in the post-1999 period examined in this paper. Bergin, Glick and Taylor (2006) instead develop a microeconomic model in which a continuum of goods are differentiated by productivity and where tradability is endogenously determined. Firms experiencing productivity gains are more likely to enter the export markets and crowd out firms not experiencing productivity gains. The Balassa-Samuelson assumption of productivity gains being concentrated in the tradable sector thus emerges endogenously (i.e. there is no exogenous distinction between the tradable and non-tradable sectors) and the Balassa-Samuelson effect appears gradually over time. Finally, the strengthening of the Balassa-Samuelson relationship over time has also been discussed in Taylor and Taylor (2006).

[26] We explicitly did not consider any financial variables in our BEER model, other than real interest rate differentials, in that these variables more naturally explain temporary fluctuations in nominal exchange rates, when the aim of the BEER model is to single out long-run real determinants of real exchange rates (on this issue, see also Hossfeld, 2010).

[27] For the sake of brevity we only show results referring to relative CPI deflators as the dependent variable. All other deflator results are available upon request. Moreover, appropriate unit root and cointegration tests were run prior to estimation: results of these tests are also available upon request.

[28] Similar results also hold when computing the indicator as the share of old persons only.

ahead relative to the current period). Under the life-cycle hypothesis, greater labour participation, a lower dependency rate or higher projected aging can imply higher savings, lower demand for non-traded goods, and hence a more depreciated RER. None of these indicators was found to be statistically significant. Indeed, in the existing literature fertility, for example, is mainly found to be significant in explaining REERs of low-income countries, and this may explain the lack of statistical significance of these three demographic variables in our regressions, similarly to findings in Phillips et al. (2013). Moreover, longer term annual data are probably needed in order for the effect of demographics to show up. For example, Giagheddu and Papetti (2017) find that the higher the dependency rate the more appreciated is the REER on an annual panel dataset of 45 countries over the period 1980-2004.

Next, we considered the ratio of investment to GDP, which may capture technological progress. This is particularly important in that to proxy the Balassa-Samuelson effect we consider labour productivity measures and not total factor productivity (TFP) measures suggested by the theory.[29] Whereas technical progress could lead to productivity rises and therefore to a real appreciation, given their high import content they also may affect the trade balance negatively with an opposite impact on the exchange rate. This additional variable too was found not to be statistically significant, possibly because the two effects offset each other, and was therefore not considered in our baseline BEER model.

Finally, Lane and Milesi-Ferretti (2004) have argued that net foreign assets (NFAs) of a country are a significant determinant of RERs, even when controlling for terms of trade. Indeed, according to the intertemporal budget constraint, in the long run countries with significant external liabilities need to run trade surpluses in order to service the interest payments due, thereby guaranteeing solvency, and thus they require a RER depreciation; conversely, a positive net external asset position enables a country to run persistent trade deficits, which in turn, all else equal, requires an appreciated RER (i.e. the "transfer effect"). This implies a positive (conditional) correlation between RERs and NFAs. We thus also included NFAs in our baseline specification (4). However, results available upon request pointed to an insignificant or even a negative relationship between RERs and NFAs.[30] This could be due to various reasons. First, Lane and Milesi-Ferretti's (2004) study is based on annual data, whereas with higher frequency data, such as those employed in this paper, the link between RERs and NFAs can also turn negative (see, for example, Choi and Taylor, 2017). Second, as discussed in Phillips et al. (2013), the steady-state relationship is mainly expressed in the cross-section dimension and is thus

[29] Amongst others, De Gregorio, Giovannini and Kreuger (1993) show that replacing labour productivity for TFP is not innocuous. However, internationally comparable capital data for a large number of countries, moreover at a quarterly frequency, are not readily available and the few studies that attempt to estimate TFP levels are restricted to OECD countries (see, e.g., De Gregorio, Giovannini and Wolf, 1994) or to euro area countries (Berka, Devereux and Engel, 2017)

[30] This applies both to relative and to absolute NFA levels, the latter used, for example, in Phillips et al. (2013) due to the fact that NFAs are a relative concept by definition. Moreover, because of valuation effects and the fact that NFAs can be contemporaneously affected by exchange rate movements, NFAs were also lagged by one year, as in various studies, such as Ricci, Milesi-Ferretti and Lee (2013), Adler and Grisse (2014) and Comunale (2015). Again, we found no evidence of a statistically significant relationship, similarly to Phillips et al. (2013).

difficult to detect when country fixed effects are included. Third, and more importantly, the sample of countries considered in this paper includes fewer emerging economies than in Lane and Milesi-Ferretti's (2004). Indeed, the latter study shows that the transfer effect weakens as output per capita increases and the point estimate associated with the NFA variable turns negative for the highest income group. Finally, it is noteworthy that in a recent extension to Lane and Milesi-Ferretti's (2004) model, Choi and Taylor (2017) argue that foreign exchange reserve accumulation may offset the positive correlation between RERs and private net foreign assets, especially in the case of financially closed countries. However, including measures of private NFAs (i.e. excluding foreign exchange reserves) in our regression does not yield a significant, positive coefficient. Consequently, we did not include this variable in our baseline specification.[31]

In addition to testing alternative specifications and sample sizes, we also conducted a robustness check on the chosen estimation procedure. We therefore re-estimated our baseline specification with DOLS. As shown in Table C9 of Appendix C, our main findings are confirmed, with one exception, namely that government expenditure enters the regression significantly but with a negative sign. Our preferred estimation method however remains the CCEMG estimator, owing to the presence of cross-sectional correlation in our sample of countries.

4 The magnitude and persistence of real effective exchange rate misalignments

4.1 The magnitude of REER misalignments

We employ the in-sample predictions obtained from the estimated relations provided in Table 1 in order to compute the equilibrium values of both bilateral RERs and of REERs, the latter obtained by weighting the bilateral rates with gross trade flow weights discussed in Schmitz et al. (2012) and in ECB (2015). The resulting series provide a time-varying and country-specific benchmark against which one may assess actual REERs. REER misalignments are computed as the percentage point difference between the observed REERs and its equilibrium level at date *t*.[32] Given the definition of the REER, positive (negative) misalignments indicate overvaluations (undervaluations) of the REER. Misalignment values give the magnitude of the REER adjustment that would restore equilibrium. By computing ten misalignment estimates (two Balassa-Samuelson effect proxies x five alternative deflators) for each country-quarter, we provide some robustness of our estimates.

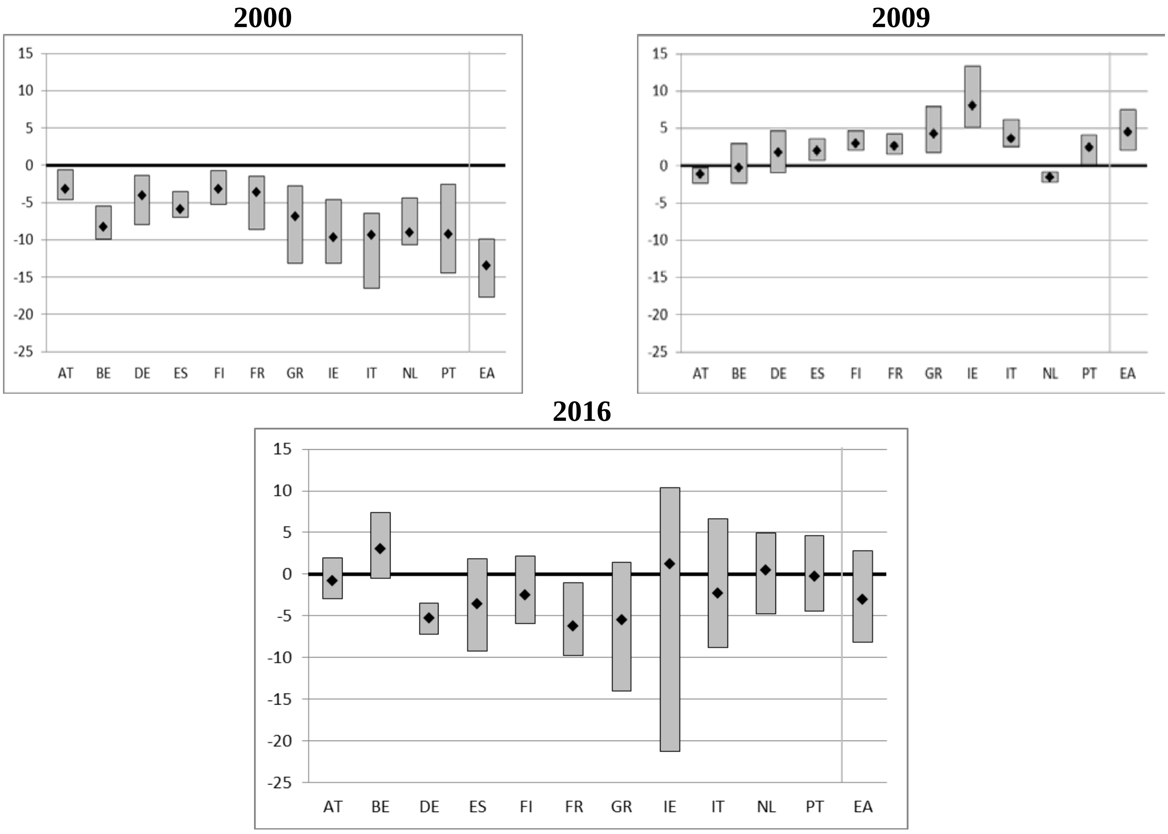
[31] Moreover, we tested for the significance of an interaction term between relative NFAs and relative openness, since Lane and Milesi-Ferretti (2004) find a smaller transfer effect the more open an economy. We do not find evidence for this in our sample, since the interaction term too is always statistically insignificant.

[32] Since the economic fundamentals are selected according to their statistical significance and since the BEER approach relies on a cointegrating relationship, BEER models generally yield smaller estimates of misalignment than more "normative" approaches, discussed in Annex A. This does not, however, affect the findings of our paper, focused on comparing real misalignments computed in a consistent manner across countries within different country groupings. A further criticism to the BEER approach is that fundamentals may themselves be misaligned, although to assume they are systematically misaligned over a nearly 20-year period is a strong claim. We therefore also used the "long-term" values of fundamentals in the estimation, by filtering the actual series, which however did not affect the estimated equilibria.

Our misalignment estimates, reported for selected euro area countries and years in Figure 1, are broadly in line with conventional wisdom and with estimates in Couharde et al. (2017), which, to our knowledge, is the only comparable BEER-model study that provides time series of REER misalignments. Despite the margin of uncertainty surrounding the magnitude of misalignments, our estimates consistently suggest that at the turn of the millennium the HCIs of the largest individual euro area countries were strongly undervalued relative to their fundamentals, and the REER of the euro even more so, mainly due to the plunge in the nominal exchange rate of the euro. This result is in line with that in Maeso-Fernandez, Osbat and Schnatz (2001), a study which specifically aims at assessing the detachment of the euro area REER from its economic fundamentals in 2000. As to be expected, the euro area REER misalignments fluctuate more than HCIs of individual euro area countries because they are calculated against third currencies with generally flexible parities, whereas the HCIs of euro area countries are calculated relatively to their trading partners, most of them also members of the euro area, with fixed parities. By 2009 the outlook had reversed, with most euro area countries displaying an overvaluation, similarly to the overall euro area. By 2016 the euro area REER was broadly in line with its economic fundamentals, as were most HCIs of individual euro area countries, with the exception of some "core" countries recording undervaluations.

Figure 1. REER misalignments in selected euro area countries

(percentage points)



Notes: The reported years refer to both local troughs and peaks in the nominal effective exchange rate of the euro since 1999 and to the last year available at the time of writing of the paper. The bars represent the range of estimated REER misalignments for each reference country and year. The diamond represents the mean of the ten estimated REER misalignments (two Balassa-Samuelson proxies and five different REER deflators).

Based on these estimates, we can assess the magnitude of real currency misalignments within country groupings in order to tackle the first part of our research question. Misalignments are taken in absolute values, since both under and overvaluations are considered suboptimal, and based purely on estimates referred to the broad sample of countries in order to allow for meaningful comparisons. Median absolute HCI misalignments across countries in the euro area 11 (excluding those countries that joined after 2001 and excluding Luxembourg)[33] were about 3 percent on average in the period considered, significantly below those in all other country groupings that adopted different nominal exchange rate regimes (i.e. other non-euro area advanced economies and emerging economies, as shown in Figure 2, top panel).[34] If one breaks the overall 1999-2016 period down into two sub-periods (1999-2008 and 2009-2016), HCI misalignments appear to have decreased in the second relative to the first, widening the gap relative to the other non-euro area advanced economies. This first piece of descriptive evidence lends support to the view that abandoning flexible exchange rates and adopting the euro does not appear to have amplified currency misalignments, but rather could have limited such misalignments, in line with the finding of Berka, Devereux and Engel (2012).

There is, however, some heterogeneity in misalignments within the euro area (Figure 2, middle panel). Median absolute misalignments were larger in so-called "stressed" euro area 11 countries than in "core" economies until 2009, although still more contained than those recorded by non-euro area countries, reported in the upper panel of Figure 2. After 2009, misalignments in "stressed" countries visibly decreased to a level which is currently lower than that of "core" countries.[35]

One may argue, however, that the documented lower median misalignments in the euro area relative to other country groupings may be due to euro-area specific factors other than the adoption of a single currency. To test for this possibility, we first consider median misalignments of the group of countries with pegged currencies to either the euro or the US dollar for most of the 16 years under study (Figure 2, bottom panel).[36] We find that also for these countries median absolute misalignments are on average lower than those in countries with a flexible exchange rate, although higher than those

[33] We exclude Luxembourg since it is a clear outlier relative to other euro area countries, in that it recorded a significant undervaluation over the whole period under analysis. The findings here shown are anyhow robust also to the inclusion of Luxembourg in the euro area aggregate, as well as in the "core" euro area aggregate.

[34] Median misalignments have the advantage of being less influenced by outliers than mean misalignments, which anyhow lead to qualitatively similar results to those discussed here and which are available upon request.

[35] These within-euro area results are confirmed when we take the average across all five (instead of three, as in Fig. 2) deflators, which are available for all euro area 11 countries.

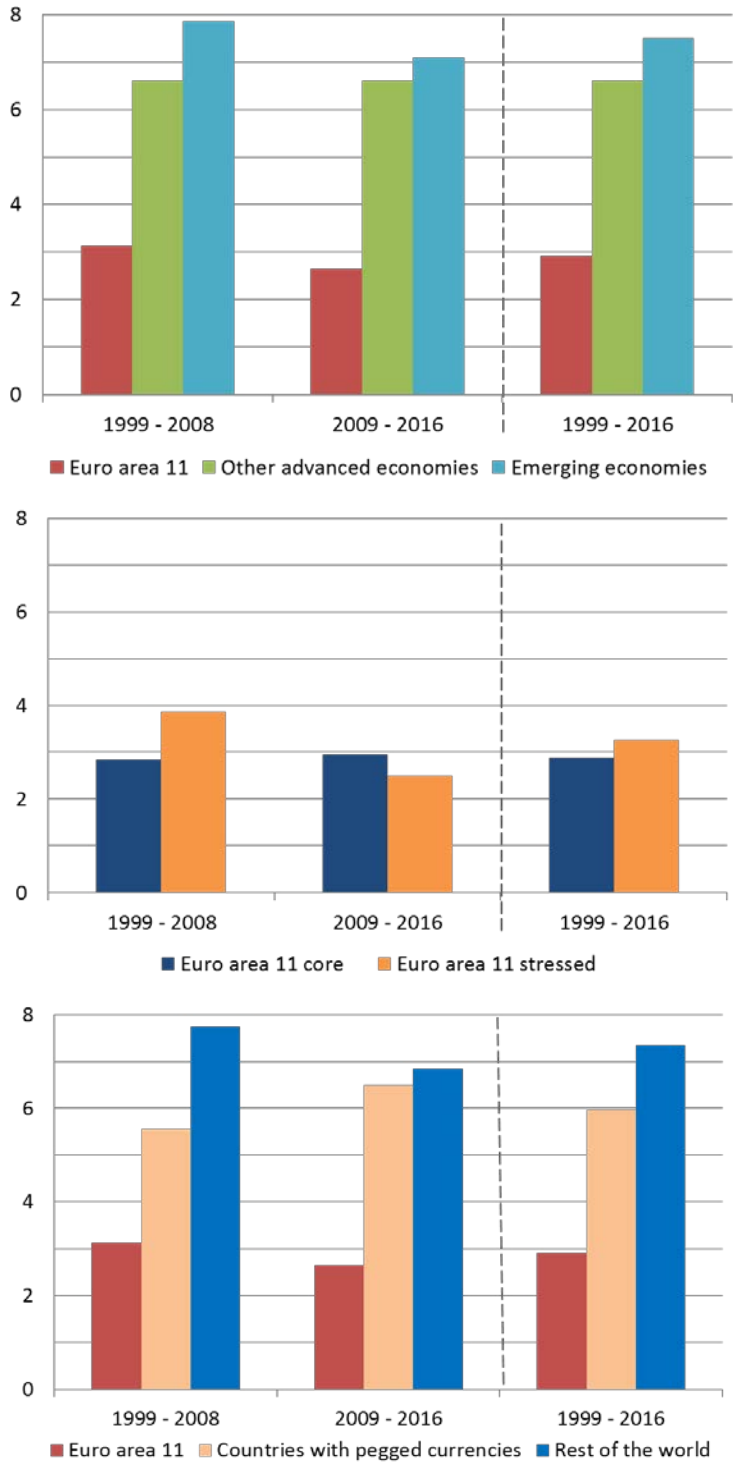
[36] We identified Bulgaria, China, Croatia, Denmark, Hong Kong, Morocco and Venezuela as economies with a pegged currency, based on the classification provided in Shambaugh (2004), according to which a currency is considered to be pegged if the exchange rate of a country fluctuates within a +/-2 percent band against a base currency (i.e the currency with historical importance for the local country, the nearby dominant economy to which other currencies were pegged, or the dollar as a default). Relative to Shambaugh's (2004) classification, we however exclude Malaysia from the sample of countries with a pegged currency, as it has adopted a floating exchange rate since 2005, and add Croatia, as it was tightly linked to the euro for most of the period considered in this paper.

observed in the euro area.[37] The latter finding also reflects the fact that for countries with a pegged currency the anchor-currency country typically has a lower weight in their effective exchange rate than other euro area countries have for individual euro area countries. This evidence too challenges the view that limiting fluctuations in exchange rates fosters larger real currency misalignments.

[37] This result would seem at odds with those in Coudert and Couharde (2009), which point to larger overvaluations in countries with pegged countries than in countries with floating rates (where REERs are found to be strongly undervalued). However, our results are not comparable as we consider both over- and undervaluations at the same time.

Figure 2. Median REER/HCI misalignments by country groupings

(median absolute average misalignments in percentage points)



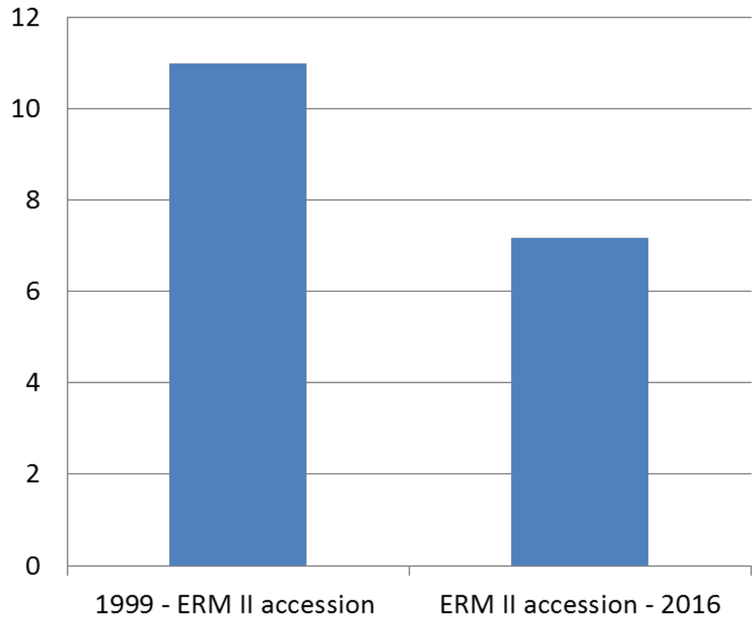
Source: Authors' estimations.

Notes: Euro area 11 includes those countries that had adopted the euro by 2001 (with the exception of Luxembourg). For the list of non-euro area advanced economies and emerging economies see Table C2 of Annex C. "Core" euro area-11 countries include Austria, Belgium, Finland, France, Germany and the Netherlands, whereas "stressed" euro area-11 countries include all other euro area 11 countries. Countries with pegged currencies include Bulgaria, China, Croatia, Denmark, Hong Kong, Morocco and Venezuela. The misalignments reported are average estimates based on the three "broad sample" deflators (CPI, PPP and GDP deflator) and on the two baseline measures of the Balassa-Samuelson effect (GDP per capita and labour productivity).

Moreover, in Figure 3 we consider the euro area countries that adopted the euro after 2001 to assess any difference in median misalignments before and after the adoption of the single currency; we could not conduct this exercise for the euro area 11 countries, given the lack of (quarterly) data prior to 1999. In particular, given that a pre-condition for joining the euro area is to have participated in ERM II, under which national currencies are allowed to fluctuate within a narrow band around a central rate, we consider country-specific ERM II accession dates, shown in Table C10 of Annex C, as the timing of the structural break. Our descriptive evidence points to a reduction in the size of median real currency misalignments after the accession date.

Figure 3. REER/HCI misalignments before and after ERM II accession

(median absolute average misalignments in percentage points)



Source: Authors' estimations.
Notes: The countries considered are: Cyprus, Estonia, Latvia, Lithuania, Malta, Slovakia and Slovenia. The country-specific accession dates are provided in Table C11 of Annex C. The misalignments reported are average estimates based on the three "broad sample" deflators (CPI, PPP and GDP deflator) and on the two baseline measures of the Balassa-Samuelson effect (GDP per capita and labour productivity).

In sum, all the descriptive evidence provided so far suggests that the adoption of a fixed exchange rate regime or to a currency union does not necessarily lead to larger REER disequilibria; to the contrary, it appears to have curbed these misalignments in the euro area. Some plausible explanations are the following. The convergence process that countries underwent in order to join the euro area in the course of the 1990s was mirrored in muted price developments, as inflation rates came down and converged across euro area 11 countries (e.g. Santos Silva and Tenreyro, 2010; Estrada, Galì and Lòpez-Salido, 2013).[38] This reduction in inflation differentials across the future members of the euro

[38] Similarly, Alesina, Ardagna and Galasso (2008; 2010) found substantial signs of wage moderation and smaller second-round inflationary effects (i.e. a slowing down of the adjustment of nominal wages to past inflation) in the countries preparing to enter the euro area during the period from 1993 to 1998.

area plausibly went hand in hand with a reduction in their REER misalignments, which would explain the small misalignments in these countries relative to non-euro area countries already in the first decade after the adoption of the euro.[39]

In the 1999-2009 period both the enhanced trade flows stemming from the adoption of the single currency, as suggested by Rose (2000) and Frankel and Rose (2002), and the elimination of a possible source of volatility arising in financial markets, as argued by Bergin, Glick and Wu (2017) amongst others, could have further contributed to the small size of these misalignments in the euro area. Based on the findings of the recent trade literature, the elimination of financial volatility was probably a more important cap on REER misalignments in this period –characterised by significant global financial integration and large international asset trade volumes –, than the international price convergence fostered by enhanced trade flows. The trade gains from a currency union estimated by Rose (2000) and Frankel and Rose (2002) were indeed significantly revised downwards in a recent article (Glick and Rose, 2015).[40] Consistently, Engel and Rogers (2004) and Lane (2006) find that price dispersion across EMU members did not significantly decrease after the introduction of the euro; rather, price differentials fell substantially in the aftermath of the 1992 European Union "single market" initiative. Furthermore, in general, nominal exchange rate shocks are more volatile and larger than price shocks, as documented by Berka, Devereux and Engel (2012) and Bergin, Glick and Wu (2017), so the elimination of the former shocks via the adoption of the single currency appears to have mattered in limiting the magnitude of real misalignments in the euro area, relative to countries that were not shielded from these shocks.

Finally, after 2009, with the general slowdown in trade also within the euro area, the curbing of volatility by the adoption of the single currency, in a period of heightened financial turbulence, was plausibly an even more important barrier to the amplification of REER misalignments. The latter indeed continued to fall within the euro area, against a broadly stability of disequilibria experienced by the other advanced economies in our sample.

4.2 The persistence of REER misalignments

4.2.1 Standard regressions of the REER adjustment process

After having examined the size of currency misalignments under different exchange rate regimes, we now investigate their persistence over time. In order to do so, we estimate the reactivity of the

[39] Caselli (2008) argues that in the post-1993 period inflation rates were low in all advanced economies and not specifically in euro area countries. However, as stated by Santos-Silva and Tenreyro (2010), one cannot reject on this basis the alternative and more positive view that the overall good monetary performance in advanced economies has been itself a by-product of the introduction of the euro and its commitment to stability, which led to greater independence of central banks and to inflation targeting, and discouraged beggar-thy-neighbour inflationary policies.

[40] Santos Silva and Tenreyro (2010) actually found no significant trade effect of the creation of the euro, after having controlled for the fact that euro area 12 countries already traded much more intensively between themselves than with comparable countries prior to 1999. Glick and Rose (2015, p. 17) acknowledge that the trade gains of the euro adoption vary significantly across estimation frameworks but they conclude that it "seems to have at least a mildly stimulating effect on exports".

observed developments in REERs to past real misalignments, following a similar exercise in Abiad, Kannan and Lee (2009) and Salto and Turrini (2010), in a standard panel regression setting. The estimated elasticity may be interpreted as an inverse measure of persistence of REER misalignments. Deviations from equilibrium levels can also be narrowed down by changes in economic fundamentals, reducing the necessary adjustments in the exchange rates. We thus also include changes in fundamentals as a control variable in our regression,[41] which is expressed in logs and takes the following form:

(7) $\Delta reer_{t/(t-20)} = \alpha_i + \beta_1 \, mis_{t-20} + \gamma_1 \, \Delta fun_{t/(t-20)} + \varepsilon_t$

where α_i are country fixed effects, the coefficient β_1 measures the sensitivity of exchange rate changes to past (i.e. lagged by 20 quarters or five years) misalignments, $mis_{t-20} = (reer^*_{i,t-20} - reer_{i,t-20})$, $reer^*$ is the equilibrium REER, γ_1 controls for the effects of changes in fundamentals on changes in the actual REERs, $\Delta fun_{t/(t-20)} = (reer^*_{i,t} - reer^*_{i,t-20})$ and ε_t is a random error.[42]

Estimation results are provided in Table 2; the upper panel displaying results obtained with relative GDP per capita as a proxy of the Balassa-Samuelson effect and the lower panel reporting results obtained when relative labour productivity is employed. We here consider solely the CPI-deflated indicators, whereas results referring to all other deflators, which confirm our main findings, are presented in Table C11 of Annex C. In column 1 we find that over the entire 1999-2016 period, on the basis of the full sample of countries, β_1 is statistically significant, also when controlling for changes in economic fundamentals, and displays a negative value. This implies that more overvalued currencies tend to experience larger real depreciations over the specified time horizon; conversely, the more undervalued currencies tend to record larger real appreciations. The size of the coefficient is in line with that reported in Abiad, Kannan and Lee (2009). In particular, on average a 1 percentage point overvaluation in time *t* was associated with an 0.7 percentage point reduction approximately in REERs in the subsequent five years.[43] The coefficient γ_1 displays a positive sign across all specifications, signalling that an appreciation of the equilibrium REER due to changes in economic fundamentals is associated with an appreciation of the actual REER.

In order to investigate whether the sensitivity of REERs to past deviations from equilibrium values is different within the euro area relative to all other countries considered in our sample we also include in equation (7) interaction terms between the two explanatory variables and a dummy variable taking value 1 if a country is a member of the euro area, 0 otherwise, leading to the following specification:

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[41] As in Abiad, Kannan and Lee (2009), the change in economic fundamentals is measured by the change in the estimated equilibrium.

[42] Hausman test results, available upon request, suggest that fixed-effects estimation is more appropriate than random-effects estimation, as in Abiad, Kannan and Lee (2009). The results presented in this section are confirmed also when fixed effects are excluded from the regressions.

[43] This interval allows for sufficient time to observe real adjustments take place. We also re-ran all regressions in this section on three instead of five-year intervals and all main findings were confirmed, although the sensitivity coefficients decreased slightly, as to be expected.

(8) $\Delta reer_{t/(t-20)} = \alpha_i + \beta_1\, mis_{t-20} + \beta_2\, EA * mis_{t-20} + \gamma_1\, \Delta fun_{t/(t-20)} + \gamma_2\, EA * \Delta fun_{t/(t-20)} + \varepsilon_t$

where the sensitivity of euro area countries' REERs to past misalignments (i.e. the persistence of misalignments in the euro area) is given by β_1+β_2 and the sensitivity to changes in fundamentals by γ_1+ γ_2. Corresponding estimation results are provided in column 2 of Table 2. An alternative way to explore this possibility is to split the sample of countries, and estimate equation (8) solely for euro area countries.[44] Since 1999 and until 2009 the sensitivity of REERs to past misalignments within the euro area has been smaller (i.e. persistence of misalignments has been higher), compared with non-euro area countries (columns 3 and 5 of Table 2).[45] This finding is in line with Huang and Yang (2015) specifically on REER misalignments, but also with the evidence in Lane (2006). Angeloni and Ehrmann (2007), de Haan (2010) and Estrada, Galì and Lòpez-Salido (2013), which documents a large persistence of inflation and of inflation differentials within the euro area after 1999, also if compared with, for example, the different macro-regions in the United States. Conversely, after 2009 the adjustment of REERs within the euro area has been much larger than in the past (columns 4 and 6 of Table 2) and broadly comparable to that of the other countries in the sample (i.e. the misalignment interaction term with the euro area dummy is not significant). This term is however statistically significant and positive when other deflators are employed to construct the REERs, as seen in Table C11 of Annex C, suggesting a slower adjustment of euro area countries with respect to the rest of the sample also in recent years. However, the main take-away is that, across all deflators, the reactivity of HCIs to past misalignments increased in the euro area after 2009 relative to the pre-2009 period.[46]

[44] Sample splitting is equivalent to the introduction of interaction terms with the euro-area dummy because both control variables are interacted, since the euro-area membership may plausibly affect all coefficients in the specification.

[45] This result holds also when excluding emerging economies from the sample of countries.

[46] In auxiliary regressions to this paper, available upon request, we also explore the possibility of a potentially different sensitivity of changes in REERs to positive vs. negative currency misalignments (asymmetric effects), as well as to small vs. large deviations in that small deviations may persist in the presence of transaction costs, whereas large deviations are generally offset (i.e. we control for nonlinear effects, measured by the interaction between misalignments and their absolute value which preserves sign changes, as in Parsley and Popper, 2001). In our sample of countries we find no conclusive evidence of the existence of asymmetries (similarly to Salto and Turrini, 2010) nor of nonlinearities. The latter result implies that the larger persistence of euro area misalignments is not due to their smaller magnitude.

Table 2. Regression of CPI-deflated REERs on past misalignment: baseline results

GDP per capita as proxy for Balassa-Samuelson effect	*All countries* 1999-2016Q3	1999-2016Q3	<2009	≥2009	*EA countries* <2009	≥2009
Dependent variable: changes in CPI-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.736***	-0.778***	-0.934***	-0.874***	-0.494***	-0.794***
	(0.016)	(0.018)	(0.021)	(0.032)	(0.030)	(0.023)
Misalignment (t-20)***EA** dummy		0.124***	0.440***	0.080		
		(0.046)	(0.066)	(0.090)		
Changes in fundamentals (t/t-20)	0.732***	0.789***	0.941***	0.547***	0.428***	0.398***
	(0.017)	(0.019)	(0.020)	(0.063)	(0.026)	(0.019)
Changes in fundamentals (t/t-20)***EA** dummy		-0.287***	-0.514***	-0.149		
		(0.042)	(0.057)	(0.092)		
Number of countries	*57*	*57*	*57*	*57*	*19*	*19*
Observations	*2,902*	*2,902*	*1,140*	*1,762*	*380*	*589*
Adjusted R-squared	0.429	0.438	0.655	0.359	0.420	0.677
Labour productivity as proxy for Balassa-Samuelson effect	*All countries* 1999-2016Q3	1999-2016Q3	<2009	≥2009	*EA countries* <2009	≥2009
Dependent variable: changes in CPI-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.740***	-0.769***	-0.933***	-0.914***	-0.501***	-0.807***
	(0.016)	(0.018)	(0.021)	(0.031)	(0.031)	(0.025)
Misalignment (t-20)***EA** dummy		0.095**	0.432***	0.107		
		(0.048)	(0.069)	(0.094)		
Changes in fundamentals (t/t-20)	0.736***	0.777***	0.943***	0.292***	0.437***	0.426***
	(0.018)	(0.020)	(0.021)	(0.065)	(0.027)	(0.022)
Changes in fundamentals (t/t-20)***EA** dummy		-0.238***	-0.506***	0.134		
		(0.047)	(0.061)	(0.102)		
Number of countries	*57*	*57*	*57*	*57*	*19*	*19*
Observations	*2,902*	*2,902*	*1,140*	*1,762*	*380*	*589*
Adjusted R-squared	0.415	0.420	0.638	0.359	0.407	0.652

Notes: Standard errors in parentheses. Panel fixed effects regressions. Country fixed effects are included, but here not reported. *** p<0.01, ** p<0.05, * p<0.1.

It is again possible that, although we control for changes in economic fundamentals and for country fixed effects, there may be other factors behind the slower correction of HCIs within the euro area than the adoption of the single currency. In order to further investigate the impact of different exchange rate regimes on the REER adjustment process, we again single out non-euro area countries with a pegged currency in our sample, as done in Figure 2. We next assess whether also for these countries, which are both advanced and emerging economies and therefore constitute a significantly heterogeneous pool of countries, reversion to the equilibrium REER is more sluggish than in countries with a flexible exchange rate. In particular, we adjust equation (8) by replacing the euro area dummy with the peg country dummy and by running the regression on the non-euro area country sample:

(9) $\Delta reer_{t/(t-20)} = \alpha_i + \beta_1\, mis_{t-20} + \beta_2\, peg * mis_{t-20} + \gamma_1\, \Delta fun_{t/(t-20)} + \gamma_2\, peg * \Delta fun_{t/(t-20)} + \varepsilon_t$

As seen in Table 3, indeed, the reaction of REERs to past misalignments in pegged countries is generally smaller relative to countries with a freely fluctuating currency, suggesting that also pegged exchange rate arrangements constrain the response of exchange rates to deviations. The lower reactivity of REERs to past deviations in euro area countries appears therefore plausibly to be due to the absence of a nominal adjustment channel, similarly to the case of pegged countries.

Table 3. Regression results of CPI-deflated REERs on past misalignment: the role of pegging

	Dependent variable: changes in REERs (t/t-20)				
	1	*2*	*3*	*4*	*5*
GDP per capita as proxy for Balassa-Samuelson effect	Relative CPI	Relative GDP deflator	Relative PPP deflator	Relative PPI	Relative ULCT
Misalignment (t-20)	-0.856***	-0.970***	-0.895***	-0.923***	-0.842***
	(0.022)	(0.018)	(0.021)	(0.020)	(0.027)
Misalignment (t-20)***peg** dummy	0.094	0.219***	0.190***	0.302***	0.471***
	(0.068)	(0.071)	(0.071)	(0.064)	(0.052)
Changes in fundamentals (t/t-20)	0.884***	0.983***	1.157***	1.192***	1.437***
	(0.023)	(0.019)	(0.035)	(0.059)	(0.052)
Changes in fundamentals (t/t-20)***peg** dummy	-1.383***	-1.126***	-1.265***	0.041	-0.171*
	(0.093)	(0.061)	(0.066)	(0.126)	(0.103)
Number of countries	*38*	*38*	*38*	*20*	*19*
Observations	*1,933*	*1,935*	*1,935*	*1,020*	*969*
Adjusted R-squared	0.476	0.622	0.634	0.704	0.704
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1					

	Dependent variable: changes in REERs (t/t-20)				
	1	*2*	*3*	*4*	*5*
Labour productivity as proxy for Balassa-Samuelson effect	Relative CPI	Relative GDP deflator	Relative PPP deflator	Relative PPI	Relative ULCT
Misalignment (t-20)	-0.867***	-0.961***	-0.885***	-0.926***	-0.887***
	(0.022)	(0.018)	(0.022)	(0.022)	(0.027)
Misalignment (t-20)***peg** dummy	0.095	0.297***	0.234***	0.206***	0.563***
	(0.066)	(0.066)	(0.067)	(0.066)	(0.047)
Changes in fundamentals (t/t-20)	0.897***	0.967***	1.075***	1.220***	1.232***
	(0.023)	(0.019)	(0.027)	(0.075)	(0.043)
Changes in fundamentals (t/t-20)***peg** dummy	-1.808***	-1.144***	-1.240***	-0.133	-0.150*
	(0.097)	(0.056)	(0.060)	(0.171)	(0.081)
Number of countries	*38*	*38*	*38*	*20*	*19*
Observations	*1,933*	*1,935*	*1,935*	*1,020*	*969*
Adjusted R-squared	0.491	0.618	0.637	0.705	0.692
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1					

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Panel fixed effects regressions. Country fixed effects are included, but here not shown. Countries with pegged currencies, similarly to Shambaugh (2004) with few alterations due to our different time-span, include: Bulgaria, Croatia, China, Denmark, Hong Kong, Morocco and Venezuela. Euro area countries are excluded from this regression.

Next, we consider a possible divergent HCI behaviour in the face of past misalignments within the euro area, as documented by the differing developments between "core" and "stressed" countries seen in Figure 2. We therefore run the following regression:

(10) $\Delta reer_{t/(t-20)} = \alpha_i + \beta_1 \, mis_{t-20} + \beta_2 \, stressed * mis_{t-20} + \gamma_1 \, \Delta fun_{t/(t-20)} + \gamma_2 \, stressed * \Delta fun_{t/(t-20)} + \varepsilon_t$

According to CPI-deflated results reported in Table 4, also confirmed by the other deflators as shown in Annex C, the sensitivity of HCIs to past misalignments in "stressed" countries was on average larger than that of the other euro area countries, suggesting lower persistence of real misalignments, although this finding is entirely due to post-2009 developments. This result is consistent with the significant decrease in the size of HCI misalignments of "stressed" countries reported after 2009 in the intermediate panel of Figure 2.

Table 4. Regression results of CPI-deflated HCIs on past misalignments in "stressed" euro area countries

	GDP per capita			Labour productivity		
	1999-2016Q3	*<2009*	*≥2009*	*1999-2016Q3*	*<2009*	*≥2009*
Dependent variable: changes in CPI-based REERs (t/t-20)	(1)	(2)	(3)	(1)	(2)	(3)
Misalignment (t-20)	-0.627***	-0.803***	-0.327***	-0.609***	-0.816***	-0.339***
	(0.025)	(0.043)	(0.043)	(0.026)	(0.044)	(0.049)
Misalignment (t-20)***Stressed**	-0.332***	0.036	-0.687***	-0.489***	0.017	-0.807***
	(0.050)	(0.065)	(0.068)	(0.056)	(0.065)	(0.090)
Changes in fundamentals (t/t-20)	0.179***	0.104***	0.113***	0.204***	0.044	0.116***
	(0.027)	(0.033)	(0.024)	(0.034)	(0.038)	(0.032)
Changes in fundamentals (t/t-20)***Stressed**	0.460***	0.356***	0.597***	0.589***	0.386***	0.880***
	(0.042)	(0.061)	(0.055)	(0.062)	(0.072)	(0.088)
Number of countries	*12*	*12*	*12*	*12*	*12*	*12*
Observations	*612*	*240*	*372*	*612*	*240*	*372*
Adjusted R-squared	*0.819*	*0.775*	*0.614*	*0.794*	*0.777*	*0.517*

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Panel fixed effects regressions. Country fixed effects are included, but here not reported. "Stressed" euro area countries include all 19 euro area countries except for Austria, Belgium, Finland, France, Germany, Luxembourg and the Netherlands.

4.2.2 Assessing the role of regulatory and institutional quality in the REER adjustment process

Finally, inspired by the literature discussed in Section 2, we consider the role of regulatory and institutional quality in the REER correction process, although acknowledging that a causal analysis would be warranted to fully address this issue.

In particular, we test the hypothesis of differences in the quality of regulation and institutions in affecting the persistence of REER misalignments in our sample of countries.[47] In particular, we augment specification (6) with an interaction term between real misalignment and one of six indicators of governance sourced from the World Bank, which are available for all the countries in our

[47] One could argue that institutional quality is a determinant of RERs and, therefore, should be included as an explanatory variable in the BEER model. On the one hand, countries with better governance may attract more foreign capital inflows, as a result of low expropriation risks, and thus lead to an appreciated currency. On the other hand, as discussed in Christiansen et al. (2009), better institutions may generate an environment more conducive to saving, which leads to less demand for goods and a more depreciated real exchange. To our knowledge no existing BEER model includes institutional variables, possibly because the latter mainly exhibit a cross-sectional variation and are therefore captured indirectly by the country fixed effects, as in equation (4). For these reasons, we only consider the possible impact of institutions on the REER adjustment process, via the two channels discussed in Section 2.

sample and for the whole period under study.[48] Three indicators refer to accountability, political stability and government effectiveness, which capture the first channel through which institutions affect REER adjustment, as discussed in Section 2, and other three refer to regulatory quality, rule of law and control of corruption, which take into account the second channel discussed. An increase in any indicator implies an improvement in the quality of the institutional dimension considered. Table C13 of Annex C provides summary statistics of these governance indicators for the full sample and for three different country groupings over the whole period.

The new full specification is thus the following, where *gov* represents one of the six mentioned governance indicators:

$$(11)\ \Delta reer_{t/(t-20)} = \alpha_i + \beta_1\, mis_{t-20} + \beta_2\, mis_{t-20} * gov_{t-20} + \beta_3\, EA * mis_{t-20} + \gamma_1\, \Delta fun_{t/(t-20)} + \gamma_2\, EA * \Delta fun_{t/(t-20)} + \varepsilon_t$$

Regression results in Table 5, based on CPIs but confirmed by all deflators (with the related results available upon request), show that on average in all countries the reactivity of REERs to past deviations from equilibrium values increases the better a country scores in terms of all dimensions of regulatory and institutional quality, with the only exception of political stability, which, although statistically insignificant, presents a negative sign too. These findings suggest that both channels discussed in Section 2 are at play in our sample of countries. Moreover, the non-significance of β_3 across all specifications implies that the role of institutions in the adjustment process is as important for euro area countries as it is for non-euro area advanced and emerging economies.[49]

To sum up, misalignments are found to have been more persistent in the euro area than in countries with different nominal exchange rate regimes, yet only until 2009. Indeed, in a monetary union, abstracting from varying trade patterns, changes in real exchange rates can take place only through inflation differentials, since nominal exchange rates are fixed by definition. The larger persistence in real misalignments in the euro area may thus be linked to the adoption of the single currency. The lower persistence of misalignments in the recent recessionary phase, driven mainly by the higher sensitivity of HCIs to past disequilibria in stressed countries, is possibly associated to the structural reforms enacted as a result of the global financial crisis in these countries, which removed existing real rigidities, and to a lower "tolerance" of REER misalignments, in turn speeding up the adjustment process.[50] Indeed, according to standard OECD indicators on both product and labour market legislation in key sectors – which for the countries and years available are highly correlated with the regulatory quality indicator employed in our regressions –, the extent of deregulation in the years

[48] The indicators are available at the following website: http://info.worldbank.org/governance/wgi.

[49] In a robustness check we also investigated whether the level of development of an economy may affect the persistence of misalignments. We therefore interacted the misalignment variable with relative GDP per capita. Results vary across the differently deflated REERs but generally point to insignificant interaction terms. This implies that it is indeed the regulation and institution channels that affect the reactivity of REERs to past misalignments and not more generally the level of development of an economy.

[50] As stressed by Alesina, Ardagna and Galasso (2010), in periods of low economic growth structural-reform opponents may lose their political clout, thereby leading to an easier approval of reforms.

prior to the crisis were comparable in both euro and non-euro area advanced economies (where the latter can be considered as a "control group" relative to the "treated" euro area group).[51] However, in the more recent period since 2009 loosening of regulation became relatively more intense in euro area countries, and in particular in the "stressed" countries (Fig. 4).[52] Of course, changes in the structural indicators commented herein do not always neatly map to reform episodes and viceversa, so this evidence can only be suggestive of the impact of structural reforms in the euro area.

[51] It has been argued that entry into the Economic and Monetary Union could act as an external constraint, pushing countries to reform, in particular to liberalise labour and product markets in order to counteract the suppression of the nominal exchange rate channel and therefore of the "palliative" of competitive devaluation (Alesina, Ardagna and Galasso, 2010). In particular, this euro promotion of structural reforms could have occurred via two channels. On the one hand, as firms lost competitiveness, they could have become more vocal in demanding deregulation in upstream sectors to contain costs. On the other hand, the euro could have been used as a political argument by reformers to push through structural reform. Our evidence runs counter to these expectations. Anyhow, when controlling for economic variables that raise the probability of joining the euro, such as trade between countries and business cycle synchronization, product market regulation is not found to be significantly and robustly lower in euro area vs. other advanced economies in the period until 2003 (Alesina, Ardagna and Galasso, 2008), consistently with the results presented in this paper.

[52] On this see also Franks et al. (2017). Moreover, in general Blanchard and Giavazzi (2003) suggest that in the short run product market deregulation generate costs for both incumbent firms and their workers, who thus tend to oppose reforms. However, when rents decrease due, for example, to low growth, resistance to deregulation falls as the incumbents' losses can be outweighed by the future benefits of deregulation. This implies that it is easier to implement reforms in crisis times, as found by Alesina, Ardagna and Galasso (2010).

Table 5. Regression results of CPI-deflated REERs on past misalignment: the role of institutions

Panel A. Regulatory quality	GDP per capita	Labour productivity
	1999-2015	*1999-2015*
Dependent variable: changes in CPI-based REERs (t/t-20)	(1)	(2)
Misalignment (t-20)	-0.727***	-0.743***
	(0.023)	(0.023)
Misalignment (t-20)***Regulatory quality** (t-20)	-0.082***	-0.041*
	(0.023)	(0.024)
Misalignment (t-20)*EA dummy	0.292***	0.259**
	(0.108)	(0.116)
Misalignment (t-20)***Regulatory quality** (t-20)* **EA dummy**	-0.128	-0.137
	(0.096)	(0.101)
Changes in fundamentals (t/t-20)	0.848***	0.806***
	(0.025)	(0.026)
Changes in fundamentals (t/t-20)*EA dummy	-0.388***	-0.313***
	(0.049)	(0.056)
Number of countries	*57*	*57*
Observations	*2,902*	*2,902*
Adjusted R-squared	0.441	0.421

Panel B. Rule of law	GDP per capita	Labour productivity
	1999-2015	*1999-2015*
Dependent variable: changes in CPI-based REERs (t/t-20)	(1)	(2)
Misalignment (t-20)	-0.749***	-0.751***
	(0.020)	(0.020)
Misalignment (t-20)***Rule of law** (t-20)	-0.064***	-0.042**
	(0.019)	(0.019)
Misalignment (t-20)*EA dummy	0.181**	0.144*
	(0.073)	(0.077)
Misalignment (t-20)***Rule of law** (t-20)* **EA dummy**	-0.038	-0.038
	(0.070)	(0.073)
Changes in fundamentals (t/t-20)	0.831***	0.804***
	(0.023)	(0.023)
Changes in fundamentals (t/t-20)*EA dummy	-0.349***	-0.285***
	(0.046)	(0.052)
Number of countries	*57*	*57*
Observations	*2,902*	*2,902*
Adjusted R-squared	0.440	0.421

Panel C. Control of corruption	GDP per capita	Labour productivity
	1999-2015	*1999-2015*
Dependent variable: changes in CPI-based REERs (t/t-20)	(1)	(2)
Misalignment (t-20)	-0.752***	-0.758***
	(0.020)	(0.020)
Misalignment (t-20)***Control of corruption** (t-20)	-0.048***	-0.022
	(0.018)	(0.018)
Misalignment (t-20)*EA dummy	0.131**	0.106
	(0.064)	(0.067)
Misalignment (t-20)***Control of corruption** (t-20)* **EA dummy**	0.002	-0.008
	(0.062)	(0.063)
Changes in fundamentals (t/t-20)	0.828***	0.795***
	(0.024)	(0.025)
Changes in fundamentals (t/t-20)*EA dummy	-0.335***	-0.263***
	(0.046)	(0.051)
Constant	0.001	0.001
	(0.002)	(0.002)
Number of countries	*57*	*57*
Observations	*2,902*	*2,902*
Adjusted R-squared	0.439	0.420

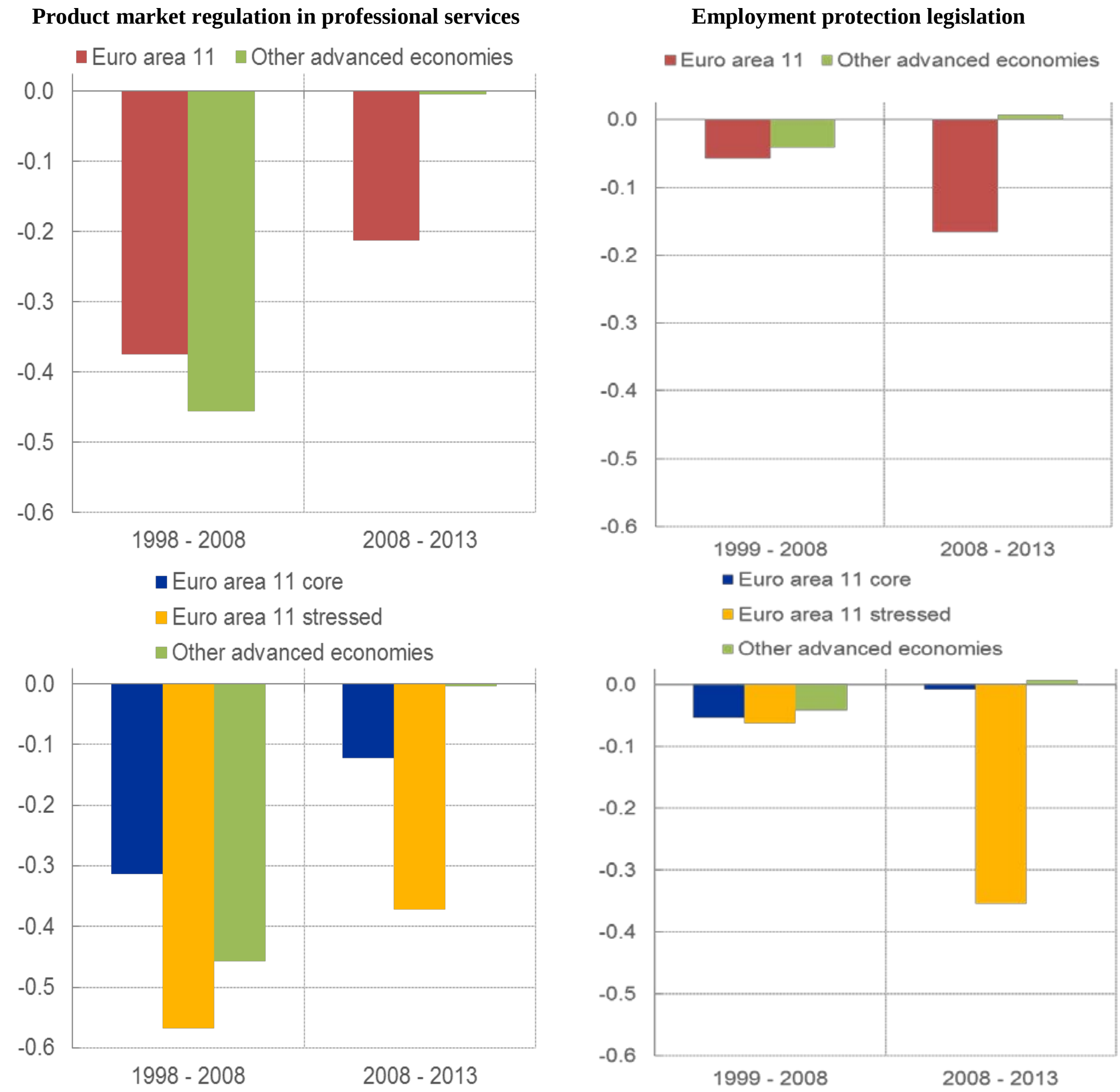
Panel D. Accountability	GDP per capita	Labour productivity
	1999-2015	*1999-2015*
Dependent variable: changes in CPI-based REERs (t/t-20)	(1)	(2)
Misalignment (t-20)	-0.743***	-0.739***
	(0.022)	(0.023)
Misalignment (t-20)***Accountability** (t-20)	-0.070***	-0.059**
	(0.026)	(0.027)
Misalignment (t-20)*EA dummy	0.338**	0.261
	(0.170)	(0.179)
Misalignment (t-20)***Accountability** (t-20)* **EA dummy**	-0.170	-0.127
	(0.159)	(0.166)
Changes in fundamentals (t/t-20)	0.796***	0.783***
	(0.019)	(0.020)
Changes in fundamentals (t/t-20)*EA dummy	-0.320***	-0.269***
	(0.046)	(0.052)
Constant	0.001	0.001
	(0.002)	(0.002)
Number of countries	*57*	*57*
Observations	*2,902*	*2,902*
Adjusted R-squared	0.439	0.421

Panel E. Government effectiveness	GDP per capita	Labour productivity
	1999-2015	*1999-2015*
Dependent variable: changes in CPI-based REERs (t/t-20)	(1)	(2)
Misalignment (t-20)	-0.747***	-0.750***
	(0.022)	(0.022)
Misalignment (t-20)***Government effectiveness** (t-20)	-0.051**	-0.033
	(0.022)	(0.022)
Misalignment (t-20)*EA dummy	0.193**	0.151
	(0.094)	(0.098)
Misalignment (t-20)***Government effectiveness** (t-20)* **EA dummy**	-0.051	-0.043
	(0.085)	(0.087)
Changes in fundamentals (t/t-20)	0.815***	0.794***
	(0.022)	(0.023)
Changes in fundamentals (t/t-20)*EA dummy	-0.330***	-0.270***
	(0.046)	(0.051)
Constant	0.001	0.001
	(0.002)	(0.002)
Number of countries	*57*	*57*
Observations	*2,902*	*2,902*
Adjusted R-squared	0.439	0.420

Panel F. Political stability	GDP per capita	Labour productivity
	1999-2015	*1999-2015*
Dependent variable: changes in CPI-based REERs (t/t-20)	(1)	(2)
Misalignment (t-20)	-0.775***	-0.767***
	(0.018)	(0.018)
Misalignment (t-20)***Political stability** (t-20)	-0.025	-0.025
	(0.023)	(0.023)
Misalignment (t-20)*EA dummy	0.182	0.068
	(0.129)	(0.132)
Misalignment (t-20)***Political stability** (t-20)* EA dummy	-0.037	0.049
	(0.126)	(0.128)
Changes in fundamentals (t/t-20)	0.790***	0.777***
	(0.019)	(0.020)
Changes in fundamentals (t/t-20)*EA dummy	-0.290***	-0.237***
	(0.042)	(0.047)
Constant	0.001	0.001
	(0.002)	(0.002)
Number of countries	*57*	*57*
Observations	*2,902*	*2,902*
Adjusted R-squared	0.438	0.420

Notes: Panel fixed effects regressions. Country fixed effects are included, but here not reported. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figure 4. Changes in regulation in the euro area
and in other non-euro area advanced economies
(average percentage changes in selected sub-periods)



Source: OECD.
Notes: For PMR, euro area 11 is euro area 12 excluding Portugal. Other advanced economies: Australia, Canada, Denmark, Japan, New Zealand, Norway, Sweden and the United Kingdom. Euro area 11 core includes Austria, Belgium, Germany, Finland, France, Luxembourg and the Netherlands.. Euro area 11 stressed includes Greece (as of 2003), Ireland, Italy and Spain. For EPL, euro area 11 is euro area 12 excluding Luxembourg. Euro area 11 core includes Austria, Belgium, Germany, Finland, France, and the Netherlands. Euro area 11 stressed includes Greece, Ireland, Italy, Portugal and Spain. Other advanced economies: Australia, Canada, the Czech Republic, Denmark, Japan, Korea, New Zealand, Norway, Sweden, Switzerland, the United Kingdom and the United States. A reduction in the index signals a loosening of regulation. Time periods are selected according to the availability of the PMR indicator.

5 Conclusions

This paper draws upon a behavioural equilibrium exchange rate (BEER) model in order to analyse the magnitude and persistence of currency misalignments in real terms within the euro area to assess any differences with respect to other countries that have adopted different nominal exchange rate arrangements. It therefore contributes to the literature aimed at investigating whether countries in a currency union or with fixed exchange rates have worse outcomes for REERs than countries with flexible exchange rates.

In the construction and estimation of the BEER model, particular care is given to: a) the selection of the economic fundamentals to be included in the specification and to the estimation of the so-called Balassa-Samuelson effect; b) the dataset employed: the BEER model is estimated for a larger sample of countries and at a higher frequency than what is usually done in the literature; moreover, given that recent studies suggest that no optimal deflator exists for REERs, we estimate the model using five alternatively deflated REERs; c) the panel cointegration estimation method, which, amongst various desirable properties, accounts for cross-section dependence, resulting from the fact that countries may be affected by common, global shocks.

Our BEER estimation results are consistent with the existing literature. We find a significant and positive relationship between real exchange rates and either GDP per capita or labour productivity, i.e. significant evidence of the Balassa-Samuelson effect. Moreover, real appreciation is found to be associated with higher trade restrictions, proxied by lower trade openness, higher terms of trade, higher government expenditure and higher short-term real interest rates.

Using these estimated relationships, we construct measures of REER misalignments in order to tackle our research question. Our findings are the following. Since 1999 misalignments of HCIs (the equivalent of REERs for euro area countries) have been found to be significantly smaller in euro area economies in comparison with the other countries in our sample, and even more so in the recent recessionary phase. Based on these results, one cannot easily make the case that the adoption of the euro amplified misalignments. Rather evidence for the most recent members of the euro area at least has pointed to the use of the single currency seemingly curbing these misalignments. This result is plausibly due to the elimination of a significant source of volatility, nominal exchange rate fluctuations, stemming from financial market shocks. Within the euro area "stressed" countries recorded larger misalignments than "core" countries, yet only until 2009, after which a sharp downward correction was enacted in the former set of economies.

Although smaller to those observed in non-euro area countries, real misalignments in the euro area are however found to be more persistent. Indeed, there is evidence of a significant REER adjustment process also within the euro area, yet the reactivity of HCIs in euro area countries is on average more contained than that of the other economies in the sample. After 2009 the sensitivity of euro-area HCIs to past misalignments increased significantly relative to the previous period, implying a lower persistence of real misalignments.

On the back of the evidence in this paper, one could make the case that the policies enacted prior to 1999 in order to comply with the Maastricht convergence criteria and to adopt the euro prior to 1999 led to the reaping of the "low-hanging fruits" of a currency union, signalled by small real exchange rate misalignments as of 1999. Yet, the remaining disequilibria turned out to be more persistent relative to those of countries outside the euro area, owing to the absence of a nominal adjustment channel and to the fact that the pace of structural reforms after 1999 within the euro area was no faster than that observed in other economies, at least according to standard OECD regulatory indicators.

However, as of 2009 the reactivity of REERs to past misalignments in euro area countries has increased, mainly due to faster adjustment in the "stressed" euro area countries, signalling a lower persistence relative to the previous period. This result could be due to cyclical factors, linked to the severe recession the area euro experienced, and thus could be expected to be reversible. But it could also be due to structural factors, tied, for example, to the pronounced loosening of regulation in both product and labour markets implemented as a result of the crisis in the euro area (relative to other non-euro area advanced economies) and especially in the "stressed" euro area countries, which could thus be related to the documented lower persistence of real misalignments in the euro area observed in recent years. We indeed find significant empirical evidence that an improvement in various dimensions of domestic regulation and institutions favours the REER correction process, since plausibly it removes structural rigidities and thus can partly compensate for the loss of the nominal adjustment channel that the adoption of a single currency implies.

Annex A. Alternative models for estimating real effective exchange rate misalignments

The BEER model employed in this paper to estimate REER misalignments and described in Section 3, by measuring the statistical relationship between RERs and a set of economic fundamentals, is a direct estimation method that determines equilibrium exchange rates empirically. It is free from any normative assumption on whether and how the current account should adjust and is not subject to the explicit requirement of "sustainable external and internal balance". It is based on the assumption of mean reversion in the long run, so that a deviation from the cointegration relationship will tend to be progressively reversed, albeit at a speed that can be slow, and on different hypotheses concerning the long-run drivers of the equilibria values. Its main drawback is indeed that it is data-determined, in the sense that the equilibrium rate is consistent with the actual values of the fundamental determinants of RERs. A BEER model therefore assumes that on average in the overall period under estimation the latter are in equilibrium. This may not be the case for some countries, especially over short time periods. The main econometric techniques employed to overcome this shortcoming, such as filtering the right hand-side variables in the BEER model, are not sufficient to entirely overcome this drawback, which can be tackled only by expanding the estimation window over time as much as possible (although free of any structural break in institutions, for instance, which could make historical relationships no longer valid)The latter requirement, however, cannot be fully met, given the data constraints any researcher faces (for example, in this paper in order to guarantee satisfactory country coverage and to obtain quarterly estimates it was not possible to estimate the BEER model prior to 1999, although this preserves us from having to treat the structural break linked to the adoption of the euro).

Alternative empirical approaches to estimating the determinants of real exchange rates and their equilibrium values are exempt from this shortcoming, yet present different issues. The lack of consensus on the definition and measurement of equilibrium exchange rates has indeed made a unique approach difficult to establish (e.g. MacDonald, 2000; Driver and Westaway, 2004). In this Annex we briefly recall two alternative equilibrium exchange rate methodologies.

The natural real exchange rate (NATREX) approach, originally formulated by Stein (1990), defines the "natural" RER as the RER that ensures the equilibrium of the balance of payments in the absence of cyclical factors, speculative capital movements and changes in international reserves. The NATREX guarantees both the internal and the external equilibrium in the long run. The internal equilibrium is achieved when demand is at the level of supply potential and the capacity utilization rate is at its stationary mean; any output gap is zero and unemployment is at the non-accelerating inflation rate of unemployment. The external equilibrium is obtained when the balance of payments is in equilibrium in the long run, i.e. at the given exchange rate, investors are indifferent between holding domestic or foreign assets and the surplus of national investment relative to national savings is entirely financed through long-term borrowing. Although there are some attempts to measure the structural model underlying NATREX (e.g. Gandolfo and Felettigh, 1998 and Siregar and Rajan, 2006), this approach often boils down to estimating a reduced-form equation. Therefore, as noted by Stein (2001), in the latter case the main difference between the BEER and the NATREX models is only that the NATREX approach is theoretically grounded on a dynamic stock-flow model.

Another broad methodology is the Fundamental Equilibrium Exchange Rate (FEER) approach, advocated by Wren-Lewis (1992) and Williamson (1994), where the FEER is the RER that "is consistent with *medium-term macroeconomic equilibrium*" (Wren-Lewis, 1992, p. 75), i.e. that simultaneously attains internal and external balance. As discussed by MacDonald and Clark (1998) and similarly to the NATREX model, the FEER approach does not embody a theory of exchange rate determination, but implicitly assumes that the REER will converge over time to the FEER. In its most popular applications (Isard, 2007; Lee et al., 2008; Cline and Williamson, 2010), the FEER approach is based on a partial equilibrium model and, in particular, on the computation of the required exchange rate adjustment to close the gap between the cyclically-adjusted current account and the "current account norm", which represents an optimal and sustainable value of the current account over a medium-term horizon. The norm is either set in a normative manner or is derived from reduced-form regressions that estimate an equilibrium relationship between the current account and a set of plausible economic fundamentals that influence the investment-savings ratio. The calibration of the adjustment in the exchange rate necessary to close the current account gap is based on some additional assumptions about the exchange-rate pass-through coefficients and the price elasticities of exports and imports. The magnitude of the required exchange-rate adjustment crucially hinges on the accuracy of the estimation of the current account gap and on the measurement of the trade elasticities; in other terms, the FEER and the resulting REER misalignments are very sensitive to the underlying assumptions (on this specific point, see Schnatz, 2011). The FEER model can be reconciled with the NATREX approach by estimating a target level for the net foreign assets position rather than for the current account balance. In particular, under the "external sustainability approach", described in Phillips et al. (2013, the equilibrium REER is defined as the rate that closes the gap between a country's actual current account balance and the balance that would stabilise the net foreign asset position of the country at some benchmark level.

In sum, there is no single dominant approach to modelling equilibrium REERs, although the issue has been heatedly debated for decades (e.g. Cheung, Chinn and Fujii, 2010), also in connection with exchange-rate forecasting (e.g. Meese and Rogoff, 1983a, 1983b; Gandolfo, Padoan and de Arcangelis, 1993; Cheung et al., 2017). This is the main reason for which, in order to conduct an accurate analysis of REER misalignments of individual countries, a range of models should be employed.[53] This paper is instead focused on comparing real misalignments within different country

[53] This is indeed the approach adopted by the IMF, which bases its exchange rate assessments on three complementary sets of models (Phillips et al., 2013); see also Bénassy-Queré, Béreau and Mignon (2010).

groupings and the main requirement for the analysis is therefore that the disequilibria are computed in a consistent manner across countries, regardless of the model employed.

Annex B. The Balassa-Samuelson effect

The intuition behind the Balassa-Samuelson effect may be formally derived assuming two two-sector economies, Home and Foreign.[54] If we consider in a static framework a two-sector small economy, Home, that produces both tradable and non-tradable goods using only homogeneous labour as an input, the general price index P may be considered as a geometric average of the Home tradable and non-tradable goods.

(B1) $P \equiv P_T^{\theta} P_{NT}^{(1-\theta)}$

where P_T and P_{NT} are the prices of tradables and non tradables, respectively, and $0 < \theta < 1$. In the long run labour is perfectly mobile between sectors so that long-run real wages in the two sectors are equal: $\frac{W_N}{P} = \frac{W_{NT}}{P} = \frac{W}{P}$, where w_T and w_{NT} are the wages in the tradable and non-tradable sector, respectively; the nominal wages are also equalised between sectors in the long run. Under perfect competition, the nominal wages are also equal to the marginal revenue product of labour: $w_T = P_T A_T = W$ and $w_{NT} = P_{NT} A_{NT} = W$, where A_T and A_{NT} is the marginal product of labour in, respectively, the tradable and non-tradable sectors. Therefore:

(B2) $\frac{P_{NT}}{P_T} = \frac{A_T}{A_{NT}}$

Or, in other terms, relative prices of non-traded and traded goods in a country are inversely related to the relative productivity in the two sectors. The relative price of non-tradable goods is thus entirely determined by technology and is independent of demand conditions. Taking into account the identity (B1):

(B3) $P = P_T (\frac{A_T}{A_{NT}})^{(1-\theta)}$

In other terms, relatively higher productivity growth in the tradable sector leads to an overall price rise in the long-run.Assuming the law of one price holds for traded goods in the long run, this implies, as seen already in equation (3) in the main text:

(B4) $P_T^* = eP_T$

where * indicates a foreign country (Foreign) and e is the exchange rate (i.e the Foreign price in Home currency). Assuming Foreign has the same economic structure as Home, the following equation also holds:

(B5) $P^* = P_T^* (\frac{A_T^*}{A_{NT}^*})^{(1-\theta *)}$

Equations (B3), (B4) and (B5) lead to the following equation for the long-run real exchange rate Q:

(B6) $Q \equiv \frac{eP}{P^*} = (\frac{A_T}{A_{NT}})^{(1-\theta)} / (\frac{A_T^*}{A_{NT}^*})^{(1-\theta *)}$

if the consumption basket of tradables and non tradables is similar in both countries, i.e. $\theta = \theta^*$, then the long-run real exchange rate is determined by the productivity differential between the tradable and

[54] The simplified derivation presented here is taken from Obstfeld and Rogoff (1996) and Lothian and Taylor (2008).

non-tradable sectors in Home relative to that in Foreign.[55] If the productivity differential is the same in the two countries, then E = 1 (i.e. the absolute purchasing power parity level).[56]

As shown in Lothian and Taylor (2008), supposing that productivity in the non-tradable sector is constant in both Home and Foreign, and taking logarithms of equation (B6), we obtain:

(B7) $q = \gamma_0 + \gamma_1 a_T - \gamma_2 a_T^*$

where lower cases denote logarithms, $\gamma_0 = -(1-\theta)a_N + (1-\theta^*)a_N^*$, $\gamma_1 = (1-\theta) > 0$ and $\gamma_2 = (1-\theta^*) < 0$. In general, equation (B7) suggests that, in a static setting, prices are higher in higher-(tradable) productivity countries relative to those in lower-(tradable) productivity countries; in a dynamic context, prices in faster (tradable) productivity-growing countries will rise relative to prices in slower (tradable) productivity-growing countries. If productivity in the non-tradable sector is constant across countries, γ_0 becomes a constant,[57] the exchange rate is proportional only to the tradable sector's productivity, as is total productivity.

[55] As Froot and Rogoff (1994) explain, if two countries have different weights of tradables in their consumption baskets (i.e. $\theta \neq \theta^*$in equation B6), but identical technologies ($A_{NT}^* = A_{NT}$ and $A_T^* = A_T$), this is sufficient to yield a trend in the real exchange rate. Ultimately, for the real exchange rate to converge in the long run, one must have convergence in tastes, as well as technology.

[56] Balassa's (1964) model explains deviations from the *absolute* purchasing power parity. As discussed in Bergin, Glick and Taylor (2006), the Balassa-Samuelson effect is not guaranteed to exist, as it assumes that innovation is mainly concentrated in the tradable sector and thus that the growth path of an economy is biased towards this sector. If the sources of growth are evenly spread out between the tradable and non-tradable sectors (i.e. balanced growth hypothesis), the effect does not appear, unless non-traded goods are relatively more labour-intensive than traded goods, as Froot and Rogoff (1994) show using an extension of the simplified Balassa-Samuelson model shown here to a two-factor production model with perfectly mobile capital. Moreover, if technological changes were biased toward non-tradable goods (i.e. biased growth), then a price level could actually fall if countries get richer, leading to the opposite of the Balassa-Samuelson effect (see, for example, Devereux, 1999 for evidence of a counter Balassa-Samuelson effect due to high productivity growth in distribution services as a result of productivity gains in manufacturing). Ultimately, the presence of the Balassa-Samuelson effect is an empirical issue. For it to emerge over time, either the biasedness of productivity growth towards the tradable sector has to increase or the share of non-traded goods should increase over time, both plausible facts. Finally, see Hassan (2016) for a discussion of a possible non-monotonicity of the Balassa-Samuelson effect. We refer to Section 2 for the empirical evidence of the Balassa-Samuelson effect in our sample of countries.

[57] This assumption is strong, yet there is evidence for many countries over long time spans that productivity growth in private service sectors, a proxy of the non-tradable sector, is significantly slower to that of sectors open to trade and often close to zero across countries (e.g., Timmer, Inklar and O'Mahony, 2010; Broadberry, Giordano and Zollino, 2013; Giordano, Toniolo and Zollino, 2017). As is known, estimation of productivity growth in the public sector, instead, is subject to large measurement issues, given that the value added of this sector is based on its employees' wages, and productivity is therefore by definition constant.

Annex C. Additional tables and figures

Table C1. An overview of variables included in a selection of BEER models

References	Countries	Time-span	Frequency	Explanatory variables	Deflator	Estimation methodology
Couharde et al. (2017)	182	1973-2016	A	GDP per capita (+), net foreign assets (+); terms of trade (+)	CPI	a) FMOLS b) DOLS c) Pooled mean group
Comunale (2017)	27 (EU countries)	1994-2012	A	Foreign net capital inflows (+); terms of trade(+); GDP per capita(+)	CPI	GM-FMOLS
Hajek (2016)	12 (EA countries)	1980-2014	A	GDP per capita(+); trade balance (-); terms of trade (+)	CPI	DOLS
Gnimassoun and Mignon (2015)	22 (industrialized countries)	1980-2011	A	GDP per capita (+): net foreign assets in percentage of GDP (+)	CPI	DOLS
Adler and Grisse (2014)	a) 21 b) 23 (advanced economies)	a) 1980-2011 b) 1995-2011	A	a) GDP per capita(+); government expenditure(+); labour productivity(-); net foreign assets(+); terms of trade(+) b) GDP per capita; government expenditure(+); labour productivity; net foreign assets; terms of trade(+)	CPI	DOLS
Fischer and Hossfeld (2014)	57 (advanced and emerging economies)	1980-2011	A	Labour productivity(+)	PPP	a) Panel OLS b) Pooled OLS c) Panel DOLS
Mancini-Griffolo, Meyer, Natal and Zanetti (2014)	18 (advanced economies)	1973-2011	A	Net foreign assets(+); output per capita(+); terms of trade(+); government consumption(+); sectorial labour productivity	CPI; PPI	DOLS
Coudert, Couhart and Mignon (2013)	11 (EA countries)	1980-2010	A	GDP per capita (+): net foreign assets in percentage of GDP (+)	CPI	DOLS
Bussière, Ca' Zorzi, Chudík, Dieppe (2010)	a) 44 b) 14 (advanced and emerging economies)	1980-2007	a) A b) Q	Commodity terms of trade(+); fiscal policy(+); civil liberties(-); openness(-); net foreign assets; investment; government expenditure; trade restriction index; GDP per capita (+); commodity prices	PPP	Single-country estimations: Autoregressive distributed lag approach (ARDL). Pure cross section and panel estimations: common correlated effects mean group estimators(CCEMG); common correlated effects pooled (CCEP)
Hossfeld (2010)	17 (US and its 16 major trading partners)	1986-2006	Q	Net foreign assets to GDP (-); trade balance to GDP; terms of trade(+); government consumption; openness	CPI	Single country estimations: a) DOLS; b) FMOLS Panel estimations: a) Group-mean DOLS; b) FMOLS.
Bénassy-Queré, Béreau and Mignon (2009; 2010)	15		A	Relative CPI to PPI ratio (+): net foreign assets in percentage of GDP (+); real interest rate differentials (+); terms of trade (+)	CPI	DOLS
Ricci, Milesi-Ferretti and Lee (2008)	48 (advanced and emerging economies)	1980-2004	A	Trade restriction index(+); price controls(-); commodity terms of trade(+); net foreign assets to trade(+);government expenditure to GDP(+); labour productivity tradables(+); labour productivity nontradables(-)	CPI	a) DOLS b) FMOLS
Lane and Milesi-Ferretti (2004)	64 (industrial and middle-income developing countries)	1975-1996	A	Net foreign assets (+); GDP per capita (+); terms of trade (+)	CPI; WPI	Cross-section and panel estimations: DOLS
Maeso Fernández, Osbat and Schnatz (2004)	25 (OECD countries)	1975-2002	A	GDP per capita(+); government expenditure to GDP(+); openness(-)	PPP	a) Error correction mean-group estimator (MGE /PMGE) b) FMOLS (weighted / unweighted) c) DOLS (weighted / unweighted)
Maeso Fernández, Osbat and Schnatz (2001)	23 (advanced economies)	1975-1998	Q	Labour productivity (+); accumulated current account to GDP; real price of oil(+); long-term interest rate differential(-)	CPI	VECM
Clark and MacDonald (1998)	7 (G-7 countries)	1960-1996	A	Terms of trade(+); CPI/PPI ratio(+); net foreign assets as ratio of GDP(+); relative stock of government debt(+); real interest rate(-)	CPI	Johansen cointegration method

Notes: A=annual; Q=quarterly. The explanatory variables reported are those included in the baseline specifications of the selected studies. When the + or - sign is omitted the estimated relationship is not statistically significant.

Table C2. The list of countries in our sample

Euro area	Other advanced economies	Emerging economies
Austria (AT)*	Australia (AU)*	Algeria (DZ)
Belgium (BE)*	Canada (CA)*	Argentina (AR)
Cyprus (CY)*	Czech Republic (CZ)*	Brazil (BR)
Estonia (EE)*	Denmark (DK)*	Bulgaria (BG)*
Finland (FI)*	Hong Kong (HK)*	Chile (CL)
France (FR)*	Iceland (IS)	China (CN)*
Germany (DE)*	Israel (IL)	Croatia (HR)*
Greece (GR)*	Japan (JP)*	Hungary (HU)*
Ireland (IE)*	Korea, Republic of (KR)*	India (IN)
Italy (IT)*	New Zealand (NZ)	Indonesia (ID)
Latvia (LV)*	Norway (NO)*	Malaysia (MY)
Lithuania (LT)*	Singapore (SG)*	Mexico (MX)
Luxembourg (LU)*	Sweden (SE)*	Morocco (MA)
Malta (MT)*	Switzerland (CH)*	Philippines (PH)
Netherlands (NL)*	Taiwan (TW)	Poland (PL)*
Portugal (PT)*	United Kingdom (GB)*	Romania (RO)*
Slovakia (SK)*	United States (US)*	Russian Federation (RU)
Slovenia (SI)*		South Africa (ZA)
Spain (ES)*		Thailand (TH)
		Turkey (TR)**
		Venezuela (VE)

Notes: (*) Countries included in the narrow sample.
(**) PPIs, but not ULCTs, are available for Turkey.

Table C3. Panel unit root test results

	P-value of IPS test statistic	P-value of CIPS test statistic
CPI-deflated real exchange rate	0.995	0.998
PPP-deflated real exchange rate	0.995	1.000
PPI-deflated real exchange rate	0.830	0.999
GDP deflator-deflated real exchange rate	1.000	1.000
ULCT-deflated real exchange rate	0.994	1.000
Relative GDP per capita	0.395	0.468
Relative labour productivity	0.829	0.008
Relative short-term interest rate	0.000	0.000
Relative openness	0.084	0.000
Relative terms of trade	1.000	0.987
Relative government expenditure	0.847	0.194

Notes: The null hypothesis of no unit root is rejected at a 10 per cent confidence level when the p-value is lower than 0.100.

Table C4. Panel cointegration test results

Dependent variable	Covariates: *Productivity measure*	Covariates: *Additional variables*	Pedroni (1999) group-mean rho test statistic	Pedroni (1999) group-mean t test statistic	Pedroni (1999) group-mean adf test statistic
CPI-deflated real exchange rate	Relative GDP per capita	Relative trade, interest rate and government expenditure variables	2.890	-0.033	-2.118
PPP-deflated real exchange rate	Relative GDP per capita	Relative trade, interest rate and government expenditure variables	2.802	-0.086	-2.296
PPI-deflated real exchange rate	Relative GDP per capita	Relative trade, interest rate and government expenditure variables	2.170	-0.942	-2.411
		Relative trade, interest rate and government expenditure variables			
GDP deflator-deflated real exchange rate	Relative GDP per capita	Relative trade, interest rate and government expenditure variables	2.610	-0.618	-1.616
		Relative trade, interest rate and government expenditure variables			
ULCT-deflated real exchange rate	Relative GDP per capita	Relative trade, interest rate and government expenditure variables	0.677	-2.703	-3.680
		Relative trade, interest rate and government expenditure variables			
CPI-deflated real exchange rate	Relative labour productivity	Relative trade, interest rate and government expenditure variables	2.873	-0.182	-2.773
		Relative trade, interest rate and government expenditure variables			
PPP-deflated real exchange rate	Relative labour productivity	Relative trade, interest rate and government expenditure variables	2.577	-0.558	-2.200
		Relative trade, interest rate and government expenditure variables			
PPI-deflated real exchange rate	Relative labour productivity	Relative trade, interest rate and government expenditure variables	1.614	-1.873	-3.524
		Relative trade, interest rate and government expenditure variables			
GDP deflator-deflated real exchange rate	Relative labour productivity	Relative trade, interest rate and government expenditure variables	2.759	-0.588	-1.993
		Relative trade, interest rate and government expenditure variables			
ULCT-deflated real exchange rate	Relative labour productivity	Relative trade, interest rate and government expenditure variables	1.226	-2.004	-3.229

Notes: The null hypothesis of no cointegration is rejected at a 10 per cent confidence level when the test statistics are lower than -1.29.

Table C5. BEER estimation results, 1999Q1-2008Q4

	Dependent variable				
	1	*2*	*3*	*4*	*5*
	Relative CPI	Relative GDP deflator	Relative PPP deflator	Relative PPI	Relative ULCT
A.					
Relative GDP per capita	0.4756**	0.3043	0.3560*	0.1606	0.3126
	(0.2149)	(0.2121)	(0.1996)	(0.1964)	(0.3282)
Relative openness	-0.2725***	-0.2677***	-0.2325***	-0.1373**	-0.2475***
	(0.0654)	(0.0609)	(0.0635)	(0.0671)	(0.0833)
Relative terms of trade	0.1106	0.2754***	0.3050***	0.5302***	0.2277
	(0.0847)	(0.1031)	(0.1083)	(0.1912)	(0.2113)
Relative government expenditure	0.3911	0.0128	0.5134*	0.0245	1.6845***
	(0.2966)	(0.2513)	(0.2662)	(0.2814)	(0.3135)
Relative short-term interest rates	0.0008	0.0020***	0.0024***	-0.0001	-0.0004
	(0.0008)	(0.0007)	(0.0007)	(0.0008)	(0.0010)
Number of countries	*57*	*57*	*57*	*39*	*38*
Number of observations	*2,280*	*2,280*	*2,280*	*1,560*	*1,520*
B.					
Relative labour productivity	0.1554	0.0822	0.1226	-0.3035*	-0.3597*
	(0.1425)	(0.1679)	(0.1526)	(0.1662)	(0.1850)
Relative openness	-0.2708***	-0.2874***	-0.2622***	-0.1016	-0.2028***
	(0.0825)	(0.0697)	(0.0740)	(0.0786)	(0.0785)
Relative terms of trade	0.2433**	0.3380***	0.4216***	0.3391*	-0.0012
	(0.1152)	(0.1178)	(0.1379)	(0.2023)	(0.1683)
Relative government expenditure	0.3123	0.0967	0.4095	0.0814	1.5409***
	(0.3049)	(0.3187)	(0.3026)	(0.2436)	(0.2476)
Relative short-term interest rates	0.0009	0.0018**	0.0021***	-0.0000	-0.0010
	(0.0007)	(0.0008)	(0.0008)	(0.0007)	(0.0009)
Number of countries	*57*	*57*	*57*	*39*	*38*
Number of observations	*2,257*	*2,257*	*2,257*	*1,560*	*1,520*

Notes: Standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Outlier-robust estimates obtained with a common correlated effects mean group (CCEMG) estimator on the period 1999Q1-2008Q4. The specification includes country fixed effects and cross-section means, here not reported.

Table C6. Narrow-sample CPI, GDP and PPP deflator estimation results

	Dependent variable		
	1	*2*	*3*
	Relative CPI	Relative GDP deflator	Relative PPP deflator
A.			
Relative GDP per capita	0.0151	0.2602**	0.2800**
	(0.1427)	(0.1266)	(0.1359)
Relative openness	-0.2864***	-0.2848***	-0.2568***
	(0.0606)	(0.0642)	(0.0600)
Relative terms of trade	0.1689	0.3783***	0.4960***
	(0.1177)	(0.1052)	(0.1337)
Relative government expenditure	0.1865	0.1010	0.3509
	(0.2112)	(0.2320)	(0.2429)
Relative short-term interest rates	0.0021*	0.0029**	0.0035***
	(0.0012)	(0.0012)	(0.0012)
Number of countries	*38*	*38*	*38*
Number of observations	*2,698*	*2,698*	*2,698*
B.			
Relative labour productivity	0.0459	0.0531	0.0589
	(0.1360)	(0.1116)	(0.1240)
Relative openness	-0.2534***	-0.3019***	-0.2671***
	(0.0626)	(0.0698)	(0.0667)
Relative terms of trade	0.2656**	0.4586***	0.5677***
	(0.1042)	(0.1127)	(0.1189)
Relative government expenditure	-0.0762	-0.3634	-0.0662
	(0.2417)	(0.3283)	(0.3057)
Relative short-term interest rates	0.0022**	0.0015	0.0026*
	(0.0011)	(0.0014)	(0.0013)
Number of countries	*38*	*38*	*38*
Number of observations	*2,698*	*2,698*	*2,698*

Notes: Standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Outlier-robust estimates obtained with a common correlated effects mean group (CCEMG) estimator on the period 1999Q1-2016Q3. The specification includes country fixed effects and cross-section means, here not reported.

Table C7. Alternative Balassa-Samuelson measure panel cointegration estimation results

	Dependent variable		
	1	*2*	*3*
	Relative GDP deflator	Relative PPP deflator	Relative ULCT
Relative CPI-to-PPI ratio	0.3507***	0.3917***	0.3658***
	(0.1035)	(0.1166)	(0.1223)
Relative openness	-0.2366***	-0.2054***	-0.3538***
	(0.0511)	(0.0561)	(0.0909)
Relative terms of trade	0.5754***	0.6606***	0.5166**
	(0.1429)	(0.1538)	(0.2120)
Relative government expenditure	-0.1830	0.0466	1.6873***
	(0.2851)	(0.3024)	(0.3734)
Relative short-term interest rates	0.0023*	0.0034***	0.0023
	(0.0012)	(0.0013)	(0.0016)
Number of countries	*39*	*39*	*38*
Number of observations	*2,769*	*2,769*	*2,698*

Notes: Standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Outlier-robust estimates obtained with a common correlated effects mean group (CCEMG) estimator on the period 1999Q1-2016Q3. The specification includes country fixed effects and cross-section means, here not reported.

Table C8. Panel cointegration estimation results with additional explanatory variables

	Dependent variable				
	1	*2*	*3*	*4*	*5*
	Relative CPI	Relative CPI	Relative CPI	Relative CPI	Relative CPI
A.					
Relative GDP per capita	0.6373	0.2057	0.2128	0.0810	0.3396**
	(0.7435)	(0.1660)	(0.1373)	(0.1250)	(0.1430)
Relative openness	-0.2740***	-0.3304***	-0.3994***	-0.4562***	-0.4435***
	(0.0699)	(0.0824)	(0.0864)	(0.0873)	(0.0801)
Relative terms of trade	0.1278*	0.1975**	0.2337**	0.3030**	0.1214
	(0.0760)	(0.0767)	(0.1033)	(0.1191)	(0.0876)
Relative government expenditure	0.1359	0.3307	0.2934	0.0093	0.4994**
	(0.1888)	(0.2302)	(0.2183)	(0.1770)	(0.2185)
Relative short-term interest rates	-0.0007	-0.0001	-0.0002	0.0004	0.0004
	(0.0006)	(0.0007)	(0.0007)	(0.0008)	(0.0009)
Squared relative GDP per capita	-0.5178				
	(1.0573)				
Relative participation rate		-0.4823			
		(0.4205)			
Relative total population dependency rate			0.5291		
			(1.5303)		
Relative aging structure				1.3362	
				(1.6491)	
Relative investment rate					-0.0032
					(0.1223)
Number of countries	*57*	*57*	*51*	*51*	*57*
Number of observations	*4,034*	*4,016*	*3,610*	*3,610*	*4,034*
B.					
Relative labour productivity	0.1002	0.1438	0.2005	0.2384	0.2605**
	(0.4340)	(0.1460)	(0.1406)	(0.1592)	(0.1303)
Relative openness	-0.3198***	-0.3181***	-0.4447***	-0.3841***	-0.4040***
	(0.0672)	(0.0816)	(0.0884)	(0.0786)	(0.0776)
Relative terms of trade	0.1854*	0.1840**	0.2197**	0.2221**	0.1488*
	(0.1064)	(0.0787)	(0.0871)	(0.1040)	(0.0847)
Relative government expenditure	-0.1605	0.1429	0.0891	0.0047	0.0776
	(0.2843)	(0.1979)	(0.2175)	(0.2849)	(0.2749)
Relative short-term interest rates	0.0007	-0.0000	0.0002	0.0005	0.0014
	(0.0008)	(0.0007)	(0.0007)	(0.0009)	(0.0011)
Squared relative labour productivity	-0.6888				
	(0.7906)				
Relative participation rate		0.2611			
		(0.4629)			
Relative total population dependency rate			1.2944		
			(1.5121)		
Relative aging structure				1.0804	
				(1.7088)	
Relative investment rate					-0.1083
					(0.1397)
Number of countries	*57*	*57*	*51*	*51*	*57*
Number of observations	*4,016*	*4,016*	*3,592*	*3,592*	*4,016*

Notes: Standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Outlier-robust estimates obtained with a common correlated effects mean group (CCEMG) estimator on the period 1999Q1-2016Q3. The specification includes country fixed effects and cross-section means, here not reported.

Table C9. DOLS estimation results

	Dependent variable				
	1	*2*	*3*	*4*	*5*
	Relative CPI	Relative GDP deflator	Relative PPP deflator	Relative PPI	Relative ULCT
A.					
Relative GDP per capita	2.8914***	1.6665***	1.7374***	-1.1956*	-0.4106
	(0.4905)	(0.5695)	(0.5819)	(0.6219)	(0.6127)
Relative openness	-3.1892***	-3.4984***	-3.5350***	0.8393**	0.5878*
	(0.1875)	(0.2150)	(0.2197)	(0.3543)	(0.3198)
Relative terms of trade	-0.9560***	-0.8811***	-0.9020***	4.2108***	4.2315***
	(0.1036)	(0.1207)	(0.1233)	(1.0665)	(1.0040)
Relative government expenditure	-6.0372***	-5.5033***	-5.9950***	-9.7460***	-6.3410**
	(1.7094)	(2.0362)	(2.0806)	(2.5630)	(2.6519)
Relative short-term interest rates	0.0156***	0.0138**	0.0134**	0.0470***	0.0561***
	(0.0046)	(0.0053)	(0.0054)	(0.0135)	(0.0139)
Number of countries	*57*	*57*	*57*	*39*	*38*
Number of observations	*4,045*	*4,047*	*4,047*	*2,769*	*2,698*
B.					
Relative labour productivity	1.0525***	0.9236***	0.9460***	0.1750	0.3949
	(0.1510)	(0.1459)	(0.1466)	(0.8533)	(0.8497)
Relative openness	-3.3234***	-3.6322***	-3.6669***	0.1019	0.3030
	(0.1684)	(0.1627)	(0.1635)	(0.2935)	(0.2865)
Relative terms of trade	-0.8224***	-0.6329***	-0.6543***	3.5324***	3.8807***
	(0.1063)	(0.1027)	(0.1032)	(1.0637)	(1.0367)
Relative government expenditure	-11.1653***	-10.1598***	-10.5635***	-8.7418***	-6.2803**
	(1.0478)	(1.0124)	(1.0173)	(2.4957)	(2.6062)
Relative short-term interest rates	0.0178***	0.0115***	0.0113***	0.0350***	0.0512***
	(0.0037)	(0.0035)	(0.0036)	(0.0099)	(0.0107)
Number of countries	*57*	*57*	*57*	*39*	*38*
Number of observations	*4,016*	*4,016*	*4,016*	*2,769*	*2,698*

Notes: Standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Estimates obtained with a panel DOLS estimator on the period 1999Q1-2016Q3. Only the contemporaneous levels of the explanatory variables are reported here, although lags, leads and first differences are also included in the model.

Table C10. Accession dates to ERM II and to the euro area for its most recent members

	Cyprus	Estonia	Latvia	Lithuania	Malta	Slovakia	Slovenia
ERM II joining date	02/05/2005	28/06/2004	02/05/2005	28/06/2004	02/05/2005	28/11/2005	28/06/2004
Euro adoption date	01/01/2008	01/01/2011	01/01/2014	01/01/2015	01/01/2008	01/01/2009	01/01/2007

Table C11. The relationship between REERs, real misalignments and changes in economic fundamentals: regression results according to alternative deflators

	All countries				*EA countries*	
GDP per capita as proxy for Balassa-Samuelson effect	*1999-2016Q3*	*1999-2016Q3*	*<2009*	*≥2009*	*<2009*	*≥2009*
Dependent variable: changes in GDP deflator-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.823***	-0.874***	-0.958***	-1.100***	-0.495***	-0.721***
	(0.014)	(0.015)	(0.020)	(0.030)	(0.039)	(0.026)
Misalignment (t-20)***EA** dummy		0.244***	0.463***	0.379***		
		(0.043)	(0.072)	(0.081)		
Changes in fundamentals (t/t-20)	0.807***	0.867***	0.968***	0.505***	0.421***	0.472***
	(0.015)	(0.016)	(0.020)	(0.041)	(0.033)	(0.020)
Changes in fundamentals (t/t-20)***EA** dummy		-0.316***	-0.547***	-0.033		
		(0.038)	(0.062)	(0.069)		
Number of countries	*57*	*57*	*57*	*57*	*19*	*19*
Observations	*2,904*	*2,904*	*1,140*	*1,764*	*380*	*589*
Adjusted R-squared	0.551	0.562	0.675	0.522	0.285	0.631

	All countries				*EA countries*	
Labour productivity as proxy for Balassa-Samuelson effect	*1999-2016Q3*	*1999-2016Q3*	*<2009*	*≥2009*	*<2009*	*≥2009*
Dependent variable: changes in GDP deflator-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.803***	-0.854***	-0.944***	-1.099***	-0.436***	-0.664***
	(0.014)	(0.016)	(0.020)	(0.030)	(0.040)	(0.027)
Misalignment (t-20)***EA** dummy		0.255***	0.508***	0.436***		
		(0.043)	(0.072)	(0.079)		
Changes in fundamentals (t/t-20)	0.778***	0.836***	0.950***	0.423***	0.368***	0.431***
	(0.015)	(0.016)	(0.020)	(0.037)	(0.034)	(0.021)
Changes in fundamentals (t/t-20)***EA** dummy		-0.319***	-0.582***	0.008		
		(0.040)	(0.061)	(0.068)		
Number of countries	*57*	*57*	*57*	*57*	*19*	*19*
Observations	*2,904*	*2,904*	*1,140*	*1,764*	*380*	*589*
Adjusted R-squared	0.527	0.539	0.667	0.501	0.220	0.568

	All countries				*EA countries*	
GDP per capita as proxy for Balassa-Samuelson effect	*1999-2016Q3*	*1999-2016Q3*	*<2009*	*≥2009*	*<2009*	*≥2009*
Dependent variable: changes in PPP-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.849***	-0.903***	-0.882***	-1.079***	-0.426***	-0.750***
	(0.017)	(0.019)	(0.023)	(0.030)	(0.032)	(0.028)
Misalignment (t-20)***EA** dummy		0.307***	0.456***	0.328***		
		(0.042)	(0.063)	(0.081)		
Changes in fundamentals (t/t-20)	0.750***	0.809***	1.085***	0.538***	0.502***	0.472***
	(0.023)	(0.027)	(0.031)	(0.040)	(0.033)	(0.021)
Changes in fundamentals (t/t-20)***EA** dummy		-0.256***	-0.583***	-0.066		
		(0.050)	(0.069)	(0.069)		
Number of countries	*57*	*57*	*57*	*57*	*19*	*19*
Observations	*2,904*	*2,904*	*1,140*	*1,764*	*380*	*589*
Adjusted R-squared	0.559	0.570	0.692	0.517	0.405	0.611

Labour productivity as proxy for Balassa-Samuelson effect	*All countries*				*EA countries*	
	1999-2016Q3	*1999-2016Q3*	*<2009*	*≥2009*	*<2009*	*≥2009*
Dependent variable: changes in PPP-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.814***	-0.871***	-0.899***	-1.077***	-0.390***	-0.720***
	(0.018)	(0.020)	(0.025)	(0.030)	(0.033)	(0.029)
Misalignment (t-20)***EA** dummy		0.286***	0.509***	0.356***		
		(0.042)	(0.066)	(0.080)		
Changes in fundamentals (t/t-20)	0.792***	0.836***	0.973***	0.505***	0.482***	0.452***
	(0.020)	(0.022)	(0.024)	(0.039)	(0.035)	(0.023)
Changes in fundamentals (t/t-20)***EA** dummy		-0.282***	-0.491***	-0.053		
		(0.052)	(0.068)	(0.071)		
Number of countries	*57*	*57*	*57*	*57*	*19*	*19*
Observations	*2,904*	*2,904*	*1,140*	*1,764*	*380*	*589*
Adjusted R-squared	0.549	0.559	0.670	0.510	0.354	0.564

GDP per capita as proxy for Balassa-Samuelson effect	*All countries*				*EA countries*	
	1999-2016Q3	*1999-2016Q3*	*<2009*	*≥2009*	*<2009*	*≥2009*
Dependent variable: changes in PPI-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.860***	-0.894***	-0.510***	-1.032***	-0.587***	-0.975***
	(0.014)	(0.016)	(0.039)	(0.028)	(0.043)	(0.030)
Misalignment (t-20)***EA** dummy		0.087***	-0.078	0.057		
		(0.028)	(0.063)	(0.048)		
Changes in fundamentals (t/t-20)	0.795***	1.170***	1.190***	1.351***	0.545***	0.446***
	(0.024)	(0.045)	(0.070)	(0.066)	(0.040)	(0.040)
Changes in fundamentals (t/t-20)***EA** dummy		-0.522***	-0.645***	-0.904***		
		(0.052)	(0.084)	(0.083)		
Number of countries	*39*	*39*	*39*	*39*	*19*	*19*
Observations	*1,989*	*1,989*	*780*	*1,209*	*380*	*589*
Adjusted R-squared	0.681	0.696	0.361	0.709	0.321	0.639

Labour productivity as proxy for Balassa-Samuelson effect	*All countries*				*EA countries*	
	1999-2016Q3	*1999-2016Q3*	*<2009*	*≥2009*	*<2009*	*≥2009*
Dependent variable: changes in PPI-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.898***	-0.901***	-0.561***	-1.074***	-0.630***	-1.014***
	(0.014)	(0.017)	(0.041)	(0.030)	(0.045)	(0.033)
Misalignment (t-20)***EA** dummy		0.057*	-0.069	0.060		
		(0.029)	(0.067)	(0.051)		
Changes in fundamentals (t/t-20)	0.826***	1.166***	1.306***	1.369***	0.593***	0.502***
	(0.026)	(0.057)	(0.085)	(0.084)	(0.043)	(0.054)
Changes in fundamentals (t/t-20)***EA** dummy		-0.449***	-0.713***	-0.867***		
		(0.064)	(0.099)	(0.109)		
Number of countries	*39*	*39*	*39*	*39*	*19*	*19*
Observations	*1,989*	*1,989*	*780*	*1,209*	*380*	*589*
Adjusted R-squared	0.699	0.707	0.360	0.707	0.336	0.629

GDP per capita as proxy for Balassa-Samuelson effect	*All countries* 1999-2016Q3	1999-2016Q3	<2009	≥2009	*EA countries* <2009	≥2009
Dependent variable: changes in ULCT-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.787***	-0.707***	-0.539***	-0.955***	-0.901***	-1.031***
	(0.016)	(0.021)	(0.044)	(0.027)	(0.057)	(0.030)
Misalignment (t-20)***EA** dummy		-0.114***	-0.362***	-0.077*		
		(0.032)	(0.077)	(0.046)		
Changes in fundamentals (t/t-20)	0.916***	1.372***	1.176***	1.337***	0.766***	0.774***
	(0.022)	(0.040)	(0.060)	(0.050)	(0.051)	(0.027)
Changes in fundamentals (t/t-20)***EA** dummy		-0.616***	-0.410***	-0.563***		
		(0.047)	(0.082)	(0.060)		
Number of countries	*38*	*38*	*38*	*38*	*19*	*19*
Observations	*1,938*	*1,938*	*760*	*1,178*	*380*	*589*
Adjusted R-squared	0.674	0.702	0.447	0.787	0.390	0.790

Labour productivity as proxy for Balassa-Samuelson effect	*All countries* 1999-2016Q3	1999-2016Q3	<2009	≥2009	*EA countries* <2009	≥2009
Dependent variable: changes in ULCT-based REERs (t/t-20)	(1)	(2)	(3)	(4)	(5)	(6)
Misalignment (t-20)	-0.733***	-0.705***	-0.470***	-0.896***	-0.645***	-0.911***
	(0.016)	(0.021)	(0.045)	(0.028)	(0.063)	(0.030)
Misalignment (t-20)***EA** dummy		-0.023	-0.175**	-0.015		
		(0.032)	(0.078)	(0.044)		
Changes in fundamentals (t/t-20)	0.837***	1.200***	1.036***	1.260***	0.530***	0.658***
	(0.021)	(0.035)	(0.055)	(0.043)	(0.053)	(0.028)
Changes in fundamentals (t/t-20)***EA** dummy		-0.543***	-0.506***	-0.601***		
		(0.043)	(0.077)	(0.053)		
Number of countries	*38*	*38*	*38*	*38*	*19*	*19*
Observations	*1,938*	*1,938*	*760*	*1,178*	*380*	*589*
Adjusted R-squared	0.609	0.639	0.372	0.747	0.194	0.692

Notes: Panel fixed effects regressions. Country fixed effects are included, but here not reported. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table C12. The relationship between actual HCIs and real misalignments in “stressed” euro area countries: regression results according to different deflators

	GDP per capita			Labour productivity		
	1999-2016Q3	*<2009*	*≥2009*	*1999-2016Q3*	*<2009*	*≥2009*
Dependent variable: changes in GDP deflator-based REERs (t/t-20)	(1)	(2)	(3)	(1)	(2)	(3)
Misalignment (t-20)	-0.452***	-0.780***	-0.288***	-0.395***	-0.733***	-0.267***
	(0.030)	(0.053)	(0.043)	(0.031)	(0.057)	(0.049)
Misalignment (t-20)***Stressed**	-0.455***	-0.015	-0.600***	-0.703***	-0.102	-0.705***
	(0.061)	(0.074)	(0.089)	(0.070)	(0.079)	(0.109)
Changes in fundamentals (t/t-20)	0.244***	0.091**	0.190***	0.250***	0.080**	0.178***
	(0.029)	(0.037)	(0.024)	(0.031)	(0.037)	(0.027)
Changes in fundamentals (t/t-20)***Stressed**	0.677***	0.517***	0.980***	0.754***	0.551***	1.195***
	(0.045)	(0.067)	(0.061)	(0.057)	(0.070)	(0.094)
Number of countries	*12*	*12*	*12*	*12*	*12*	*12*
Observations	*612*	*240*	*372*	*612*	*240*	*372*
Adjusted R-squared	*0.771*	*0.734*	*0.632*	*0.713*	*0.703*	*0.475*
	GDP per capita			Labour productivity		
	1999-2016Q3	*<2009*	*≥2009*	*1999-2016Q3*	*<2009*	*≥2009*
Dependent variable: changes in PPP-based REERs (t/t-20)	(1)	(2)	(3)	(1)	(2)	(3)
Misalignment (t-20)	-0.454***	-0.746***	-0.257***	-0.415***	-0.709***	-0.245***
	(0.031)	(0.047)	(0.045)	(0.033)	(0.049)	(0.052)
Misalignment (t-20)***Stressed**	-0.387***	-0.026	-0.584***	-0.637***	-0.111	-0.742***
	(0.059)	(0.069)	(0.087)	(0.070)	(0.071)	(0.112)
Changes in fundamentals (t/t-20)	0.176***	0.070**	0.098***	0.199***	0.062*	0.096***
	(0.030)	(0.034)	(0.025)	(0.034)	(0.036)	(0.030)
Changes in fundamentals (t/t-20)***Stressed**	0.730***	0.490***	1.033***	0.839***	0.519***	1.310***
	(0.046)	(0.065)	(0.060)	(0.063)	(0.072)	(0.095)
Number of countries	*12*	*12*	*12*	*12*	*12*	*12*
Observations	*612*	*240*	*372*	*612*	*240*	*372*
Adjusted R-squared	*0.769*	*0.756*	*0.613*	*0.717*	*0.742*	*0.467*
	GDP per capita			Labour productivity		
	1999-2016Q3	*<2009*	*≥2009*	*1999-2016Q3*	*<2009*	*≥2009*
Dependent variable: changes in PPI-based REERs (t/t-20)	(1)	(2)	(3)	(1)	(2)	(3)
Misalignment (t-20)	-0.904***	-0.805***	-0.808***	-0.903***	-0.710***	-0.847***
	(0.026)	(0.078)	(0.048)	(0.025)	(0.077)	(0.049)
Misalignment (t-20)***Stressed**	-0.093	-0.181*	-0.194**	-0.154***	-0.245**	-0.258***
	(0.063)	(0.108)	(0.097)	(0.054)	(0.103)	(0.096)
Changes in fundamentals (t/t-20)	-0.162***	-1.044***	-0.021	-0.522***	-1.494***	-0.238**
	(0.062)	(0.106)	(0.064)	(0.091)	(0.149)	(0.101)
Changes in fundamentals (t/t-20)***Stressed**	0.676***	0.969***	1.027***	0.712***	1.219***	0.451**
	(0.109)	(0.239)	(0.177)	(0.155)	(0.256)	(0.214)
Number of countries	*12*	*12*	*12*	*12*	*12*	*12*
Observations	*612*	*240*	*372*	*612*	*240*	*372*
Adjusted R-squared	*0.760*	*0.614*	*0.593*	*0.770*	*0.586*	*0.580*

	GDP per capita			Labour productivity		
	1999-2016Q3	*<2009*	*≥2009*	*1999-2016Q3*	*<2009*	*≥2009*
Dependent variable: changes in ULCT-based REERs (t/t-20)	(1)	(2)	(3)	(1)	(2)	(3)
Misalignment (t-20)	-0.514***	-0.774***	-0.548***	-0.422***	-0.651***	-0.457***
	(0.037)	(0.077)	(0.071)	(0.035)	(0.080)	(0.058)
Misalignment (t-20)***Stressed**	-0.413***	-0.133	-0.601***	-0.683***	-0.305***	-0.640***
	(0.068)	(0.101)	(0.117)	(0.073)	(0.109)	(0.103)
Changes in fundamentals (t/t-20)	0.388***	0.097*	0.416***	0.314***	0.094*	0.297***
	(0.043)	(0.054)	(0.050)	(0.035)	(0.048)	(0.033)
Changes in fundamentals (t/t-20)***Stressed**	0.674***	0.079	0.750***	0.981***	0.265**	1.745***
	(0.063)	(0.108)	(0.088)	(0.067)	(0.108)	(0.088)
Number of countries	*12*	*12*	*12*	*12*	*12*	*12*
Observations	*612*	*240*	*372*	*612*	*240*	*372*
Adjusted R-squared	*0.826*	*0.579*	*0.700*	*0.798*	*0.529*	*0.746*

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Panel fixed effects regressions. Country fixed effects are included, but here not reported. Stressed euro area countries include all 19 euro area countries except for Austria, Belgium, Finland, France, Germany, Luxembourg, and the Netherlands.

Table C13. Governance indicators in our sample of countries: summary statistics

	Full sample	**Euro area**	**Other advanced economies**	**Emerging economies**
Accountability				
Mean	0.7	1.2	1.1	0.0
Median	1.0	1.2	1.3	0.1
Standard deviation	0.8	0.3	0.5	0.7
Min	-1.6	0.8	-0.1	-1.6
Max	1.6	1.6	1.6	1.1
Control of corruption				
Mean	0.8	1.1	1.7	-0.2
Median	0.9	1.1	2.0	-0.3
Standard deviation	1.0	0.7	0.7	0.6
Min	-1.1	0.1	0.3	-1.1
Max	2.4	2.4	2.4	1.4
Government effectiveness				
Mean	1.0	1.3	1.7	0.1
Median	1.1	1.3	1.7	0.1
Standard deviation	0.8	0.5	0.4	0.5
Min	-1.1	0.5	0.9	-1.1
Max	2.2	2.1	2.2	1.2
Political stability				
Mean	0.4	0.8	0.8	-0.4
Median	0.6	0.9	1.0	-0.4
Standard deviation	0.8	0.4	0.6	0.7
Min	-1.4	0.0	-1.3	-1.4
Max	1.5	1.5	1.3	0.8
Regulatory quality				
Mean	0.9	1.3	1.5	0.1
Median	1.1	1.2	1.6	0.3
Standard deviation	0.8	0.3	0.3	0.7
Min	-1.3	0.7	0.9	-1.3
Max	1.9	1.8	1.9	1.5
Rule of law				
Mean	0.8	1.2	1.5	-0.1
Median	1.0	1.1	1.7	-0.1
Standard deviation	0.9	0.5	0.4	0.6
Min	-1.5	0.5	0.9	-1.5
Max	2.0	2.0	1.9	1.3

Notes: The indicators vary between -2.5 and + 2.5, where a higher value of the indicator entails better institutions. Averages are taken over the period 1999-2015.

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