Open Econ Rev (2014) 25:635–653
DOI 10.1007/s11079-013-9294-4

RESEARCH ARTICLE

Real Exchange Rates, the Trade Balance and Net Foreign Assets: Long-Run Relationships and Measures of Misalignment

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Published online: 4 December 2013

Abstract In this paper we estimate equilibrium exchange rates for 23 OECD countries and four less mature economies in a panel data setting. Our empirical analysis demonstrates significant links between the trade balance and net foreign assets, and between real exchange rates and the trade balance, rather than between real exchange rates and net foreign asset, as predicted by the model of Lane and Milessi-Ferretti (2002). Our study indicates that, in terms of the association between real exchange rates and trade balance, there is heterogeneity between the emerging market economies and the OECD countries. Finally, we construct various measures of exchange rate misalignment for all the exchange rates included in our panels.

Keywords Real exchange rates · Trade balance · Net foreign assets · Misalignment · Panel data

1 Introduction

Long-run equilibrium real exchange rates and corresponding actual currency misalignments are key concerns of monetary authorities and government policy makers due to significant macroeconomic effects of exchange rate adjustments (Kappler et al. 2013). During the past two decades several international economic events have highlighted the need for the evaluation of equilibrium exchange rates. In particular, these events include the recent global economic crisis starting in 2008, the Asian financial crises of the 1990s, the integration of the European economies to a uniform monetary unit, the Euro, and the debate on whether the increasing US trade deficit is caused by an undervalued Chinese renminbi. In practice, the calculated equilibrium exchange rates

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act as the principle values of currencies and are then taken as the basis to adjust the corresponding economic policies.

A number of studies have used various approaches to calculate equilibrium exchange rates for the key currencies in the world. For example, such studies have used capital enhanced measure of real exchange rates (CHEER), the behavioural equilibrium exchange rates (BEER), permanent equilibrium exchange rates (PEER) and studies based on the internal-external balance (IEB) approach. Using the theoretical framework of Lane and Milesi-Ferretti (2002), we intensively reassess real equilibrium exchange rates using the association between the real exchange rate, trade balance and net foreign assets. Specifically, we compare three panels over the period 1980 to 2011 using the same theoretical framework: a panel containing 23 selected OECD countries,[1] a panel containing the 23 OECD countries (which we refer to as our base-line panel) and China, a panel containing the same OECD countries and four less mature economies including China, Malaysia, Pakistan and the Philippines. Since our sample spans the East Asian crisis we focus on Asian developing countries as representatives of less mature economies and due to data availability, the Asian countries consist of China, Malaysia, Pakistan and the Philippines. Of course for our sample period, particularly the second half, issues of the appropriate value of the renminbi have been keenly debated and this is a further important reason for including China in one of our samples.

Using these data we firstly test for unit roots in the relevant variables and then go on to test for cointegrating relationships amongst our chosen variables. We utilise three different popular cointegration methods: fully modified OLS (FMOLS), dynamic OLS (DOLS) and a pooled mean group estimator (PMGE). Our primary cointegration analysis supports the hypothesis that there is a long-run cointegration relationship between the trade balance and net foreign assets and between real exchange rates, the trade balance or net foreign assets. Our study demonstrates for our sample period a negative relationship between real exchange rates and the trade balance and a weak result for the association between the real exchange rate and net foreign assets. Our study also demonstrates that in the association concerning real exchange rates and the trade balance, there is heterogeneity between the four less mature economies (China, Malaysia, Pakistan and the Philippines) and 23 selected mature OECD economies.

Compared with the relevant literature examining equilibrium exchange rates for a particular economy, this study has several distinguishing features. First, our study is based on the theoretical association between exchange rates, trade balance and net foreign assets, which has been intensively studied by Lane and Milesi-Ferretti (1999, 2000 and 2002). In particular, Lane and Milesi-Ferretti (2002) examine the links between these three series and suggest that the association between real exchange rates and net foreign assets is better decomposed into two channels. The first channel is between net foreign assets and the trade balance and the second channel relates to the association between the real exchange rate and the trade balance. Furthermore, Lane and Milesi-Ferretti argue that their theoretical framework can be used to evaluate the equilibrium exchange rates and to the best of our knowledge we are the first to use their methods to assess equilibrium exchange rate issues in a comprehensive manner.

[1] 23 OECD countries are chosen due to the data availability: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.

Specifically, we use the various panel data sets defined above, rather than focussing on purely time series data that has been the focus of the majority of other studies.

With the integration of the international economy it is of interest to compare the OECD economies with less mature economies such as China, Malaysia, Pakistan and the Philippines, and there is similarity between developing and developed countries, for example, between Germany and China (Aizenman and Sengupta 2011). Second, we focus on the examination of real exchange rates in a panel data setting. Specifically, we examine the sensitivities of the association between real exchange rates, the trade balance or net foreign assets, when we gradually add four less mature economies (China, Malaysia, Pakistan and the Philippines) into the panel consisting of 23 selected OECD economies. Our study uses already developed nonstationary techniques for panel data to implement the unit root tests, cointegration analyses and panel estimations. In the panel context we investigate the sensitivities between these panel estimation approaches which concern mean-group estimations, pooling estimations and the approaches combining mean-group and pooling approaches. Finally, our study is based on an extended sample span covering 1980 to 2011 for our base line panel and our four less mature economies; the study of Lane and Milesi-Ferretti (2002) covers the sample 1970 to 1998 for 20 OECD countries.

The rest of paper is set out as follows: Section 2 briefly reviews the theoretical issues concerning real exchange rates, trade balances and net foreign assets. Section 3 describes the data set and implements the empirical unit root tests and cointegration tests. Section 4 implements the estimates and analyses the results. Section 5 concludes the paper.

2 Theoretical Issues

Our empirical analysis adopts the theoretical framework proposed by Lane and Milesi-Ferretti (2002). The key contribution of their study is the decomposition of the impact of net foreign assets on the long-run real exchange rate into two channels: a negative long-run relationship between net foreign assets and the trade balance and a negative relationship between the trade balance and the real exchange rate, holding other determinants fixed. We briefly summarize the key points of the Lane and Milesi-Ferretti (2002) study. Firstly, the association between net foreign assets and the trade balance is related to the rates of return on external assets and liabilities, which is specified in the equation as follows:

$$tb = -r * nfa, \tag{1}$$

where tb is the ratio of the trade balance to GDP, r is the rate of return on external assets and liabilities (for simplicity we assume that the rates on the external assets are equal to the rates on liabilities), nfa is the ratio of net foreign assets to GDP. Equation (1) explains the relationship between the trade balance and net foreign assets: a country can run a steady-state trade deficit that equals the net investment income on its net foreign assets. The real exchange rate is a function of the trade balance, which is specified as follows:

$$rer = -\varphi tb + \lambda X, \tag{2}$$

where rer is the log CPI-based real exchange rate and X are the other factors affecting the real exchange rate. Equation (2) states that for a given combination of other factors, X, the real exchange rate will become more depreciated the bigger the steady-state trade surplus. Using (1) and (2), we can obtain the following equation for the real exchange rate, in terms of net foreign assets:

$$rer = \varphi r^* nfa + \lambda X \equiv \alpha * nfa + \lambda X. \tag{3}$$

Lane and Milesi-Ferretti (2002) argue that there are two reasons why it is not suitable to use the specification above to assess the real exchange rate: First, rates of return vary across countries, over time and between different categories of assets and liabilities and, second, in a nonzero growth environment the intrinsic dynamics of the net foreign asset position depends on the output growth rate as well as rates of return. Due to these two reasons, Lane and Milesi-Ferretti suggest the relationship between the relevant variables can be captured separately via two channels: the relationship between net foreign assets and the trade balance and the relationship between the trade balance and real exchange rates. In implementing the relationship between the trade balance and real exchange rate empirically Lane and Milesi-Ferretti include relative output per capita and the terms of trade. Specifically, for a panel of 20 OECD countries over 1978–1998, Lane and Milesi-Ferretti (2002) examine the following specification:

$$rer_t = f(tb_t, yd_t, tot_t) + \mu_t, \tag{4}$$

where tb_t is the trade balance, yd_t is the relative GDP per capita and tot_t is the terms of trade. Their analysis shows that there is a negative relationship between the trade balance and the real exchange rate, which indicates $\partial f(.)/\partial tb<0$ and the magnitude of the coefficient of trade balance is increasing in the country size, which means $\partial f(.)/\partial yd>0$. The relative price of nontradables co-moves with the trade balance, even controlling for relative sectoral productivity, which suggests $\partial f(.)/\partial tot>0$.

Our study focuses on using the kind of relationship given by (4) to estimate equilibrium real exchange rate relationships in a panel data setting. Specifically, we aim to examine the relationship between the real exchange rate, *rer*, the terms of trade, *tot*, relative GDP per capita, *gdppercapita*, and the trade balance, *tb*, or net foreign assets, *nfa*, as summarized by the vectors $x_1=[rer,tot,gdppercapita,tb]$ and $x_2=[rer,tot,gdppercapita,nfa]$.[2]

3 Data Description

The panel analysis is carried out on the basis of annual data spanning the period 1980 to 2011.[3] All of the relevant data are taken from World Development Indicators online service. The data on real exchange rates - *rer* - refer to the real effective change rate index which is defined in terms of foreign currency per unit of domestic currency, and we use the logarithm form in this study. The terms of trade -*tot*-

[2] Our preliminary trial empirical panel estimation demonstrates that the terms of trade is consistently insignificant in the three panels; the final estimation is based on the regression without the terms of trade and the panel cointegration tests are implemented without the terms of trade, although the panel unit root tests are implemented for this term. Relevant literatures also find the insignificance of the terms of trade determining real exchange rates, see Nodir (2011), Zulfiqar and Mahboo (2005), Li (2004) and Iscan (2000).

[3] China introduced its open door policy in 1978, and the country's foreign investment and international trade were opened up to the outside world. However, due to data availability of the series of interest, our sample has to start in 1980.

denotes the logarithm of the terms of trade, which is defined as the ratio of the domestic export unit value to import unit value. When both the price and the quantity of goods traded are taken into account for the balance of payments, the terms of trade is calculated by the formula as follows:

$$tot = \left(p_x^c q_x^0 / p_x^0 q_x^0\right) / \left(p_m^c q_m^0 / p_m^0 q_m^0\right), \tag{5}$$

where p_x^c denotes the price of exports in the current period, q_x^0 denotes the quantity of exports in the base period, p_x^0 denotes the price of exports in the base period, p_m^c denotes the price of imports in the current period. q_m^0 denotes the quantity of imports in the base period and p_m^0 denotes the price of imports in the base period. All the data take the year 2000 as the base period. For our trade balance to GDP ratio term - *tb* - we use the trade balance in goods and services, calculated by offsetting imports of goods and services against exports of goods and services. The exports and imports of goods and services comprise all transactions involving a change of ownership of goods and services between residents of one country and the rest of the world (All data are in current U.S. dollars). Relative GDP per capita is measured as the logarithm of relative GDP per capita of the country of interest to global average. For the net foreign asset to GDP ratio - *nfa* - we use the sum of foreign assets held by the monetary authorities and deposit money banks less their foreign liabilities. The data source is the international monetary fund (IMF) International Financial Statistics.

Using this data we then construct the three panel data sets mentioned in Section 1: our base-line panel; a panel that adds China to the base; and a panel that adds three more less mature economies (Malaysia, Pakistan and the Philippines) to the second panel (panel-1, panel-2 and panel-3, hereafter). In the following sections we examine the association between real exchange rates, the trade balance and net foreign assets using these three panels.

4 Empirical Data Analysis

The empirical analysis of nonstationary panel data requires the identification of three pre-conditions before the actual panel estimation (Maeso-Fernandez et al. 2004). The first is that all the variables should be nonstationary and they are cointegrated in a single cointegrating vector. This assumption can be addressed by using panel unit root tests and cointegration tests. The second pre-condition is that the slope homogeneity for all the cross sections in the sample panel is the same. The pooled and mean-group estimators can be used to test the slope homogeneity. The pooled estimator estimates the long-run parameters jointly and it maximizes the degrees of freedom in the estimation. The pooled estimator is consistent and efficient under the assumption of slope homogeneity, while it is not consistent under the alternative hypothesis. In contrast, the mean-group estimator estimates the parameters section-by-section and then averages them across cross-sections. The mean-group estimator is always consistent, but it is not efficient if the slopes are homogeneous. The third pre-condition is the absence of cross-sectional correlation, which can be handled by using time dummies or subtracting the cross-sectional means from the data.

4.1 Stationarity Test

This section tests if the series used in this paper are stationary. We use the method of Hadri (2000) to implement the stationarity tests with both heterogeneous and homogeneous error terms. Both of the tests are based on specifications with fixed-effects. Table 1 reports the test statistics with the corresponding p-values in parenthesis.

The stationarity test results reported in Table 1 indicate that the null hypotheses of the Hadri test are strongly rejected and therefore all of these series are nonstationary variables. We also test the stationarity of the first-differences of these variables and we find that all of the series in first differences are stationary. Thus, all the series we examine in this study are non-stationary I (1) variables.

4.2 Cointegration Test

In the last section we demonstrated that the real exchange rate and the right-hand side variables are all unit root processes in levels while they are stationary in first differences. In the following subsections we formally use the cointegration methods of Pedroni (1999) to determine if there is a long-run relationship between these series.

4.2.1 Cointegration Test: Trade Balance and Net Foreign Asset

As we discussed in the theory section, the level of the trade balance depends on net foreign assets and the relationship between the real exchange rate and net foreign assets is through the trade balance. Theoretically, in the long-run there should be a cointegration relationship between the trade balance and net foreign assets, that is, for a particular economy, we have the specification as follows:

$$tb_t = \varphi * nfa_t + \varepsilon_t. \tag{6}$$

The disturbance term, ε_t, captures the temporary deviation from the long-run value, which reflects cyclical disturbances and shifts in the desired net foreign asset position. Lane and Milesi-Ferretti (2002) find an inverse relation between net foreign assets and trade. We therefore firstly investigate the long-run relationship between the trade balance and net foreign assets in our samples, before estimating the relationship between real exchange rates and the trade balance. Our cointegration analysis is based on the panel cointegrating tests proposed by Pedroni (1999). Pedroni (1999) proposes seven tests and these are shown to have distorted size and low power for sample size, T, less than 100. When T is large enough the panel-p statistic seems to be the most reliable of his tests, otherwise, for small T the parametric group-t statistic appears to have the highest power, followed by the panel-t statistics the panel-p statistic. Considering our sample size we emphasize our tests with the parametric group-t statistic. The test results are reported in top section of Table 2.

The cointegration tests reported in Table 2 suggest that, for the three panels, we cannot accept the null hypothesis of no cointegration between trade balance and net foreign assets. Thus we infer that there should be a long-run association between the two series.

Table 1 Stationarity tests of the panels

Null: no unit root Panel 1 Panel 2 Panel 3	Panel-1		Panel-2		Panel-3	
Level	Z-statistic	Heteroscedastic Z-statistic	Z-statistic	Heteroscedastic Z-statistic	Z-statistic	Heteroscedastic Z-statistic
rer	9.39031 (0.0000)	5.81746 (0.0000)	9.89101 (0.0000)	6.12770 (0.0000)	12.0259 (0.0000)	7.33243 (0.0000)
tb	11.1997 (0.0000)	7.44259 (0.0000)	11.5027 (0.0000)	7.84297 (0.0000)	14.4656 (0.0000)	10.0504 (0.0000)
tot	8.20108 (0.0000)	6.98654 (0.0000)	7.92279 (0.0000)	6.86859 (0.0000)	12.7457 (0.0000)	9.29238 (0.0000)
nfa	12.2064 (0.0000)	9.58214 (0.0000)	12.7379 (0.0000)	10.0726 (0.0000)	13.8126 (0.0000)	11.2133 (0.0000)
gdppercapita	8.37736 (0.0000)	5.71179 (0.0000)	8.56615 (0.0000)	6.24502 (0.0000)	12.0748 (0.0000)	8.29032 (0.0000)
1st difference						
rer	−0.29498 (0.6160)	−0.37515 (0.6462)	2.16960 (0.0150)	0.09047 (0.4640)	2.04368 (0.0205)	0.20942 (0.4171)
tb	0.27993 (0.3898)	1.99242 (0.0232)	0.31669 (0.3757)	2.08677 (0.0185)	−1.72038 (0.9573)	0.04319 (0.4828)
tot	0.28960 (0.3861)	0.55923 (0.2880)	0.54588 (0.2926)	0.69648 (0.2431)	−0.75862 (0.7760)	−0.43428 (0.6680)
nfa	1.66142 (0.0483)	1.58858 (0.0561)	1.69375 (0.0452)	1.61460 (0.0532)	0.67807 (0.2489)	1.24038 (0.1074)
gdppercapita	−0.00284 (0.5011)	−0.43048 (0.6666)	0.00235 (0.4991)	0.10305 (0.4590)	−0.55480 (0.7105)	−0.03171 (0.5126)

This table reports Hadri Z-statistic and Hadri Heteroskedastic Consistent Z-statistic of Hadri (2000) stationarity tests for real exchange rate *rer*, term of trade *tot*, trade balance *tb*, net foreign asset *nfa* and relative GDP per capita ratio *gdppercapita*; the stationarity test is a test of null of stationarity of series; the figures not in the parenthesis are test statistics, and the figures in the parenthesis are the *p* values of the test statistics; the tests are conducted for the three panels and implemented both at the level and first difference

Table 2 Panel cointegration tests

	Panel-1		Panel-2		Panel-3	
	Group t-statistic (parametric)	*p*-value	Group t-statistic (parametric)	*p*-value	Group t-statistic (parametric)	*p*-value
tb ~ nfa	−2.805702	0.0025	−3.280407	0.0005	−3.383034	0.0004
Rer ~ gdppercapita ~ tb	−2.406573	0.0081	−2.256340	0.0120	−2.508164	0.0061
Rer ~ gdppercapita ~ nfa	−1.185687	0.1179	−1.047784	0.1474	−1.214267	0.1123

The table reports the parametric group t-statistic of Pedroni (1999) cointegration tests between trade balance *tb* and net foreign asset *nfa*, between real exchange rate, trade balance and relative GDP per capita *gdppercapita*, and between real exchange rate, relative GDP per capita and net foreign asset for Panel-1, Panel-2 and Panel-3 (see the text for the definitions of the three panels); null hypothesis of Pedroni (1999) test is no cointegration between series. Under the null of no cointegration all the test-statistics follow standard normal distribution $N(0,1)$

4.2.2 Cointegration Test: Real Exchange Rates, Term of Trade & Trade Balance

The results in Table 2 empirically confirm the cointegration relationship between the trade balance and net foreign assets noted by Lane and Milesi-Ferretti (2002). We now turn to testing the cointegration relationship between real exchange rates and the trade balance. The middle section of Table 2 reports the cointegration tests for real exchange rates, the relative GDP per capita of trade and the trade balance, for our three panel samples.[4]

The test results in Table 2 indicate for panel-1 that there is a cointegration relationship between the real exchange rate, relative GDP per capita and the trade balance. When we add China, or the four less mature economies (including China, Malaysia, Pakistan and the Philippines), to the OECD country panel, the tests still confirm the existence of cointegration at the 5 % significance level. However, we note that the test statistics are sensitive to the particular panel in terms of the *p* values of the parametric Group t-statistics, particularly in the association between real exchange rate, relative GDP per capita and trade balance.

5 Empirical Nonstationary Panel Estimation: *rer*, *tot* and *tb*

Given the evidence in favour of cointegration amongst the variables of interest, we now use different panel estimation methods, including fixed-effect, FMOLS, DOLS and PMGE, to estimate long-run associations. Maeso-Fernandez et al. (2004), compare the

[4] The panel cointegrating tests are conducted without the terms of trade as we noted in the previous section that the terms of trade is consistently insignificant in preliminary panel estimation and our final panel estimation is implemented without the terms of trade.

advantages and disadvantages of these estimation methods, although neither they nor any other researcher has statistically compared the performance of these methods in small samples, particularly for the case with multiple regressors. We also run these different estimators with and without a common time effect. Our estimations are based on the general specification as follows:[5]

$$rer_{it} = \mu_i + \theta_t + \beta_1 {}^* tot_{it} + \beta_2 {}^* tb_{it} + \beta_3 {}^* gdppercapita_{it} + \nu + \varepsilon_{it} \tag{7}$$

where *rer*, *tot*, *gdppercapita* and *tb* are defined as before - as the real exchange rate, terms of trade, relative GDP per capita and trade balance - and ε is the disturbance term. Various specifications of the model include a fixed effect, μ_i, a time effect, θ_t, and a common intercept, ν. Following the general-to-specific modelling principle, our empirical data modelling starts from the model specification which concern all independent variables including term of trade, trade balance and relative GDP per capita. Term of trade is consistently statistically insignificant in the trial estimation that we only report estimation without the terms of trade, which is specified as below:

$$rer_{it} = \mu_i + \theta_t + \beta_1 * tb_{it} + \beta_2 * gdppercapita_{it} + \nu + \varepsilon_{it} \tag{8}$$

We firstly estimate the panels with the fixed effects and then go on to estimate the specifications which include a common time effect across the countries in the panels, labelled as T in left-hand side of Table 3. FMOLS estimation results for the three samples are reported in the middle section of Table 3. Kao and Chiang (1999) demonstrate that the dynamic ordinary least squares (DOLS) estimator has better small-sample properties than OLS and fully modified OLS (FMOLS) estimators. The DOLS estimation requires establishing the appropriate lead and lag terms before estimation. Specifically, we choose one lead and one lag (the results stay essentially unchanged using other lead and lag lengths). The DOLS estimation results are also reported in the middle section of Table 3.

Finally, the PMGE estimator allows us to investigate long-run homogeneity without imposing parameter homogeneity in the short run. For the PMGE estimation, we use the Schwarz Information Criteria (SIC) to select the lag order for each group, the static fixed effect OLS estimates are used as initial estimates(s)[6] of the long-run parameters for the pooled maximum likelihood estimations. We also consider the common time effect and estimate the regression with and without the cross-section demeaned. The mean group estimator (MGE) estimated at this stage is a simple unweighted mean of

[5] Considering the major global economic crisis during our sample period, we use a dummy variable to deal with the global impact from the crisis: Latin American debt crisis from 1975 to 1982, Asian crisis from 1997 to 1998, and recent global scale economic crisis from 2008 to 2010. The dummy series equals one during the crisis, zero otherwise. The trial estimation suggests the dummy series are consistently insignificant.

[6] The results for the mean group estimator suffer from a lack of degrees of freedom for panel estimation, particularly if they are based on DOLS. Therefore, the parameters of the static fixed-effects model have been used as the starting values for the PMGE estimations.

Table 3 Panel data estimation: *rer*, *relative GDP per capita and tb*

Dependent variable: rer										
							(P)MGE			
	Fixed-effect		FMOLS		DOLS		PMGE		MGE	
	N/T	T	N/T	T	N/T	T	N/T	T	N/T	T
Panel-1										
tb	−0.7568 (0.0918)	−0.7217 (0.0959)	−0.9587 (0.1695)	−0.4724 (0.1357)	−1.1115 (0.2023)	−0.5099 (0.1905)	−0.678 (0.221)	−2.3368 (0.5055)	−1.608 (2.208)	−0.8047 (1.6151)
Relative GDP per capita	0.0829 (0.0040)	0.0952 (0.0046)	0.0806 (0.0072)	0.0939 (0.0057)	0.0760 (0.0081)	0.0943 (0.0066)	0.093 (0.013)	0.0962 (0.0140)	0.0978 (0.0499)	−0.0596 (0.1999)
phi							−0.123 (0.021)	−0.0584 (0.0145)	−0.173 (0.028)	−0.3118 (0.0480)
Panel-2										
tb	−0.9068 (0.1205)	−0.7536 (0.1246)	−1.1526 (0.2145)	−0.3247 (0.0264)	−1.1633 (0.2529)	−0.4550 (0.1115)	0.4870 (0.4669)	−2.2717 (0.4900)	−1.8462 (2.3142)	−0.5023 (1.5756)
Relative GDP per capita	0.0832 (0.0054)	0.1052 (0.0061)	0.0813 (0.0092)	0.1389 (0.0227)	0.0764 (0.0102)	0.0834 (0.0046)	0.3436 (0.0420)	0.0956 (0.0139)	−0.0540 (0.1592)	−0.0311 0.1935)
phi							−0.0497 (0.0180)	−0.0612 (0.0142)	−0.1830 (0.0229)	−0.3083 (0.0461)
Panel-3										
tb	−1.2433 (0.1080)	−0.9474 (0.1075)	−1.5227 (0.1892)	−0.5218 (0.1669)	−1.4637 (0.2013)	−0.5605 (0.2249)	0.4606 (0.4649)	0.8630 (0.5371)	−1.5875 (2.0572)	−0.4312 (1.3978)
Relative GDP per capita	0.0865 (0.0059)	0.1206 (0.0064)	0.0866 (0.0102)	0.0967 (0.0087)	0.0801 (0.0106)	0.0966 (0.0102)	0.3434 (0.0419)	0.3732 0.0535)	0.4088 (0.6003)	0.4490 (0.3727)
phi							−0.0463 (0.0161)	−0.0420 (0.0152)	−0.1695 (0.0219)	−0.3219 (0.0439)

This table reports estimates for three panels on the relationship between rer, relative GDP per capita and tb; the estimation includes fixed-effect panel method, FMOLS, DOLS and PMGE; T and N/T denote, respectively, the estimation with and without considering common time effect across sections; standard error are reported in parentheses below the coefficients the coefficients. We report these results in the right-hand side of Table 3. We implement the estimations using the GAUSS program of Pesaren et al. (1999).

5.1 Results Analysis

Overall, the estimation results provide broad support for a negative long-run relationship between the real exchange rate and the trade balance when holding the relative GDP per capita fixed. The results suggest that an increase in the trade balance results in a real depreciation of the real exchange rate, although we note the sensitivity of the coefficient estimates on the same variables between the three panels, the different estimation methods and the various model specifications. The estimates with the trade balance, reported in Table 3, clearly demonstrate that the estimates' magnitude of fixed-effect, FMOLS and DOLS consistently become larger if we compare panel-1 with panel-2 and panel-3, which suggests the heterogeneity in the association between the three panels and indicates these less developed economies' real exchange rates might be much more sensitive to the national trade balance.

The trade balance is consistently found to be statistically significant and correctly signed in the fixed-effect, FMOLS and DOLS estimation: which shows a significant effect on the exchange rates and in the majority of specifications, including fixed-effects, FMOLS and DOLS, but not in most cases of PMGE and MGE, the absolute value of the estimated elasticity is around 1 with a range from 0.3245 to 1.5227. Thus, a one percentage point increase in the trade surplus leads to a real exchange rate depreciation of about 0.3247 percentages in panel-2 FMOLS-T or even 1.5227 percentages in panel-3 FMOLS-N/T. The relative GDP per capita is statistically significant and positive in most of the three panel estimates. Its magnitude varies from 0.672 (in panel-1 FE) to 1.082 (in panel-2 PMGE-NT).

The PMGE estimates of trade balance are only statistically significant and correctly signed in panel-1 PMGEE-T, panel-1PMGE-N/T, and panel-2 PMGE-T, with insignificant and wrongly signed estimates in panel-3. Among the PMGE estimates, the significantly negative coefficients of the adjustment term (phi) strongly suggests mean reversion of real exchange rates to a long-term equilibrium value, which supports the hypothesis of a cointegration relationship amongst the variables. The MGE estimates are consistently found to be statistically insignificant and wrongly signed in the three panels, which indicates the heterogeneity issue among the panel members.

The panel cointegration tests suggest integrated associations between the series of interest in the three panels, but the estimation demonstrates the heterogeneity exhibited by the three panels. China's gradual economic reform process has created a powerful economy that seems to be integrating with the world economy and should therefore share common characteristics with the OECD economies concerned, then we do not expect to see a big difference in the response of the real exchange rate to the underlying fundamentals, especially between the first two panels. However, in the estimations we observe the heterogeneity between the three panels.

5.2 Additional Estimation with Net Foreign Assets

Additionally, we examine the relationship between real exchange rates and net foreign assets, which is specified in Eq. (3). Although Lane and Milesi-Ferretti (2002) argue that there are two reasons to indicate it is not suitable to use only net foreign assets to assess real exchange rates, we believe this specification is relevant in our case: specifically, based on the cointegration relationship between trade balance and net foreign asset (see Table 2) and the cointegration between the real exchange rates and the trade balance, we conjecture there should be a cointegrating relationship between the real exchange rates and net foreign assets in the panels. For instance, the behavioural equilibrium exchange rate (BEER) of Clark and MacDonald (1998) uses Balassa-Samuelson effect, net foreign assets and the terms of trade as the systematic components of the real exchange rate. Table 1 report the unit root tests for the order of integration of net foreign assets and they clearly suggest that net foreign assets follows a nonstationary process. Our Pedroni cointegration tests confirm that there is no cointegrating relationship between the real exchange rate, relative GDP per capita and net foreign assets. Table 2 reports the parametric group *t*-test for the cointegration tests.

The cointegration test results do not suggest that there is a cointegration relationship between the real exchange rate, relative GDP per capita and net foreign assets, which is consistent with the theoretical indication of Lane and Milesi-Ferretti (2002) that real exchange rate is better related with trade balance rather than net foreign asset.

Analogously, we firstly estimate the fixed-effects panel for the long-run relationship between the real exchange rate, relative GDP per capita and net foreign assets. The left-had side of Table 4 reports the fixed-effect panel estimation results followed by the standard errors in parenthesis, most of which support the results of cointegrating tests that there is no cointegration relationship between these series.

We then use the same estimation methods as those in the last section to estimate the relationship between the real exchange rate and the other variables. The middle sections of Table 4 report the estimation results, and PMGE estimates are reported in the right-hand side of Table 4. Standard errors are reported in parentheses. The results show that most of the estimates with net foreign assets are insignificant and wrongly signed. However, the majority of the coefficient estimates on the relative GDP per capita are consistently significant.

Overall, the panel cointegrating tests and estimation results appear to suggest a weak relationship between real exchange rates and net foreign assets, even for the panel that contains only OECD economies. This evidence appears to confirm the theoretical framework of Lane and Milesi-Ferretti (2002) that the empirical link between real exchange rates and net foreign asset is through the association between real exchange rates and the trade balance.

5.3 Misalignment Experiments

In this section we conduct a series of misalignment experiments for all of the currencies in our sample. We use the estimates of the three panels, DOLS-N/T for panel-1 and panel-3, due to the robustness of small-sample DOLS estimators, to firstly calculate the current equilibrium real exchange rates. To evaluate the permanent effects from the fundamentals we smooth out the temporary volatile elements, using the Hodrick-Prescott (1980) filter to obtain the long-run values of the fundamentals and use these permanent fundamentals to calculate the long-run equilibrium real exchange rates. In Fig. 1 (see Appendix), we report the actual real exchange rates, current equilibrium exchange rates and long-run equilibrium exchange rates for all the currencies of interest. The solid lines represent actual real exchange rates, the circled lines represent the current equilibrium exchange rates and the filled-circled lines represent the permanent equilibrium exchange rates. From the three exchange rates plotted in each figure, we can observe the misalignments of the currencies over the sample period.[7]

The figures show that the actual values of the currencies experience different extents of under and overvaluation over the sample period. In terms of the misalignment size and direction, the majority of the two misalignments, current misalignment and total misalignment (Clark and MacDonald 1998), are closely consistent with each other. However, in terms of the misalignment directions, for some currencies at some points these two measurements conflict slightly with each other. For instance, the current misalignment for Belgium gives an undervaluation in 1991, while the total misalignment shows overvaluation, although the two misalignment magnitudes are very small. The figures also demonstrate that, during the sample period, the four less mature economies' currencies (Chinese Yuan, Malaysian ringgit, Pakistani rupee and Philippine peso) dominantly experienced undervaluation since mid/late 1980s while the 23 OECD economies experienced both different degrees of overvaluation and undervaluation over the sample period. The Fig. 1 indicates that Chinese Yuan experiences consistent overvaluation before 1987, but afterwards it starts to experience undervaluation till the end of the sample period, particularly the substantial undervaluation at the time of the Asian crisis. This narrative would seem to accord well with the perceived wisdom that the Chinese Yuan has been persistently undervalued in real terms in the recent past (see, for example, Cheung et al. (2009) and Hall et al. (2013))

However, it is noteworthy that some other currencies do not accord so well with the stylised facts. For example, the current misalignment for the real exchange rate of Greece in the period 2000 to 2005 suggests an undervalued currency whereas the perceived wisdom is that the currency was significantly overvalued in that period. For the recent crisis period up to the end of our sample, the current misalignment suggests that the actual real effective exchange rate real exchange rate is currently overvalued despite the significant improvement in competitiveness that has occurred in 2010 and 2011. What may explain the appreciation of the equilibrium rate between 2000 and

[7] Firstly we can calculate the current misalignments (CM) (Clark and MacDonald 1998) by the formula as follows:

$$CM = \frac{actual\ \mathrm{Re}alExchangeRate - currentEquilibriumExchangeRate}{currentEquilibriumExchangeRate} \times 100\%.$$

The current misalignment provides convenient and direct information of the misalignment, but the calculations directly use the current values of the fundamentals, which include the effect from the business cycles. To investigate the permanent effect of fundamentals, we evaluate the total misalignments (TM) (Clark and MacDonald 1998) by the formula as follows:

$$TM = \frac{actual\mathrm{Re}alExchangeRate - longRunEquibriumExchangeRate}{longRunEquilibriumExchangeRate} \times 100\%.$$

Table 4 Panel data estimation: *rer*, *relative GDP per capita and nfa*

Dependent variable: rer										
							(P)MGE			
	Fixed-effect		FMOLS		DOLS		PMGE		MGE	
	N/T	T	N/T	T	N/T	T	N/T	T	N/T	T
Panel-1										
nfa	−0.0380 (0.0201)	−0.0379 (0.0211)	−0.0221 (0.0361)	0.0362 (0.0309)	0.0252 (0.0445)	0.1205 (0.0385)	−0.065 (0.022)	0.033 (0.019)	0.071 (0.265)	−0.590 (1.236)
Relative GDP per capita	0.0777 (0.0041)	0.0920 (0.0048)	0.0707 (0.0076)	0.1657 (0.0307)	0.0648 (0.0085)	0.1049 (0.0061)	0.100 (0.010)	0.112 (0.005)	0.347 (0.254)	0.076 (0.051)
phi							−0.142 (0.027)	−0.235 (0.061)	−0.175 (0.025)	−0.313 (0.055)
Panel-2										
nfa	−0.0912 (0.0257)	−0.0855 (0.0269)	−0.0782 (0.0444)	0.0787 (0.0738)	0.0050 (0.0556)	0.0513 (0.1253)	−0.979 (0.236)	−0.802 (0.157)	0.733 (0.671)	0.167 (0.580)
Relative GDP per capita	0.0784 (0.0055)	0.1024 (0.0062)	0.0720 (0.0096)	0.2416 (0.0347)	0.0655 (0.0107)	0.3942 (0.0757)	0.868 (0.051)	0.669 (0.032)	2.715 3.027	12.718 (9.807)
phi							−0.294 (0.032)	−0.416 (0.036)	−0.336 (0.042	−0.405 (0.043)
Panel-3										
nfa	−0.1525 (0.0284)	−0.1008 (0.0289)	−0.1446 (0.0495)	0.0546 (0.0682)	−0.0709 (0.0585)	0.0190 (0.1190)	0.3616 (0.0733)	0.8630 (0.5371)	8.0502 (7.4905)	−0.4000 (0.9556
Relative GDP per capita	0.0808 (0.0063)	0.1188 (0.0066)	0.0751 (0.0111)	0.6641 (0.0406)	0.0679 (0.0116)	0.8324 (0.0860)	0.5003 (0.0500)	0.3732 (0.0535)	1.1775 (0.7172)	0.2127 (0.4860)
phi							−0.0371 (0.0141)	−0.0420 (0.0152)	−0.1567 (0.0206)	−0.2865 (0.0384)

This table reports estimates for three panels on the relationship between rer, relative GDP per capita and nfa; the estimation includes fixed-effect panel method, FMOLS, DOLS and PMGE; T and N/T denote, respectively, the estimation with and without considering common time effect across sections; standard error are reported in parentheses below the coefficients

2009 is that the euro exhibited a sustained appreciation during that period and this maybe what is being picked up in the effective rate.[8]

6 Conclusion

In this study we have examined the links between real exchange rates, the trade balance and net foreign assets for three different panels, over the period from 1980 to 2011. Our study is based on the theoretical framework proposed by Lane and Milesi-Ferretti (2002) that the connection between real exchange rates and net foreign assets is through the association between real exchange rates and the trade balance. Our empirical analyses indicates that there is a cointegrating relationship between the trade balance and net foreign assets, as well as an apparently significant negative relationship between real exchange rates and the trade balance in the majority of estimations. However, in the panel data setting we do not find a significant and correctly signed link between real exchange rates and net foreign assets. Furthermore, the panel estimates suggest heterogeneity between the four less mature economies and the OECD economies in the association between the real exchange rate and trade balances. Our estimates are then used to investigate currency misalignments for our sample of countries over the period 1980 to 2011 using the long-term association between the real exchange rate and trade balance and these display an interesting and rich pattern. One interesting aspect of these results is that not all of the implied misalignments accord with what would be generally accepted as the stylised facts for certain currencies. Our results therefore would seem to underscore the need to take a broader approach to the assessment of equilibrium exchange rates than purely focussing on a single method or approach.

Our paper also provides a practical comparison between different panel estimation methods (fixed-effect, DOLS, FMOLS and PMGE) in the context of our application. As we have noted, we do not find a significant link between real exchange rates and net foreign assets in a panel data setting, and that may reflect the well- known issues with respect to the measurement of the net foreign asset series. Furthermore, although it is often argued that broad panels can identify a more general pattern effectively, compared to individual time series studies, it is also the case that large panels amplify heterogeneity issues which arise when there are many diverse countries in a panel. Given the diversity of countries in our panel, this is the most likely explanation for the mixed results we obtain in our panel estimations.

Acknowledgments The authors are very grateful to George Tavlas for his helpful and constructive comments on earlier drafts of this paper.

[8] We have crossed checked our results using the IMF's set of real effective exchange rates and our results are identical to the World Bank rates used in our study.

Appendix

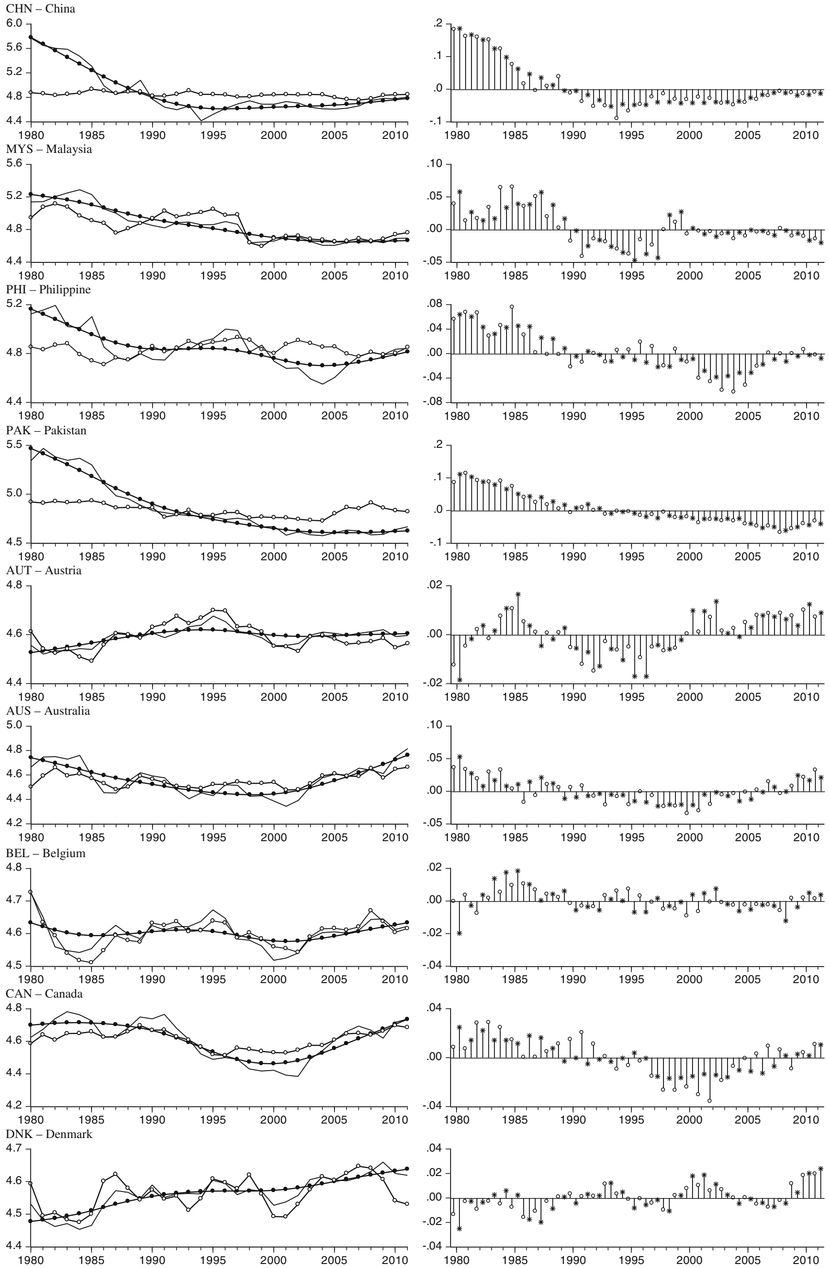

Fig. 1 Equilibrium exchange rates and misalignments. *Notes* The figures in the left-hand side show three exchange rates of 27 currencies over 1980–2011: the *solid lines* represent actual real exchange rates (exchange rate index in logarithm); the *filled-circled lines* represent the permanent equilibrium exchange rates; and the *circled lines* represent the current equilibrium exchange rates; the figures in the right-hand side show the real exchange rate misalignments based on the current equilibrium exchange rates and permanent equilibrium exchange rates: the *circled spikes* denote the current misalignments; the *stared spikes* denote the permanent misalignments; the same notations apply to the figures in the following pages; see the text for the detailed definitions

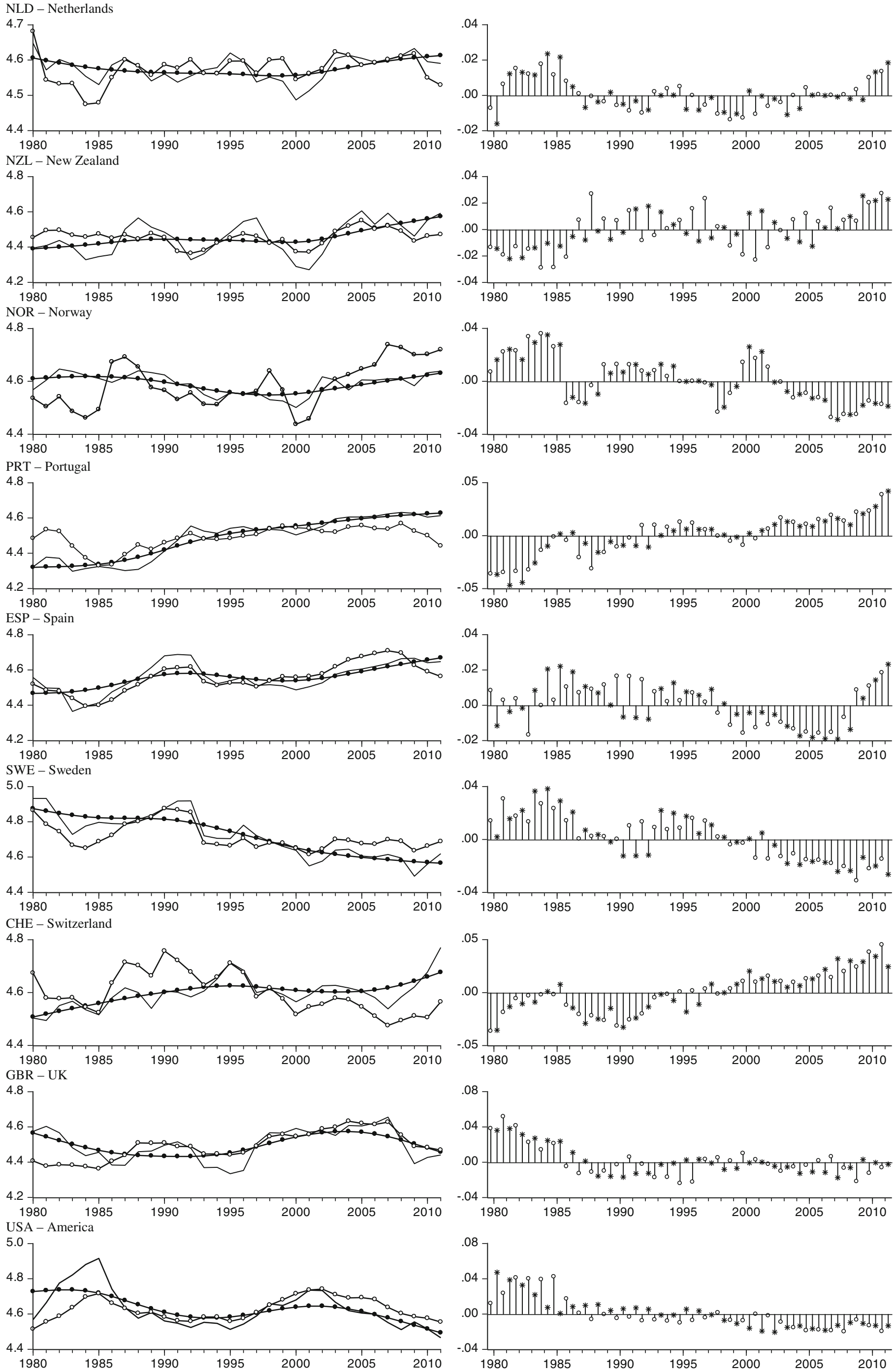

Fig. 1 (continued)

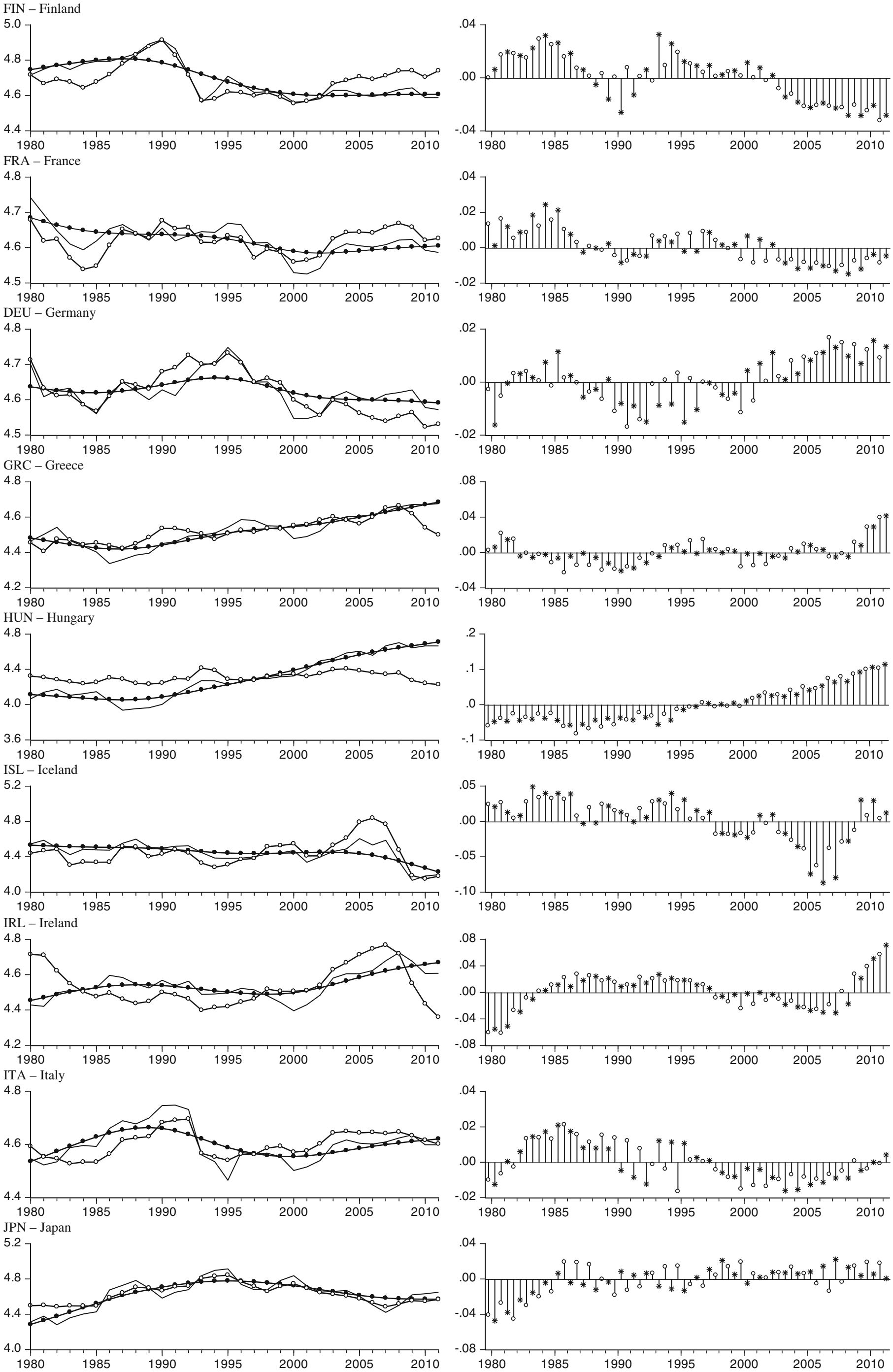

Fig. 1 (continued)

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