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PRICE AND COST COMPETITIVENESS MISALIGNMENTS OF THE EURO AREA AND OF ITS MAIN ECONOMIES ACCORDING TO A QUARTERLY BEER MODEL, 1999-2017

by Claire Giordano*

Abstract

This study first assesses recent misalignments of the real effective exchange rate (REER) of the euro area and of the Harmonized Competitiveness Indicators (HCIs) of its main economies, based on a quarterly Behavioural Equilibrium Exchange Rate (BEER) model. Next, it draws a comparison with comparable estimates published by the IMF and by CEPII. The BEER model here employed was first put forward by Fidora, Giordano and Schmitz (2017; 2018) and enables the assessment of the departure of actual REERs and HCIs from values consistent with underlying economic fundamentals (i.e. "equilibrium" values). The quarterly model has now been extended to cover a longer time span (1999-2017) and refined by employing new data sources, in particular relative to producer price indices, one of five alternative price/cost indicators used to derive the REERs and HCIs. There is evidence of a modest overvaluation of the euro-area REER in 2017, partly linked to the nominal appreciation of its currency in the second half of the year.

JEL Classification: E31, F00, F31.
Keywords: price competitiveness, cost competitiveness, real effective exchange rate, equilibrium exchange rate, misalignments.

Contents

* Balance of Payments Analysis Division, DG Economics, Statistics and Research, Bank of Italy.

1. Introduction[1]

This study presents a quarterly Behaviourial Equilibrium Exchange Rate (BEER) model,[2] which provides timely estimates of real exchange rate or Harmonised Competitiveness Indicator (HCI)[3] misalignments for a large set of – both euro and non-euro area - countries and for the euro area as a whole. The model was first put forward by Fidora, Giordano and Schmitz (2017; 2018). It has now been updated, refined, adapted to Bank of Italy's statistical infrastructure and therefore integrated into this institution's modelling toolkit.

By measuring the statistical relationship between real exchange rates and a set of economic fundamentals, the BEER methodology determines equilibrium exchange rates empirically, free from any normative assumption on, for example, whether and how the current account should adjust. It is comparable to the real effective exchange rate (REER) regressions underlying the IMF's External Balance Assessment (EBA). In particular, the BEER model presented here provides quarterly estimates since 1999 of equilibrium values of both bilateral and effective exchange rates for 57 advanced and emerging countries and of the euro area, deflated by five alternative price and cost indices, from which real misalignment measures may be derived. Estimates are available with an approximate one-quarter lag relative to the reference period (this study therefore discusses results until 2017Q4), although they may be revised at a later stage, due mainly to revisions to the national account data underlying the model.

To our knowledge, no institution has thus far published BEER model-based REER misalignment estimates for 2017 with which to compare those provided in this document. According to the results presented in this study, in 2017 the REER of the euro area and the HCIs of its four main economies were moderately misaligned relative to economic fundamentals, yet to a significantly lesser extent than in the early 2000s or in the Great Recession years, when disequilibria were the largest during the sample period. The choice of the price and cost index employed in constructing these indicators is found to significantly affect the magnitude of the estimated misalignments. The use of alternative price/cost indices, and therefore the production of a range of misalignment estimates, is thus crucial for an informed assessment of price-competitiveness imbalances.

In more detail, in 2017 the REER of the euro area was moderately overvalued with respect to its equilibrium value (+1.8% on average across the five estimates produced, against a virtually null misalignment in 2016 and a clear-cut undervaluation in 2015), mainly due to developments in

[1] The Author is very grateful to Andrea Brandolini, Silvia Fabiani, Alberto Felettigh, Michael Fidora, Martin Schmitz and Roberto Tedeschi for comments on previous versions of this document. The current version is based on the April 10 2018 data vintage. The views here expressed as those of the Author, and not of the represented Institution. Any error is the Author's responsibility.

[2] BEER models are called this way due to the fact that they do not have any comprehensive theoretical underpinning and are based on the assumption that equilibrium rates are determined by the long-run "behaviour" of their macroeconomic drivers.

[3] According to the Eurosystem terminology, HCIs provide an overview of the price and cost competitiveness of individual euro-area countries relative to their main competitors, constructed using the same methodology as the REER of the euro area. The REER of the euro area is, however, computed solely against non-euro area partners and is therefore not strictly comparable to the single euro-area members' HCIs, which are computed *vis-à-vis* both euro and non-euro area competitors; the same applies to the corresponding misalignments.

the second half of the year. Concerning individual economies, in the same year Italy's HCI was on average marginally overvalued (+1.4%, half a percentage point more than in 2016), with estimates spanning from -1.1 to +4.1%, according to the price or cost index considered. In 2017 Germany's HCI was undervalued according to all five estimates produced (in the range of -4.0%; -1.2%), albeit to a smaller extent than in 2015 and in 2016. France's and, to a lesser extent, Spain's average HCI misalignments were also negative in 2017, yet the interval of estimates for these countries is wide and, in the case of Spain, covers both positive and negative values, hindering a clear-cut assessment. As for the euro area as a whole, also for individual countries average 2017 developments were mainly driven by those in the second semester.

The document is organised as follows. Section 2 describes the quarterly BEER model and reports the estimated average long-run relationships between real exchange rates and economic fundamentals. Section 3 provides estimates of REER/HCI misalignments of the euro area and of the main euro-area countries with a specific focus on 2017. Section 4 compares estimates for the years 2014-2016 with those provided by the REER models of the IMF in the context of the EBA and by CEPII, to our knowledge the only other source which provides misalignments computed according to a comparable methodology.

2. A description of the quarterly BEER model

In a nutshell, in the BEER model here described and first put forward in Fidora, Giordano and Schmitz (2017; 2018) a reduced-form relationship between bilateral real exchange rates (RERs)/bilateral HCIs and key macroeconomic fundamentals is estimated since 1999 for 57 euro and non-euro area countries. Five alternative price and cost indices are employed to construct the RERs/bilateral HCIs. As in all BEER models, the macroeconomic variables cannot be interpreted as "causal" determinants of the latter. Nonetheless, this approach can help determine the extent to which the latter diverge from their historical relationship with economic fundamentals, and thereby measure the implied RER/bilateral HCI misalignments, which are derived as the difference between observed and fitted values. By aggregating (equilibrium and actual) bilateral RERs/bilateral HCIs into (equilibrium and actual) REERs/HCIs using trade weights, it is also possible to derive REER/HCI misalignments at a quarterly frequency for each of the 57 countries considered, as well as for the euro area as a whole.

For monitoring and analysis purposes the BEER model is estimated on quarterly, as opposed to annual, data in order to have timely misalignment estimates. The increase in the number of observations relative to an annual dataset also improves the efficiency in the estimation. However, as also discussed in Bussière et al. (2010), the main drawback of adopting high-frequency data is thinner data availability, and therefore the restriction of the estimation window to the most recent years (since 1999).

Relative to the original model published in Fidora, Giordano and Schmitz (2017; 2018), three refinements in particular have been introduced herein, for which details are provided further on: (i) the employment of the Bank of Italy's, as opposed to the ECB's, producer price indices as one of the five deflators used to construct the RERs/bilateral HCIs, available for a much broader sample of countries and which have recently undergone an in-house quality check and improvement (Felettigh and Giordano, 2018); (ii) the use of additional quarterly data sources, such as the BIS

Macroeconomic dataset, to construct selected explanatory variables, which reduces the number of cases of interpolation of annual data as a last resort; and (iii) the estimation of the model over a longer time period, which will expand further as new data become available.

The model specification

Following the seminal paper by Clark and MacDonald (1998), whose framework is described in the Annex, the dependent variable of the BEER model is the bilateral RER/bilateral HCI (rer_t) of each currency *vis-à-vis* the euro (the numéraire currency), defined in such way that an increase corresponds to a real appreciation of the domestic currency *vis-à-vis* the numéraire.[4] Correspondingly, explanatory variables need also to be expressed relative to the euro area since the dependent variable 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).[5]

In the BEER model literature there is no prior theory for the selection of economic fundamentals; hence, the choice of the determinants of the RER is based on economic intuition and on data availability. In order to select the relevant economic fundamentals herein, a general-to-specific approach is adopted, in which only the variables, suggested by the existing BEER model literature (summarised in Table A1 of the Annex), that are statistically significant at a 10% confidence level in at least one of the five specifications here considered, are kept.

Turning to these economic fundamentals, one of the most popular explanations of the deviations from equilibrium is due to Balassa (1964) and Samuelson (1964), which 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. 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. This leads to a higher general price level, which in turn implies a real appreciation in the currency. In order to empirically investigate the Balassa-Samuelson effect, in principle data on sectoral productivity should be employed. Since the BEER model is estimated at a quarterly frequency for a large set of countries, owing to data availability, aggregate, as opposed to sectoral, measures are used, as is standard in most of the BEER model literature.[6] Moreover, GDP per capita (*gdppc*) is used as a proxy of productivity, given that it is found to be more frequently statistically significant than labour productivity for the sample considered herein (results available upon request). This

[4] In the case of euro-area countries, whose currency is the euro, this simply implies considering the differential of their price or cost index relative to the euro-area's corresponding price or cost index.

[5] 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 leads 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 this potential bias is partly dealt by controlling for cross-section dependence, as discussed later on in this section. See Fidora, Giordano and Schmitz (2017; 2018) for a further discussion of this point.

[6] Moreover, if productivity growth in the non-tradable sector is constant across countries, then aggregate, as opposed to sectoral, measures may be employed without loss of generality. See Lothian and Taylor (2008) and Fidora, Giordano and Schmitz (2017; 2018) for evidence of this point.

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.[7]

Whereas the Balassa-Samuelson model assumes that the RER depends entirely on supply factors, demand-side variables are also typically considered in BEER models. First, openness to trade (*open*), i.e. the sum of exports and imports as a share of GDP, is used as an inverse proxy of the intensity of trade restrictions, which may have an effect on real exchange rates: higher trade barriers lead to an appreciation via a rise in domestically produced goods' prices (Goldfajn and Valdes, 1999; Ricci et al., 2013).

Second, an improvement in terms of trade (*tot*), e.g. an increase in export prices relative to import prices, should lead to a positive income or wealth effect in the domestic economy. The ensuing rise in domestic demand increases domestic prices and therefore leads to a RER 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 again to a RER appreciation (Melecký and Komárek, 2007).[8]

Third, fiscal policy, here captured by final government expenditure relative to GDP (*gov*), can positively affect the RER through a composition effect (Froot and Rogoff, 1992; Obstfeld and Rogoff, 1996; Hinkle and Montiel, 1999): higher government consumption, which is generally biased towards the non-tradable sector, bids up non-tradable prices and leads to a RER appreciation. 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).

Finally, an (unanticipated) increase in real interest rate differentials (*int*) should give rise to capital inflows and therefore to an appreciation of the RER (Clark and MacDonald, 1998).

The full specification of the BEER model is thus the following:

$$(1) \qquad rer_{i,t} = \beta_{1i} gdppc_{i,t} + \beta_{2i} open_{i,t} + \beta_{3i} tot_{i,t} + \beta_{4i} gov_{i,t} + \beta_{5i} int_{i,t} + \mathrm{FE} + \varepsilon_{i,t},$$

where *i* indicates the country, *t* a quarter in the period1999Q1-2017Q4, *FE* are fixed effects, namely country fixed effects[9] and cross-section means of both the dependent and explanatory

[7] Moreover, quarterly employment data are less often available for emerging economies, leading to more frequent resorting to interpolation of annual data, which also could explain the lower statistical significance of the labour productivity variable.

[8] Given the increase in the relative price of exports to imports, domestic agents could also shift their demand towards imported goods and the domestic currency would then have to depreciate to restore the external equilibrium. Empirically, however, it has been documented that the negative effect of the terms of trade on the RER is outweighed by the positive effect, owing to the fact that imports and domestic goods are imperfect substitutes (De Gregorio and Wolff, 1994; Couharde et al., 2017), thereby explaining the positive sign generally associated to the terms of trade variable (again see Table A1 of the Annex).

[9] The inclusion of country fixed effects is necessary whenever the RER/bilateral HCI is an index number, as it attempts to control for country-specific price/cost level information (Fischer and Hossfeld, 2014). However, with fixed effects the predicted RERs/bilateral HCIs are by construction on average equal to their long-run 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/bilateral HCI levels. Results are thus less reliable for countries

variables (the latter issue is discussed further on), and $\varepsilon_{i,t}$ is a random error. As mentioned earlier, all the regressors are expressed relative to the corresponding euro-area aggregate.

The dataset

The countries considered in the model include both advanced and emerging countries, accounting for over 90 per cent of global GDP in 2017, and coincide with the 57 countries employed in the construction of the ECB's official REERs and HCIs (see Table A2 of the Annex for the full list).[10] In comparison with the other studies, reported in Table A1, the sample coverage is large. The numéraire country, i.e. the euro area, is not computed as the aggregation of the 19 individual euro-area members, but is considered as a standalone country, based on official statistics.

In order to obtain real exchange rates/bilateral HCIs, nominal exchange rates are deflated by one of the following: i) consumer price index (CPI), ii) Purchasing Power Parity (PPP) rate,[11] iii) producer price index (PPI),[12] 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 REERs/HCIs (Chinn, 2006; Christodoulopoulou and Tkačevs, 2014; Giordano and Zollino, 2016; Ahn, Mano and Zhou, 2017), which makes it necessary to consider a range of alternative indices. As seen in Table A1, however, BEER models have mainly been estimated based on CPIs or PPPs. To our knowledge, Fidora, Giordano and Schmitz (2017; 2018) were the first attempt to consider such a wide range of deflators.

Since the model is estimated at a quarterly frequency, seasonally-adjusted data are used; when absent, yearly data are linearly interpolated. The following hierarchy of sources for national account data is followed: Eurostat, OECD, BIS Macroeconomic data, IMF International Financial Statistics (IFS), IMF World Economic Outlook (WEO). The latter dataset is also used for the data related to PPPs and the terms of trade.[13] Period-average nominal exchange rates and price/cost indices are sourced from the ECB and IMF, with the exception of PPIs, which are sourced from the Bank of Italy (Felettigh and Giordano, 2018). CPIs, PPP and GDP deflators are available for all 57

with a short sample span or which have experienced structural breaks over the period considered (Phillips et al., 2013). Here this shortcoming is partially overcome by adopting (quarterly) data over the period 1999-2017, which is a relatively long time-span if compared to the existing empirical literature (see Table A1). Moreover, the BEER model is programmed so that at each data update the estimation window lengthens. Finally, one of the deflators considered (the PPP) is an actual price level; when it is employed, country fixed effects may be in principle dropped from the estimation of regression (1). In this case, however, also the explanatory variables expressed as index numbers, such as terms of trade, need to be excluded to obtain reliable estimates. Moreover, PPPs suffer from measurement issues, which are discussed more in detail in the Annex. This confirms the usefulness of comparing results based on five alternative deflators, as done in this analysis.

[10] The ECB's REERs and HCIs broadly refer to the same countries employed in Bank of Italy's official price-competitiveness indicators (Felettigh et al., 2015 and 2016; Felettigh and Giordano, 2018).

[11] The PPP (implied conversion) rate between two countries, as defined by IMF (2018a), is the rate at which the currency of one country needs to be converted into that of a second country to ensure that a given amount of the first currency purchases the same volume of goods and services in the second country as in the first. See the Annex for a discussion of measurement issues related to PPPs.

[12] For most countries this is the PPI of domestically sold manufacturing goods, which in Felettigh and Giordano (2018) and other studies cited therein is argued to be a good proxy of overall production costs of all tradable (not necessarily traded) manufacturing goods.

[13] PPPs and terms of trade are currently the only two variables for which solely annual data are available.

countries in the sample, whereas PPIs are available for 55 countries,[14] and ULCTs for 38, mainly advanced, economies (the so-called "narrow sample" in Table A2). Nominal three-month money market rates, sourced from IMF-WEO, IMF-IFS, ECB and BIS, are deflated with (contemporaneous) CPIs to obtain real interest rates.[15]

Estimation results

The estimation framework employed herein is described in detail in the Annex. In a nutshell, as a first step, the time-series properties of the data are investigated. Panel unit root test results, available upon request and in line with those published in Fidora, Giordano and Schmitz (2017; 2018), point to the non-stationary nature of both the dependent and most explanatory variables in the model, which are found to be cointegrated, according to panel cointegration tests. A panel cointegration analysis is thus warranted. Moreover, there is evidence of cross-section dependence (i.e. the presence of unobserved common shocks) across the countries in the sample.

The chosen estimation method is therefore the common correlated effects mean group (CCEMG) estimator developed by Pesaran (2006) and Kapetanios, Pesaran and Yamagata (2006), which has the advantage, in a cointegration setting, both of allowing for country heterogeneity in the estimation of the coefficients and of tackling cross-section dependence, by augmenting country-specific equations with the cross-section averages of the dependent and independent variables, which are observable proxies for the common effects of the panel. Coefficients are estimated country-by-country and then averaged across countries.

The outlier-robust means of parameter coefficients across countries, obtained from estimating equation (1) using the CCEMG estimation procedure, are reported in Table 1, where each column refers to a differently deflated dependent variable. The coefficients of the cross-section averages have no economic meaning in the analysis, and are therefore not reported.

The Balassa-Samuelson effect is statistically significant and correctly signed across all specifications; the magnitude of the coefficient is in line with that reported in the BEER model literature (see, e.g. Couharde et al., 2017). All other results reported also comply with the economic priors discussed earlier. In particular, an increase in relative openness is associated with a real depreciation, a result which is strongly significant across the board. An increase in the terms of trade is associated, when statistically significant, with an appreciation of the real exchange rate. The coefficient of relative government expenditure is only statistically significant in the ULCT-deflated regression, where it is positive, thereby confirming the compositional bias of public spending towards the non-tradable sector.[16] Finally, real interest rate differentials are significantly and positively correlated with RERs/bilateral HCIs, as expected, in most specifications.

[14] Iceland and Luxembourg are excluded from the broad sample. Bank of Italy's PPIs anyhow have a much wider country coverage than the ECB PPIs employed in Fidora, Giordano and Schmitz (2017; 2018), which refer only to 39 countries.

[15] For data availability issues, short-term interest rates are here employed; they are, however, generally correlated with long-term interest rates.

[16] 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

Table 1. BEER model estimation results

	Dependent variable				
	1	*2*	*3*	*4*	*5*
	Relative CPI (1)	Relative GDP deflator	Relative PPP deflator	Relative PPI	Relative ULCT
GDP per capita	0.24**	0.44***	0.39***	0.28*	0.53***
	(0.108)	(0.116)	(0.116)	(0.147)	(0.176)
Trade openness	-0.44***	-0.47***	-0.42***	-0.33***	-0.30***
	(0.086)	(0.098)	(0.094)	(0.080)	(0.089)
Terms of trade	0.15	0.41***	0.51***	0.19	0.18
	(0.095)	(0.116)	(0.133)	(0.132)	(0.197)
Government expenditure	-0.12	-0.26	-0.14	-0.12	2.01***
	(0.321)	(0.372)	(0.319)	(0.359)	(0.497)
Short-term interest rates	0.001	0.003***	0.004***	0.004***	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of countries	*57*	*57*	*57*	*55*	*38*
Number of observations	*4,325*	*4,332*	*4,332*	*4,180*	*2,888*
RMSE	*0.039*	*0.046*	*0.046*	*0.044*	*0.026*
Normalised RMSE	*0.003*	*0.003*	*0.007*	*0.003*	*0.003*
Normalised RMSE of only FE model	*0.013*	*0.012*	*0.032*	*0.013*	*0.016*

Notes: The dependent variable is the RER/bilateral HCI deflated according to a different price or cost index in each column. Outlier-robust estimates obtained with a common correlated effects mean group (CCEMG) estimator on the period 1999Q1-2017Q4. The specification also includes country fixed effects and cross-section means, here not reported. Standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. RMSE = Root mean squared error. The normalised RMSE is obtained by dividing the RMSE by the (min-max) range of the dependent variable. The last row reports the normalised RMSE of an alternative model based solely on time and country fixed effects. (1) CPI data for Argentina are currently unavailable since 2016Q1, thereby explaining the lower number of observations in column (1) relative to columns (2) and (3).

The goodness of fit of the model is proxied by the root mean squared error (RMSE), which has been normalised across specifications, by dividing the standard RMSE by the (min-max) range of the dependent variable, in order to account for differences in the latter across columns in Table 1, and thus for comparability reasons. The normalised RMSEs are small and more contained than those based on a model only including country and time fixed effects as explanatory variables (reported in the last row of Table 1) and those of the BEER model estimated with fixed-effects OLS shown in Table A3 of the Annex, pointing to satisfactory goodness of fit.[17] They are also comparable across specifications, with only the PPP-based regression reporting a higher value, possibly due to the greater measurement issues linked to PPPs (discussed in the Annex) than to the other price and cost indices. If the BEER model is well specified (and indeed particular care has

government expenditure only affects total-economy measures of the REER and not narrow measures, limited to the tradable sector.

[17] Although the models are not strictly comparable due to different explanatory variables and to a different data frequency, as will be discussed in Section 4, the RMSE of the CPI-based regression reported herein is also much lower than that of the REER-index regression underlying the IMF's EBA estimated via fixed-effects OLS (and equal to 0.081; Phillips et al., 2013, p. 63).

been given to the selection of the most robust explanatory variables across differently deflated RERs/bilateral HCIs in Fidora, Giordano and Schmitz, 2017 and 2018, and herein), then the residual of each regression can be considered as a reasonable proxy of RER/bilateral HCI misalignments.

The results in Table 1 are broadly robust to changes in the country and time coverages, to alternative measures of the Balassa-Samuelson effect and to the inclusion of additional explanatory variables employed in the BEER model literature (such as demographic variables, net foreign assets and the investment rates, which are found, however, to be statistically insignificant and therefore not included in the model), as documented in Fidora, Giordano and Schmitz (2017; 2018). The empirical salience and stability of the regressors included in the baseline model are therefore confirmed.[18]

Finally, in Table A3 and in Table A4 in the Annex estimation results for the BEER model obtained by respectively using fixed-effects Ordinary Least Squares (OLS) and Panel Dynamic Ordinary Least Squares (PDOLS), the most common estimation procedures in the existing literature, are provided. Fixed-effect OLS results are on the whole broadly comparable to those estimated with the CCEMG procedure in Table 1, yet the Balassa-Samuelson effect loses statistical significance in the PPI-based specification and interest rate differentials are generally not significant. Moreover, as afore-mentioned, the normalised RMSEs are higher in the fixed-effects OLS regressions than in the baseline regressions in Table 1, suggesting a weaker goodness of fit in the former model. PDOLS coefficients are instead generally larger and more often statistically significant than those obtained by CCEMG, possibly due to the fact that they are also capturing unobserved, common shocks. Furthermore, in some cases elasticities present the wrong sign (for example, for relative trade openness and interest rate differentials in some specifications). For a quarterly BEER model at least, the CCEMG procedure applied herein therefore appears to be more apt, given the tested presence of unit roots, cointegration and cross-section dependence in the panel.

3. Misalignment estimates for the euro area and for the main euro-area countries

The in-sample predictions obtained from the estimated relations provided in Table 1 are employed to compute the equilibrium values of both bilateral RERs/bilateral HCIs and of REERs/HCIs, the latter obtained by weighting the bilateral rates with gross trade flows provided by the ECB.[19] The resulting series provide a time-varying and country-specific benchmark against which one may assess actual REERs/HCIs. REER/HCI misalignments are computed as the percentage point difference between the observed REERs/HCIs and their equilibrium level at date

[18] Further results available upon request derive from estimating equation (1) solely for euro-area countries, in order to assess the importance of these economic fundamentals for the main countries of interest in this analysis. The number of observations drops to 1,444 and the demanding CCEMG procedure leads to the loss of statistical significance of some variables in some specifications. However, the significance of the Balassa-Samuels effect is confirmed, as is the important role of relative trade openness and of the terms of trade in most specifications. Interest rate differentials are instead never statistically significant, plausibly due to their small deviations relative to the overall euro-area's rate; in the full sample in Table 1 the contribution of this variable is indeed the smallest.

[19] The trade weights employed are those currently underlying the ECB's official REERs and HCIs. They are three-year window rolling weights; the latest reference period is currently 2012-2015.

t.[20] Given the definition of the REER/HCI, positive (negative) misalignments thus indicate overvaluations (undervaluations) of the REER/HCI relative to its equilibrium value. By computing five estimates (one for each alternative price or cost index) for each country-quarter, a range of disequilibria estimates is provided. In the rest of the section the focus turns first to the estimated REER misalignments of the euro area as a whole, and then to the HCI disequilibria of the four largest euro-area countries. It is worth again recalling at this stage that the REER of the euro area is computed solely against non-euro area partners and is therefore not strictly comparable to the single euro-area members' HCIs, which are computed *vis-à-vis* both euro and non-euro area competitors; the same applies to the corresponding misalignments.[21]

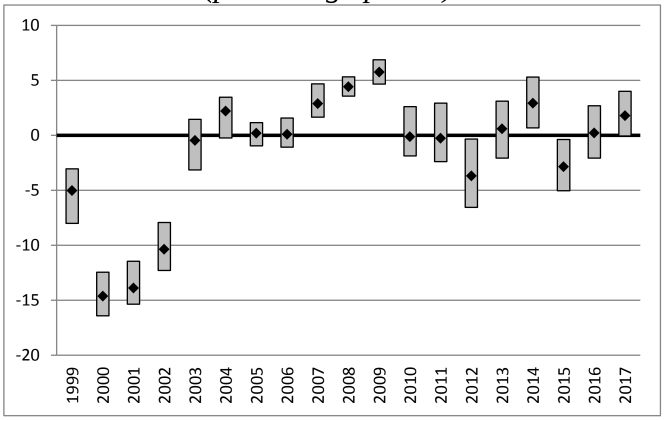
The euro area

In the first years of the monetary union the REER of the euro area was strongly undervalued, on average by nearly 15% in 2000-2001 (Fig. 1a), mainly due to the plunge in the nominal effective exchange rate of the euro (Fig. 1b), a result in line with that in Maeso Fernández, Osbat and Schnatz (2001). After a broad alignment with economic fundamentals in the mid-2000s, the REER then became overvalued peaking at an average 6% approximately in 2009. Thereafter, misalignments fluctuated in an approximate (-7%; +5%) range. In 2017, the REER of the euro area was moderately overvalued (+1.8% on average; with estimates ranging between -0.1% and +4.0%), moving from an average null disequilibrium in 2016.

[20] 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. BEER model estimates should therefore be considered as lower-bound estimates of misalignments (in absolute value). Moreover, fundamentals may themselves be misaligned, although to assume they are systematically misaligned over a nearly 20-year period is a strong claim (and less likely the longer the estimation window becomes). A possible solution is to employ the "long-term" values of fundamentals in the estimation, by filtering the actual series, but this did not significantly affect the estimated equilibria so the actual series are here employed. Future work will aim at constructing an annual BEER model, estimated as of 1980, which will contribute to the determination of a more robust measure of equilibrium values of fundamentals based on nearly forty-year-long time series.

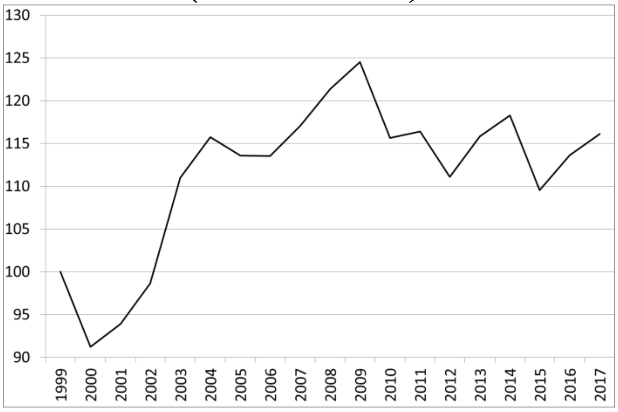
[21] Future research could aim at estimating HCI misalignments *vis-à-vis* euro and non-euro area trading partners separately (for this disaggregation applied to actual HCIs, see Schmitz et al. 2013; Felettigh et al. 2015; 2016). However, this would imply re-appraising the significant economic fundamentals and re-estimating the BEER model described in Section 2 for each set of trading partners.

Figure 1a. Annual REER misalignment estimates of the euro area
(percentage points)



Source: Author's estimations, based on an update of the original model in Fidora, Giordano and Schmitz (2017; 2018).
Notes: Annual averages of quarterly estimates. The bars represent the range, across different price/cost indices, of estimated REER misalignments for each reference country and year. The diamond represents the mean of the five estimated REER misalignments discussed in the text. A positive (negative) misalignment would require a depreciation (an appreciation) of the actual REER to unwind, provided the equilibrium rate does not change.

Figure 1b. The nominal effective exchange rate of the euro area
(index 1999=100)

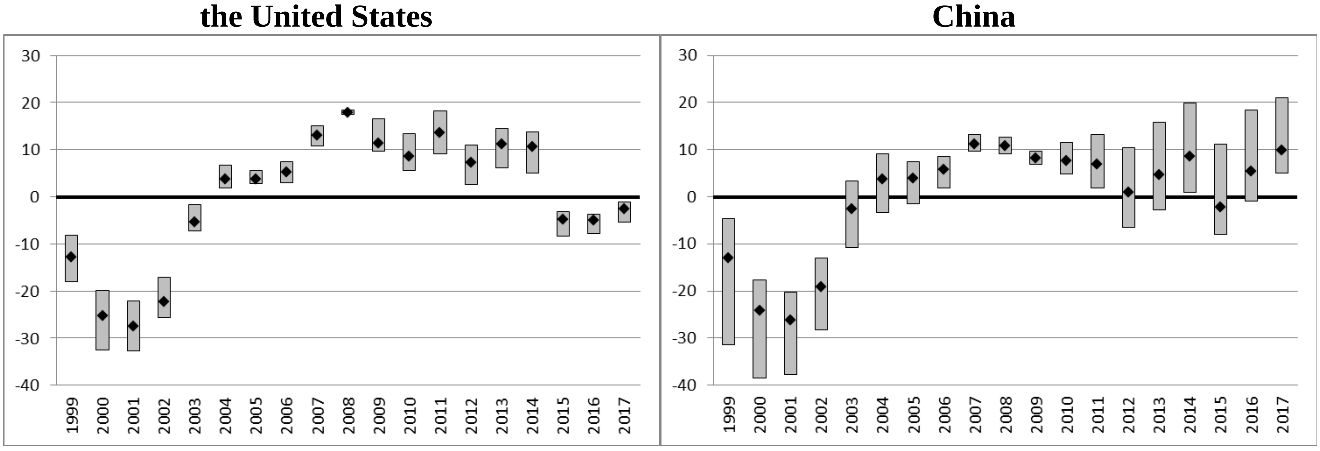


Source: ECB.
Notes: Annual averages of monthly data. The series is computed relative to 38 trading partners of the euro area.

In order to gather further insights into these developments, bilateral RER misalignments estimates relative to the two main trading partners of the euro area, namely the U.S. (which weighs around 14% in the euro-area trading basket, according to the most recent ECB REER trade weights) and China (which weighs 19%) are also reported. The undervaluation of the euro-area RER in the early 2000s was indeed particularly pronounced relative to both the U.S. and to China, as was the overvaluation in the years prior to and during the Great Recession (Fig. 2). In 2017 the euro-area RER was slightly undervalued relative to the U.S. (-2.6% on average), albeit to a lesser extent than in 2015-2016 (-4.9% on average), and largely overvalued relative to China (+9.8% on average, within a wide range of +5.0% and +21.0%, against a small overvaluation in 2016).

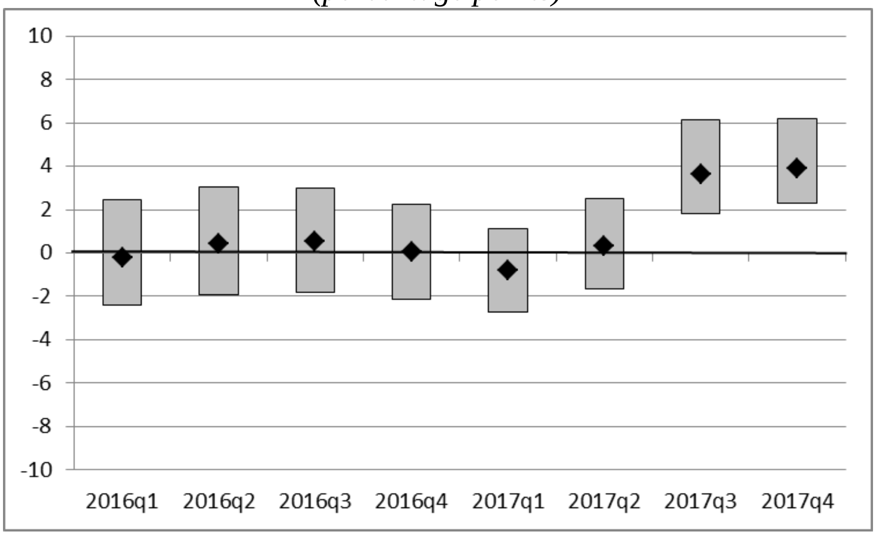
Finally, quarterly estimates of the euro-area REER misalignment over the last two years are provided in order to obtain a clearer idea of the most recent disequilibria dynamics. Figure 3 indicates that, whereas in all quarters of 2016 and in the first two of 2017, the REER of the euro area was on average generally in line with economic fundamentals, the slight overvaluation recorded in 2017, as shown in Figure 1, is entirely due to the developments in the second part of the year, when the euro-area REER became overvalued, on average, by nearly 4%. This in turn was due to the strong appreciation of the actual euro-area REER in the third quarter (consistent with developments in the NEER), compounded by a slight reduction in the equilibrium rate in the fourth quarter.

Figure 2. Annual bilateral RER misalignment estimates of the euro area relative to…
(percentage points)



Source: Author's estimations, based on an update of the original model in Fidora, Giordano and Schmitz (2017; 2018).
Notes: Annual averages of quarterly estimates. The bars represent the range, across different price/cost indices, of estimated REER misalignments for each reference country and year. The diamond represents the mean of the five estimated REER misalignments discussed in the text.

Figure 3. Quarterly REER misalignment estimates of the euro area in 2016 and 2017
(percentage points)



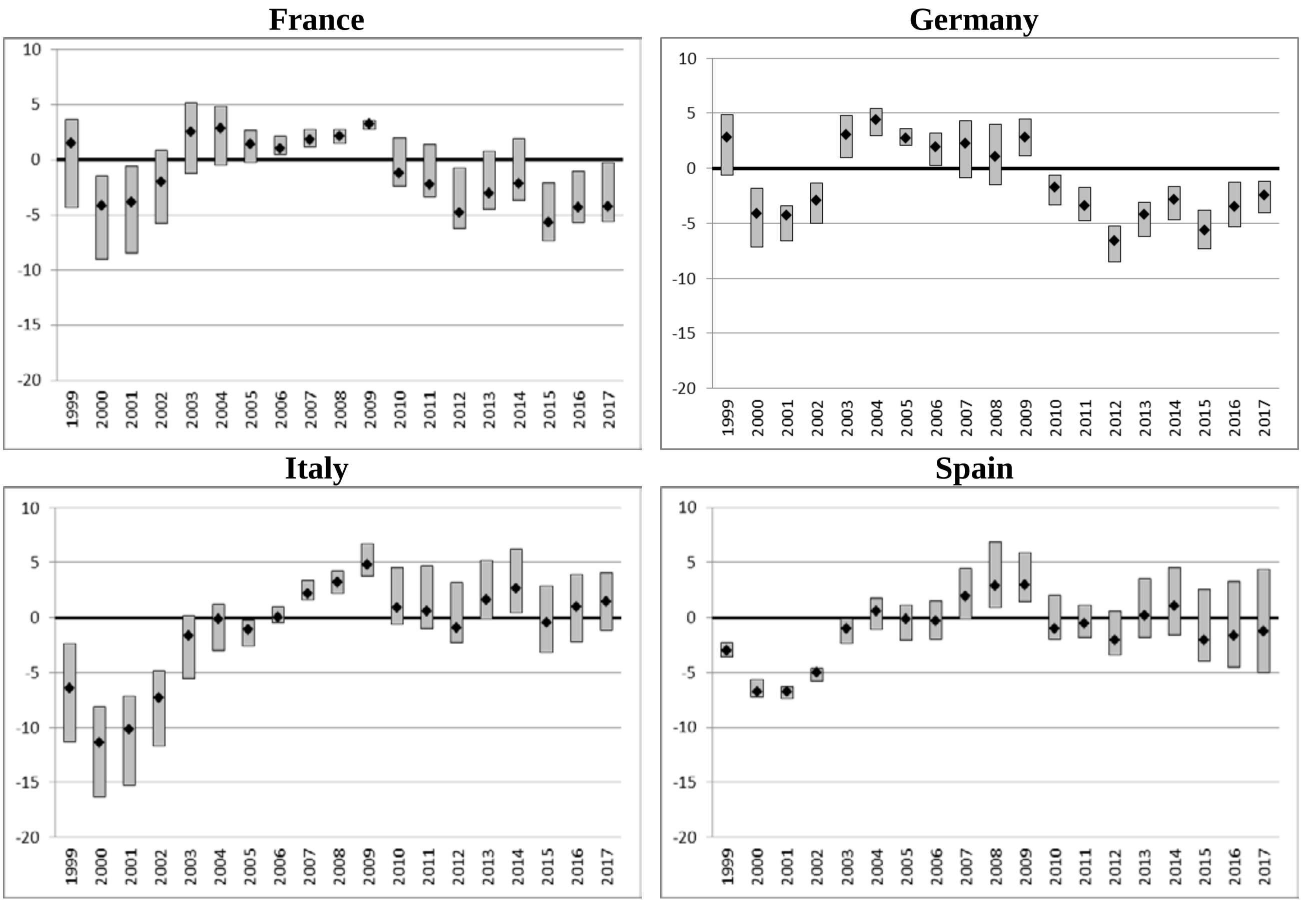
Source: Author's estimations, based on an update of the original model in Fidora, Giordano and Schmitz (2017; 2018).
Notes: The bars represent the range, across different price/cost indices, of estimated REER misalignments for each reference country and year. The diamond represents the mean of the five estimated REER misalignments discussed in the text. A positive (negative) misalignment would require a depreciation (an appreciation) of the actual REER to unwind, provided the equilibrium rate does not change.

The main euro-area countries

Moving to the four largest euro-area countries, general patterns are similar to those recorded by the euro area as a whole, with some heterogeneity especially in recent years (Fig. 4).

At the turn of the millennium the HCIs of the largest euro-area countries were strongly undervalued relative to their fundamentals, in particular in Italy. By 2009 the outlook had reversed, with an overvaluation that was marginally larger on average in Italy than in the other three economies. Since then, disequilibria have been heterogeneous across the main euro-area countries. Indeed, since 2010 Germany's HCI has been undervalued, whatever the indicator employed to measure misalignments; in 2017 and relative to the previous two years, its undervaluation has slightly reduced, currently standing within a range of -4.0% and -1.2%. In 2017 France's HCI too was undervalued on average with respect to fundamentals, although misalignments fall within a much wider range (-5.6%; -0.3%). Since 2015, when it was on average broadly aligned with economic fundamentals, Italy's HCI has recorded a gradual, slight overvaluation, yet again the latter's magnitude depends on the price/cost index employed to construct the real exchange rate. In particular, in 2017 Italy's HCI was marginally undervalued (-1.1%) according to the CPI-deflated HCI and overvalued (+4.1%) according to the ULCT-based measure;[22] its average misalignment was +1.4%. Finally, since 2016 Spain has recorded the widest range of misalignment estimates compared with the other three countries. In particular, in 2017 its HCI was on average marginally undervalued (-1.3%), yet misalignment estimates span from -5.0% (ULCT-based) to +4.4% (PPI-based), leading to an unclear assessment of the correction needed, if any, for this country.

Figure 4. Annual HCI misalignment estimates of selected euro-area countries
(percentage points)



Source: Author's estimations, based on an update of the original model in Fidora, Giordano and Schmitz (2017; 2018).
Notes: Annual averages of quarterly estimates. The bars represent the range, across different price/cost indices, of estimated HCI misalignments for each reference country and year. The diamond represents the mean of the five estimated HCI misalignments discussed in the text. A positive (negative) misalignment would require a depreciation (an appreciation) of the actual HCI to unwind, provided the equilibrium rate does not change.

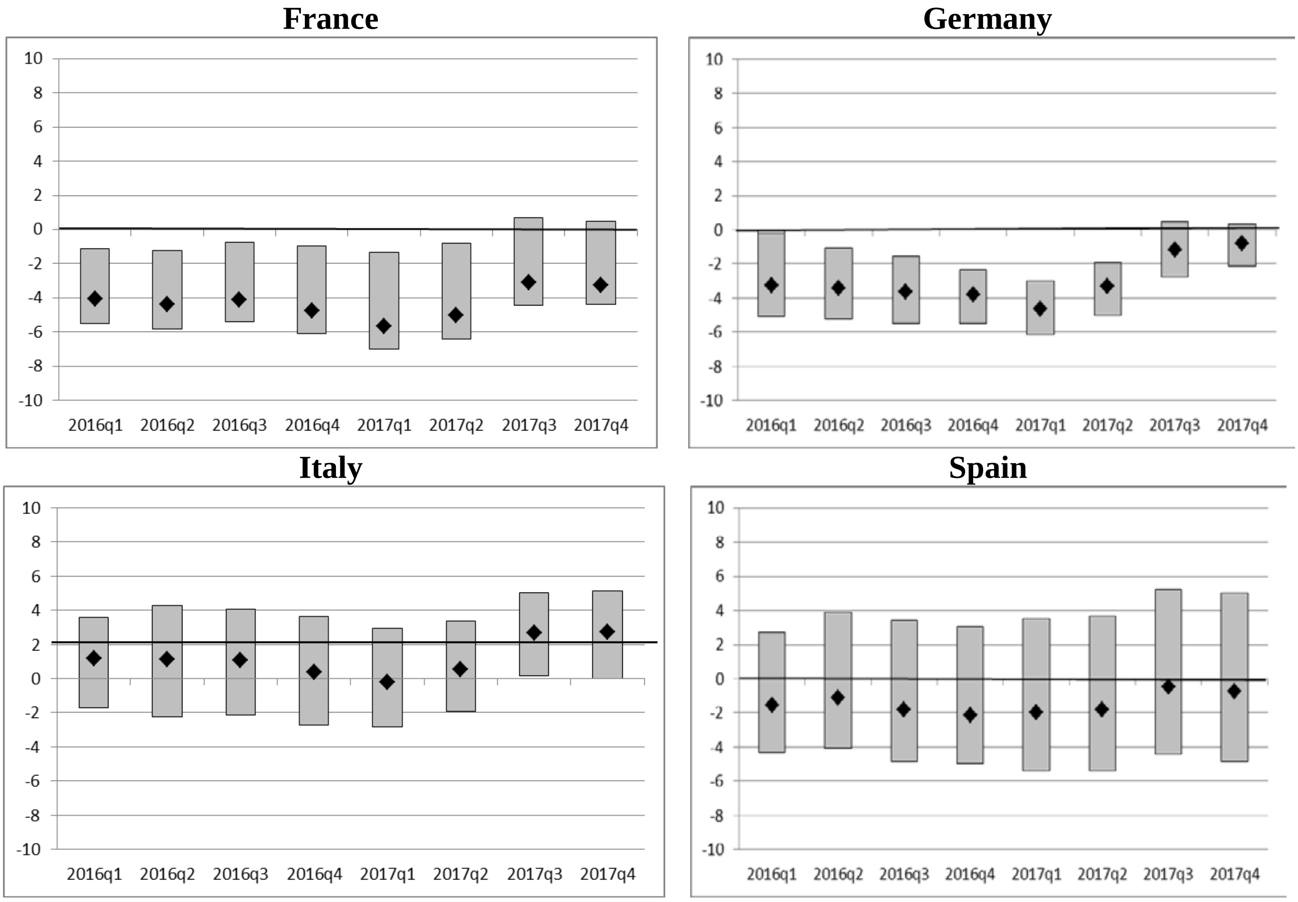
Turning to the quarterly estimates of HCI misalignments over the last two years, in all four economies, yet to a less clear extent for Spain due to its wide range of estimates, misalignments

[22] According to the ULCT-based measure, Italy's HCI has been constantly overvalued since 2007.

have turned more positive (or less negative) in the second half of 2017 (Fig. 5). This explains the mild overvaluation in 2017 on average for Italy, but also points to both France's and especially Germany's HCIs having moved towards their equilibrium values in the second part of the year.

Figure 5. Quarterly HCI misalignment estimates of the main euro-area countries in 2016 and 2017

(percentage points)



Source: Author's estimations, based on an update of the original model in Fidora, Giordano and Schmitz (2017; 2018).
Notes: The bars represent the range, across different price/cost indices, of estimated HCI misalignments for each reference country and year. The diamond represents the mean of the five estimated HCI misalignments discussed in the text. A positive (negative) misalignment would require a depreciation (an appreciation) of the actual HCI to unwind, provided the equilibrium rate does not change.

4. Comparisons with other available BEER-model estimates

The IMF External Balance Assessment (EBA) framework, which leads to the yearly publication of the External Sector Report (ESR),[23] is based on a number of different models referring to both the current-account balance and the REER. In particular, the EBA contains two REER models, which estimate the historical relationship between REERs and a large set of country fundamentals and policy variables[24] from a panel of 40 countries at a yearly frequency covering the

[23] The IMF's ESR is published in July of each year and contains an assessment of the previous year.

[24] The explanatory variables that are included in the EBA models are: output per working age population (*per se* and interacted with capital account openness), an indicator of global risk aversion (interacted with capital account openness), the share of domestic debt owned by residents (a proxy of financial home bias), population growth, expected GDP growth, commodity terms of trade, trade openness, the share of administered prices in CPI, health expenditure to

period 1980-2013 (Phillips et al., 2013; IMF, 2015).[25] The two EBA models differ depending on whether the dependent REER variable, sourced from the IMF databases such as WEO and IFS, is expressed as a CPI index number (index-REER regressions) or as a price level (level-REER regressions). The choice of employing two alternative price indicators is therefore similar in spirit to that of this study.

However, several methodological differences are present in the EBA relative to the BEER model discussed herein. Both EBA models are estimated using fixed-effects OLS, differently to the CCEMG procedure adopted here.[26] In spite of the very large number of explanatory variables when compared to the existing literature (see Table A1 again) and to this study, the RMSEs of the two EBA models, although not strictly comparable, are larger than those reported in the BEER model reported in Table 1; this could be due to the fact that even statistically insignificant explanatory variables are included in the EBA models, as well as to the selected estimation procedure, as already discussed in Section 2.[27] Moreover, the IMF euro-area aggregate covers 11 euro-area members (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain) and euro-area REER misalignments are derived from GDP-weighted averages of the assessments of the individual member countries. Herein, the euro-area aggregate instead refers to the actual euro area 19 and euro-area misalignments are computed directly for the "official" euro area as a whole, thereby only against non-euro area partners. Finally, the "REER gaps" reported in the ESR are staff assessments and thus reflect other information and staff judgment, in addition to the EBA model-based estimates.

To our knowledge, the only other publicly available time series of BEER-model estimates are those released since August 2017 by CEPII (Couharde et al., 2017). This model too is annual and is estimated for 182 countries since 1973, implying an extraordinary time and country coverage. However, it only uses the CPI to deflate the nominal exchange rates and does not provide estimates for the euro area as a whole. Moreover, it only considers three explanatory variables (GDP per capita, terms of trade and net foreign assets) and is estimated via a pooled mean group procedure, which does not account for common shocks.[28]

Figure 6 provides a comparison of REER/HCI misalignment estimates for the years 2014-2016 produced by the IMF, CEPII and by the BEER model described herein (neither the IMF nor CEPII had released estimates for 2017 at the time of writing of this document). For the IMF, the two model-based estimates, i.e. devoid of staff judgement, are reported to ease comparability with the other two sources, which do not present any judgement component. CEPII only provides CPI-

GDP, foreign exchange intervention (interacted with capital controls), short-term interest rate differentials adjusted for inflation differentials, private credit to GDP and capital controls.

[25] The EBA methodology is currently under revision, yet only with respect to its current-account model (IMF, 2018b), which is not referred to herein.

[26] Results of testing for stationarity of the REER were indeed found to be inconclusive in the IMF dataset (Phillips et al., 2013, p. 22), thereby justifying the choice of using standard OLS as opposed to panel cointegration techniques.

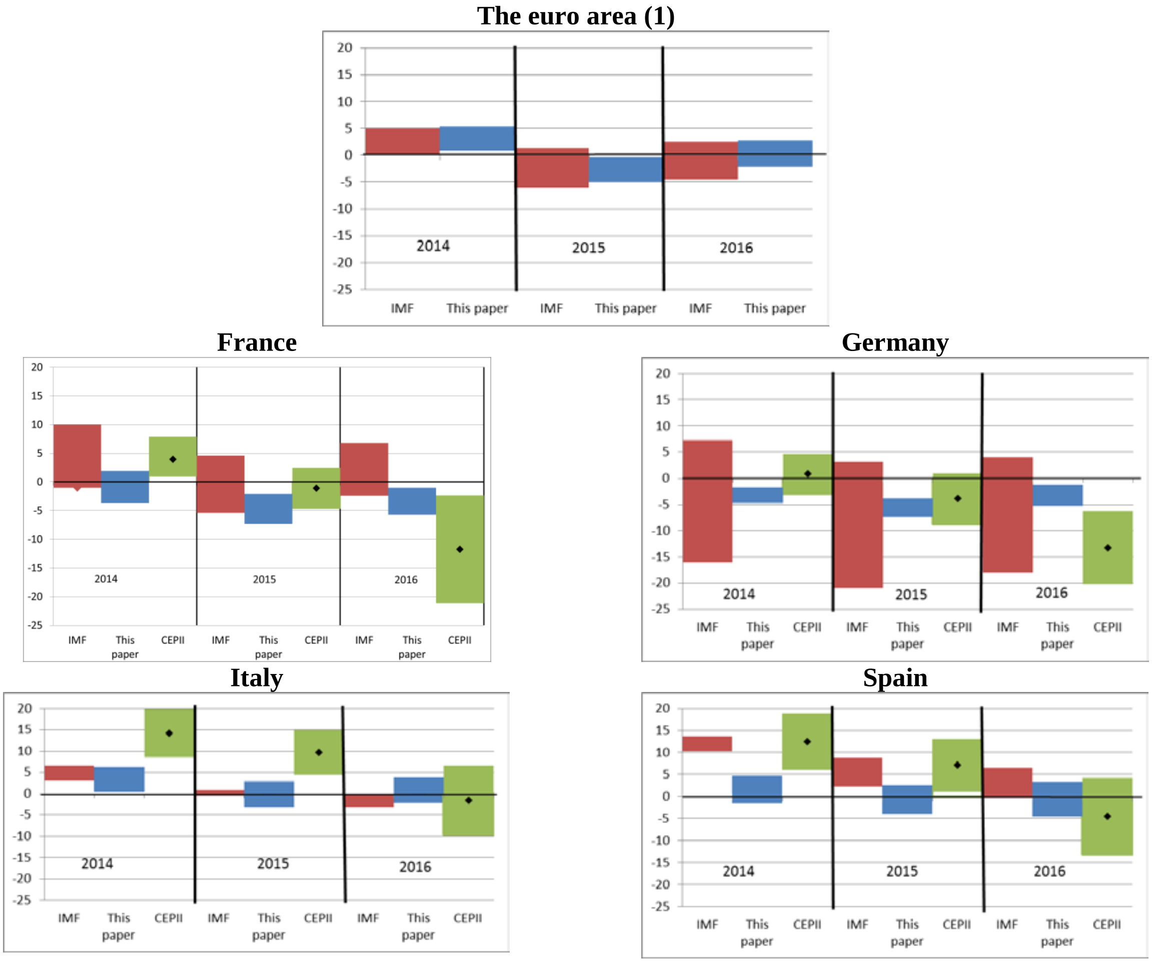
[27] In the past and for certain countries, the weak goodness of fit has led to the final assessment published in the ESR giving more weight to the current-account model, deemed more robust, than to the two EBA REER-based models (see, for example, the appraisal of Italy in IMF, 2017).

[28] The methodological reference paper (Couharde et al., 2017) does not report goodness-of-fit statistics with which to compare those reported herein and of the EBA REER models.

deflated REER/HCI misalignments, and the range refers to the standard deviations referring to the (average) point estimate. The range across the five alternative price/cost indices is instead reported for the BEER model described herein. Finally, for the euro area only IMF estimates are available for the comparison.

Figure 6. A comparison of REER/HCI misalignment estimates for the euro area and for the main euro-area countries across different sources

(percentage points)



Sources: IMF (2015; 2016; 2017); Couharde et al. (2017) and author's estimates, based on an update of the original model in Fidora, Giordano and Schmitz (2017; 2018).

Notes: The misalignments refer to the range of model-based estimates across alternative price/cost indices for IMF and for the estimates described herein, and to the range of CPI-based HCIs across alternative samples, model specifications and weighting schemes for CEPII (where the diamond represents the average estimate, and the range reflects the standard deviation of this point estimate). CEPII estimates for the euro area are not available. (1) The IMF euro-area aggregate is an aggregation of 11 euro-area members, whereas herein the euro-area aggregate refers to the official euro area 19, as explained in the main text.

For individual euro-area countries no systematic pattern stems from the comparison across the three sources, although estimates generally fall in a comparable range. If one excludes the IMF's index estimates for Germany which are known to be flawed in that they present the wrong sign (and indeed are discarded in the EBA), CEPII (average) misalignment estimates are often the largest. This is possibly due to the fact that few economic fundamentals are included in their BEER model, determining a larger residual and therefore a wider misalignment. For the euro area, the

IMF's estimates and those presented herein are quite similar, in spite of the many data and methodological differences; the range of the former is only slightly wider.[29]

5. Conclusions

This study draws upon a Behavioural Equilibrium Exchange Rate (BEER) model, first put forward by Fidora, Giordano and Schmitz (2017; 2018), in order to analyse the magnitude of real currency misalignments of the euro area and of its main economies. In the construction and estimation of the BEER model and relative to the existing literature, particular care is given to: a) the dataset employed: the 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 computing REERs, the model is estimated using five alternatively deflated RERs/bilateral HCIs; b) the panel cointegration estimation method, which, amongst various desirable properties, accounts for cross-section dependence, resulting from common, global shocks. Relative to the original model published in Fidora, Giordano and Schmitz (2017; 2018), better quality PPIs, available for a larger set of countries and described in Felettigh and Giordano (2018), are employed; a higher number of quarterly data sources are exploited to construct the explanatory variables of the model and therefore the use of interpolated linear data is more limited; the estimation period is lengthened, thereby attenuating a potentially significant bias underlying all BEER models.

The estimates are consistent with the predictions of the literature. A significant and positive relationship between real exchange rates and GDP per capita, i.e. significant evidence of the Balassa-Samuelson effect, is found. Moreover, a real appreciation is found to be associated with higher: (relative) trade restrictions, proxied by lower trade openness, (relative) terms of trade, (relative) government expenditure and real interest rate differentials.

The fitted values of the BEER model provide "equilibrium" values of both RERs/bilateral HCIs and REERs/HCIs which are used as a yardstick to appraise a country's actual price-competitiveness performance. Estimates provided in this study are in the same ballpark as those produced by the IMF and CEPII (currently available only until 2016), to our knowledge the only other BEER-model estimates that are publicly released, but are not always consistent for given countries and years, due to significant data and methodological differences.

According to the results presented in this study, on average in 2017 both the euro area and its main member states presented misaligned REERs/HCIs. In particular, the euro-area REER and Italy's HCI were on average moderately overvalued, whereas Germany's HCI continued to be undervalued, albeit to a lower extent than in the previous years. The 2017 developments were affected in particular by more positive/less negative (according to the country) misalignments in the second half of the year.

[29] Results provided herein are very similar to those published in Fidora, Giordano and Schmitz (2017; 2018), with the main difference that in the latter the range of the euro-area REER misalignments and that of Italy's HCI misalignments is wider, plausibly due to the fact that ten estimates are provided, as opposed to five herein. Indeed, in Fidora, Giordano and Schmitz (2017; 2018), in addition to considering five alternative price/cost indices, two alternative Balassa-Samuelson measures are also adopted in the baseline estimates. As motivated in Section 2. in this paper only one proxy (relative GDP per capita) is employed.

Caution is however warranted in the analysis of these estimates. First, the main drawback of the BEER methodology is that misalignments are data-determined, in the sense that equilibrium rates are consistent with the actual values of the fundamental determinants of the RERs, which are assumed to be in equilibrium on average in the overall period under estimation. This may not be the case for some countries, especially over short time periods. This drawback can be tackled only by expanding the estimation window over time as much as possible. The latter requirement, however, faces challenging data constraints. In particular, in order to guarantee satisfactory country coverage and to obtain quarterly estimates it was not possible to estimate the model prior to 1999, which therefore spans 18 years. It is, however, programmed so as to re-estimate the underlying statistical relationships between RERs/bilateral HCIs and economic fundamentals each time the dataset is updated and extended, thereby progressively attenuating this main shortcoming of BEER models.

Second, there is no single dominant approach to modelling equilibrium REERs, although the issue has been heatedly debated (e.g. Cheung, Chinn and Fujii, 2010). This is the main reason why, in order to conduct an accurate analysis of REER/HCI misalignments of individual countries, a range of models should be employed, as is done within the IMF's EBA approach, which also includes, for example, estimates of "REER gaps" that are consistent with estimated current-account disequilibria (Phillips et al, 2013), and that fall under the heading of the Fundamental Equilibrium Exchange Rate (FEER) approach (Wren-Lewis, 1992; Williamson, 1994).[30] The BEER model here described can therefore be considered as the first pillar of a more comprehensive approach to estimating REER/HCI misalignments. Future research, based on existing Bank of Italy estimates of the cyclically-adjusted current account (Fabiani, Federico and Felettigh, 2016) for several countries, could indeed aim at setting up a FEER model as a complement to the BEER model in order to more fully assess euro-area countries' HCI imbalances.

[30] Similarly to BEER models, 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. 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 thereby 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 (Schnatz, 2011).

Annex: Additional details concerning the BEER model

The analytical framework underlying the BEER model

Similarly to Clark and MacDonald (1998), the starting point of a BEER model 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):

(A1) $E_t(rer_{t+1}) - rer_t = -(r_t - r_t^*) \Rightarrow rer_t = E_t(rer_{t+1}) + (r_t - r_t^*)$,

where r 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 (1), 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 currency should depreciate in order for investors to be indifferent between holding domestic and foreign assets. Clark and MacDonald (1998) assume that the unobservable expected future 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 A1. An overview of variables included in a selection of BEER models

References	Countries	Time-span	Frequency	Price/cost index of dependent variable	Explanatory variables	Estimation methodology
Couharde et al. (2017)	182	1973-2016	A	CPI	GDP per capita (+), net foreign assets (+); terms of trade (+)	a) FMOLS b) DOLS c) Pooled mean group
Comunale (2017)	27 (EU countries)	1994-2012	A	CPI	Foreign net capital inflows (+); terms of trade(+); GDP per capita(+)	GM-FMOLS
Hajek (2016)	12 (EA countries)	1980-2014	A	CPI	GDP per capita(+); trade balance (-); terms of trade (+)	DOLS
Gnimassoun and Mignon (2015)	22 (industrialized countries)	1980-2011	A	CPI	GDP per capita (+): net foreign assets in percentage of GDP (+)	DOLS
Adler and Grisse (2014)	a) 21 b) 23 (advanced economies)	a) 1980-2011 b) 1995-2011	A	CPI	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(+)	DOLS
Fischer and Hossfeld (2014)	57 (advanced and emerging economies)	1980-2011	A	PPP	Labour productivity(+)	a) Panel OLS b) Pooled OLS c) Panel DOLS
Mancini-Griffolo, Meyer, Natal and Zanetti (2014)	18 (advanced economies)	1973-2011	A	CPI; PPI	Net foreign assets(+); output per capita(+); terms of trade(+); government consumption(+); sectorial labour productivity	DOLS
Coudert, Couhart and Mignon (2013)	11 (EA countries)	1980-2010	A	CPI	GDP per capita (+): net foreign assets in percentage of GDP (+)	DOLS
Bussière, Ca' Zorzi, Chudík, Dieppe (2010)	a) 44 b) 14 (advanced and emerging economies)	1980-2007	a) A b) Q	PPP	Commodity terms of trade(+); fiscal policy(+); civil liberties(-); openness(-); net foreign assets; investment; government expenditure; trade restriction index; GDP per capita (+); commodity prices	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	CPI	Net foreign assets to GDP (-); trade balance to GDP; terms of trade(+); government consumption; openness	Single country estimations: a) DOLS; b) FMOLS Panel estimations: a) Group-mean DOLS; b) FMOLS.
Bénassy-Queré, Béreau and Mignon (2009; 2010)	15		A	CPI	Relative CPI to PPI ratio (+): net foreign assets in percentage of GDP (+); real interest rate differentials (+); terms of trade (+)	DOLS
Ricci, Milesi-Ferretti and Lee (2008)	48 (advanced and emerging economies)	1980-2004	A	CPI	Trade restriction index(+); price controls(-); commodity terms of trade(+); net foreign assets to trade(+);government expenditure to GDP(+); labour productivity tradables(+); labour productivity nontradables(-)	a) DOLS b) FMOLS
Lane and Milesi-Ferretti (2004)	64 (industrial and middle-income developing countries)	1975-1996	A	CPI; WPI	Net foreign assets (+); GDP per capita (+); terms of trade (+)	Cross-section and panel estimations: DOLS
Maeso Fernández, Osbat and Schnatz (2004)	25 (OECD countries)	1975-2002	A	PPP	GDP per capita(+); government expenditure to GDP(+); openness(-)	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	CPI	Labour productivity (+); accumulated current account to GDP; real price of oil(+); long-term interest rate differential(-)	VECM
Clark and MacDonald (1998)	7 (G-7 countries)	1960-1996	A	CPI	Terms of trade(+); CPI/PPI ratio(+); net foreign assets as ratio of GDP(+); relative stock of government debt(+); real interest rate(-)	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 A2. The list of countries included in the BEER model

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. (**) Not available for PPIs.

The use of PPPs

As discussed in the main text, the use of actual price levels, as opposed to price indices, has the advantage of being able to avoid the inclusion of country fixed effects, which cannot be meaningfully interpreted, in the BEER model. Various studies, such as Fischer and Hossfeld (2014), as well as the IMF (2015), have employed real exchange rate *level* regressions. The natural candidate for total-economy price levels is the PPP rate.

In this study the WEO's PPP rate is employed. It derives from the figure reported by the International Comparisons Program (ICP) for 2011,[31] which is then extended backwards and forwards by the growth in relative GDP deflators (i.e. the deflator of a country divided by the deflator of the numéraire country, the United States). The extrapolation from a benchmark year has, however, the shortcoming that it does not take into account within-country changes in the price structure and thus of relative prices over time (IMF, 2003).

An alternative data source that provides PPPs, the Penn World Tables (PWT; Feenstra, Inklar and Timmer, 2015), adopts a two-stage procedure, which limits this potential bias. In the first stage the prices of items collected by the ICP are aggregated within the categories of consumption, investment and government expenditures. Because of the specific approach adopted (i.e. the so-called GEKS approach), prices outside the benchmark years of the ICP can be interpolated or

[31] This is the most recent price survey available and has been found to be significantly more reliable than the previous round (on this, see, amongst the most recent papers, Pinkovskiy and Sala-i-Martin, 2018).

extrapolated using the time-series data on consumption, investment and government price indexes for each country from national accounts. Having thus obtained a complete time-series and cross-country dataset on the prices of these three items relative to the numéraire country (again, the United States), to which relative export and import prices are added, the second stage aggregates to total expenditure. In this stage the Geary-Khamis method is employed to construct reference prices for each output component as the quantity-weighted average of these prices (relative to the numéraire country) across countries; this method guarantees additivity of components, which are then summed up. The resulting overall PPP rate is computed as the ratio of expenditure at local prices to that at reference prices measured in the currency of the numéraire country.

This two-stage procedure guarantees comparability across countries and over time, yet is very cumbersome. As a result, the PWT PPPs are currently available only until 2014, are updated with a significant lag and do not include any estimate for the euro area. They could therefore not be employed in this study. However, for the countries analysed herein, and in the period 1999-2014, percentage differences between the WEO and the PWT PPPs are at most of one percentage point (half a percentage point for the four main euro-area countries) and are quite stable over time for each country, suggesting that the WEO PPPs used here, as one of five alternative price/cost indicators, are not grossly biased.

The estimation procedure

The BEER literature has mainly employed reduced-form models in which a long-run, cointegrating relationship between RERs and economic fundamentals is estimated. Estimations here 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 efficient and robust estimates. As discussed for instance in 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) country heterogeneity and b) cross-section dependence. The estimation procedure employed herein tackles these two issues.

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 two different tests are considered. The traditional Im-Pesaran-Shin (IPS) unit root test allows for heterogeneous autoregressive parameters across units. In particular, assuming that the dependent variable y_{it} is generated by the following first-order autoregressive process:

(A2) $y_{it} = (1 - \varphi_i)\mu_i + \varphi_i y_{it-1} + \varepsilon_{it}$,

where i=1,…, N and t=1,…T, and initial values y_{i0} are given, the test verifies the null hypothesis that all variables follow a unit root process, i.e. H_0: $\varphi_i = 1$ for all units i against the alternative hypothesis of stationarity $H_A : \rho_i < 1$. Under the alternative hypothesis, some (but not all) of the countries may have unit roots. Allowing for heterogeneous slopes, and therefore for different relationships between RERs and economic fundamentals across countries, is particularly important given that the sample herein covers a vast number of (heterogeneous) countries. The IPS test statistic is then 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-section independence. Cross-section correlation in residuals may instead be present as 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 the panel considered here, strong interdependencies between cross-sectional units are likely to occur and if cross-section dependence is neglected imprecise estimates and, at worst, a serious identification problem can occur. Pesaran's (2004) test, which is used in small-T large-N panel datasets, is indeed found to reject the null hypothesis of cross-section independence in the sample of countries employed herein. Pesaran's (2007) cross-sectionally augmented IPS (CIPS) test is a unit root test that has the advantage of accounting for country interdependence. Indeed, to account for the latter Dickey-Fuller regressions are 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 with the appropriate test, the next step is to test for cointegration. Pedroni (1999) provides several 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. In particular, the Pedroni group-test-statistics, which rely on the assumption of heterogeneity in both the long-run cointegrating vectors as well as heterogeneity in the dynamics associated with short-run deviations from these cointegrating vectors in the individual countries, are implemented. These statistics can be viewed as most closely analogous to the IPS unit root statistic, mentioned above, applied to the estimated residuals of a cointegrating regression. The test statistics are constructed using the residuals from the following estimated cointegration regression:

(A3) $y_{it} = \alpha_i + \delta_i t + \beta_{1i}\, x_{1i,t} + \beta_{2i}\, x_{2i,t} + \dots + \beta_{Mi}\, x_{Mi,t} + e_{i,t}$

where M is the number of regressors and the slope coefficients β_{Mi} are allowed to vary across countries.[32] 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.

In order to estimate the BEER model the common correlated effects mean group (CCEMG) estimator developed by Pesaran (2006) and Kapetanios, Pesaran and Yamagata (2006) is then employed; it is robust both to heterogeneous slopes across countries and to cross-section dependence. Indeed, following Eberhardt (2012), the empirical setup can be formulated as follows:

(A4) $y_{it} = \beta_i\, x_{it} + u_{it}$

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

[32] In particular, the correction is achieved by assuming that there is a relationship between the residuals from the regression (A3) and first differences of the leads, lags and contemporaneous values of the regressors in first differences: $e_{i,t} = \sum_{j=-q}^{q} c_{i,j}\, \Delta x_{i,t-j} + e^*_{i,t}$. By plugging this expression into equation (A3), 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.

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 non-stationary. In the case of CCEMG estimation, the country-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. As this is a mean group procedure, the parameters are estimated country-by-country and then averaged across countries. The results are provided in Table 1 in the main text.

In order to better compare results with those of the existing literature, the BEER model described herein is also estimated via fixed-effects Ordinary Least Squares (Table A3) and by Panel Dynamic Ordinary Least Squares (PDOLS; Table A4). The latter approach was proposed by Stock and Watson (1993) and further developed by Kao and Chiang (2000) in a panel setting, which involves a parametric adjustment to the errors of the cointegration equation (A3). In particular, it consists in adding to equation (A3) lags and leads of the explanatory variables in order to absorb endogenous feedback effects from the dependent variable to the regressors. A DOLS regression is conducted for each unit and the results are then combined with a group mean approach. In order to estimate the BEER model herein, two lags and one lead are included. Results and comparisons with the baseline CCEMG estimates are discussed in the main text, in particular in Section 2.

Table A3. BEER model estimation results using fixed-effects OLS

	Dependent variable				
	1	*2*	*3*	*4*	*5*
	Relative CPI (1)	Relative GDP deflator	Relative PPP deflator	Relative PPI	Relative ULCT
GDP per capita	0.22**	0.32**	0.32**	0.08	0.42***
	(0.108)	(0.130)	(0.129)	(0.145)	(0.109)
Trade openness	-0.15***	-0.21***	-0.21***	-0.11*	-0.20*
	(0.055)	(0.072)	(0.074)	(0.057)	(0.118)
Terms of trade	0.05	0.47***	0.47***	0.21	0.75***
	(0.122)	(0.136)	(0.137)	(0.125)	(0.185)
Government expenditure	0.96***	1.34***	1.34***	0.99***	1.37
	(0.333)	(0.385)	(0.397)	(0.327)	(0.995)
Short-term interest rates	-0.008	-0.008	-0.009	-0.013	0.004
	(0.007)	(0.007)	(0.007)	(0.009)	(0.002)
Number of countries	*57*	*57*	*57*	*55*	*38*
Number of observations	*4,325*	*4,332*	*4,332*	*4,180*	*2,888*
RMSE	*0.164*	*0.180*	*0.180*	*0.185*	*0.107*
Normalised RMSE	*0.013*	*0.011*	*0.029*	*0.012*	*0.013*

Notes: Fixed-effects OLS coefficients obtained for the period 1999Q1-2017Q4. *** p<0.01, ** p<0.05, * p<0.1.

Table A4. BEER model estimation results using PDOLS

	Dependent variable				
	1	*2*	*3*	*4*	*5*
	Relative CPI (1)	Relative GDP deflator	Relative PPP deflator	Relative PPI	Relative ULCT
GDP per capita	1.07***	1.16***	0.57***	1.20***	0.34***
	(0.085)	(0.092)	(0.092)	(0.096)	(0.078)
Trade openness	0.24***	0.27***	-0.13***	0.145***	-0.127***
	(0.029)	(0.032)	(0.032)	(0.034)	(0.031)
Terms of trade	1.99***	2.22***	0.06	2.17***	5.43***
	(0.047)	(0.052)	(0.052)	(0.053)	(0.077)
Government expenditure	-3.29***	-3.54**	0.57	-1.88***	-8.83***
	(0.333)	(0.363)	(0.364)	(0.376)	(0.480)
Short-term interest rates	0.035***	0.032***	-0.015***	0.034***	-0.040***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of countries	*56*	*57*	*57*	*55*	*38*
Number of observations	*4,032*	*4,104*	*4,104*	*3,960*	*2,736*

Notes: PDOLS long-run coefficients obtained for the period 1999Q1-2017Q4. *** p<0.01, ** p<0.05, * p<0.1. Since lags and leads are included in the cointegrating regressions, the number of observations for each column is smaller than that in Table 1. (1) Argentina is dropped from the sample due to insufficient data availability.

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