

Economic growth and deviations from the equilibrium exchange rate: a panel ARDL and panel NARDL approach

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Abstract

Purpose – The purpose of this study is to provide empirical evidence on the impact of deviations from the long-run sustainable real exchange rate (RER) equilibrium on real economic growth rate applying panel autoregressive distributed lag model (ARDL) (Pooled Mean Group, Mean Group and Dynamic Fixed Effects estimators) in a dynamic heterogeneous panel setting and panel NARDL for the largest database covering 104 countries during 1995–2022 period developed by Couharde *et al.* (2017).

Design/methodology/approach – The EQCHANGE database makes available not only the equilibrium RER but also misalignments according to the Behavioral Equilibrium Exchange Rate approach for each country. One of the main objectives is to examine whether undervaluation or overvaluation RER can imply different responses on economic performance trying to differentiate between short and long run effects. Additionally, the authors consider the World Bank (WB)'s income classifications to compare the asymmetries attending to high-income, upper-middle-income, lower-middle-income and low-income levels.

Findings – Applying the panel ARDL technique, the results suggest that the RER misalignments have a negative but not significant effect on the short-run, nevertheless a negative and highly significant impact on real economic growth rate is detected on the long-run. Considering the panel NARDL, the asymmetric relationship between RER misalignment and economic growth rate is supported considering all countries in the long-run (in the short-term is not significant). In the long run is detected that undervaluation can promote economic growth rate, rather than overvaluation which can harm the economic performance. Additionally, the WB and the International Monetary Fund (IMF) income's classifications have been applied and the long-run symmetry test is strongly rejected regardless of income group.

Originality/value – To the best of the author knowledge, this is the first time the non-linear panel ARDL methodology has been applied for analyzing the impact of deviations from the long-run sustainable RER equilibrium on real economic growth. This allows us to see the asymmetric effect not seen before. The panel ARDL estimation can efficiently performed regardless of the integration level of the variables, additionally, it is consistent even in the presence of endogeneity. Besides, another advantage of this method is that it is possible to reflect not only the short but also the long-run dynamics. Moreover, this analysis offers a comparison between linear panel ARDL and non-linear to compare the advantages from the former. Additionally, this study covers the largest database, in particular, 104 countries during the 1995–2022 period implemented with the Couharde *et al.* (2017) EQCHANGE database. Finally, it is compared the asymmetries attending to different income classifications.

Keywords Equilibrium real exchange rate, Misalignments, Economic growth, Panel ARDL, Panel NARDL

Paper type Research paper



1. Introduction

The exchange rate misalignment is one of the most relevant topics in open economy macroeconomics because a significant and persistent deviation of the real exchange rate (RER) from its equilibrium level can involve current account problems and currency crises. In particular, [Frankel and Rose \(1996\)](#) indicate that an overvaluation process that last for a significant period of time can be a good predictor of possible currency crises. In the same line, misalignments are understood by [Holtemöller and Mallick \(2013\)](#) as an instrument to predict currency crisis. For this reason, policymakers concern of aligning actual exchange rate near to the long-term equilibrium exchange rate. Besides, keeping the exchange rate in an “appropriate” level contributes to the macroeconomic stabilization because it can generate optimal paths of output and employment ([Obstfeld and Rogoff, 1996](#); [Acemoglu *et al.*, 2003](#); [Easterly and Levine, 2003](#)), especially for developing countries.

The literature about the determination of the RER equilibrium goes back to [Balassa \(1964\)](#) in which this concept is associated with both external and internal balance. In fact, RER misalignments are generated due to changes in structural or macroeconomic factors. These misalignments can be explained as a consequence of the inconsistency between the nominal exchange rate and the monetary policy. Another branch that justifies the structural misalignment is proposed by [Edwards \(1989\)](#) in which the author outlines that this can happen because the RER does not react immediately to changes in its determinants.

There is a vast theoretical and empirical literature on this theme, nevertheless, there is not a consensus about which is the best method of measuring the degree of misalignment ([Dufrenot and Yehoue, 2005](#)), because the equilibrium RER is an unobservable variable. [Driver and Westaway \(2005\)](#) specify that there is not a single definition of the equilibrium RER [1]. In fact, 14 different approaches are distinguished and the classification is done depending to the time horizon concerned by the measure of equilibrium exchange rate. In particular, this equilibrium can be treated as long-run, medium-run or short-run concept, which can be considered as a stock or flow equilibrium. This measure is sensitive to the variables and model implemented ([Cheung *et al.*, 2009](#)) and the data source used ([Cheung and Fujii, 2014](#)). Part of the literature is based on deviations from purchasing power parity (PPP) while other studies focus on distortions of the equilibrium RER.

One of the main arguments about the negative effect on economic performance is that the misaligned RER leads to a nonoptimum allocation of resources among different sectors of the economy due to the relative price distortions in the tradable and nontradable goods sectors ([Edwards, 1989](#)). Another school of thought considers that real undervaluation is able to promote economic growth, especially in developing countries. Nonetheless, several studies confirm that both overvaluation and undervaluation can harm the economy.

One of the main contributions of this study related to the recent previous analyses such as [Ramos-Herrera and Sosvilla-Rivero \(2023\)](#), [Akram and Rath \(2018\)](#), [Couharde and Sallenave \(2013\)](#), [Ramos-Herrera \(2022\)](#) or [Aflouk and Mazier \(2013\)](#), among others, is that this research focuses not only on the symmetric impact of deviations from the long-run sustainable RER equilibrium on real economic growth applying panel Autoregressive Distributed Lag model (ARDL) but also this analysis examines the asymmetric effects. It is relevant to distinguish whether the effects of undervaluation and overvaluation on the economic performance are the same or they are different and simultaneously whether the impact is identical for the short and the long-run. Moreover, another value added of this analysis is that it provides empirical evidence for the largest database covering 104 countries during a large time period (1995–2022) thanks to EQCHANGE database developed by [Couharde *et al.* \(2018\)](#). Furthermore, to check the robustness of the results, two different

panels of trade partners have been applied which means that exchange rate misalignment is defined based on 186 and on 30 trade partners. Finally, to assess whether there are asymmetries according to the level of development it has been apply panel ARDL and panel non-linear ARDL (NARDL) methodology distinguishing between high-income, upper-middle income, lower-middle income and low-income levels.

The rest of the paper is structured as follows. Section 2 provides a literature review. Section 3 explains the data and variables used in this study. Section 4 provides the panel ARDL and the panel NARDL econometric methodology. Section 5 offers the results and some discussions between different income classifications comparing the asymmetric effects. Finally, in Section 6 the main conclusions are provided.

2. Literature review

There is a growing literature trying to analyze the relationship between RER misalignments and economic growth. In particular, there is a large body of research which consider the possibility of asymmetries in this relationship (Razin and Collins, 1997; Sekkat and Varoudakis, 2000; Gala, 2008; MacDonald and Vieira, 2010; Bhalla, 2012; to name a few).

On the one hand, monetary authorities who sustain the RER below its equilibrium can trigger more inflation which leads to overheating the economy (Calvo *et al.*, 1995; Goo, 2006; Haddad and Pancaro, 2010). Krugman and Taylor (1978) or Williamson (1990) confirm that undervaluations would lead unnecessary inflationary pressures on imported inputs and therefore the competitiveness would be severely resentful. In fact, in a more recent study, Ribeiro *et al.* (2020) analyze how changes in income distribution are able to affect the technological capabilities which they suggest that when both are explicitly taken into account, the direct effect on RER misalignment on growth becomes statistically non-significant for developing economies. Concretely, these authors support the idea that RER only influences on growth indirectly. However, the indirect impact of undervaluation on economic growth is small and negatively statistically significant for a wide set developing countries. By contrast, authors such as Bhalla (2012), Couharde and Sallenave (2013) and Afrouk and Mazier (2013) support that an undervalued RER is able to boost exports, employment and therefore more economic growth. In the same line, Razin and Collins (1997), Bleany and Greenaway (2000), Toulaboe (2006) or Dubas (2009), among others, emphasize the crucial role that undervaluation can generate fostering economic growth. Paying attention to the channels through the RER can lead to long-term economic growth, Eichengreen (2008) highlights how a more depreciated RER is generally linked to a lower exchange rate volatility. On the other hand, the real overvaluation can imply a negative impact on exports because of the lower competitiveness of home products which translates into current account deficits and therefore currency crises (Easterly, 2005; Gala and Lucinda, 2006; Toulaboe, 2006; Gala, 2008; Elbadawi and Soto, 2008; Sallenave, 2009; Couharde and Sallenave, 2013; among others). Studies such as Krugman (1979) or Loayza *et al.* (2005) point out the loss of external competitiveness and they warn the higher probability of suffering currency crises. Mcpherson (2000) also argue the lower business and consumer confidence as the main channel through it can be seen a deterioration on savings, investments and economic growth. In this line, Rodrik (2008a, 2008b) claims that an overvalued exchange rate restricts the economic activity leading to balance of payment emergencies and conducting to black market practices. According to Chowdhury and Ali (2012), the overvaluation can diminish productivity and economic growth and additionally, the capital does not move to the most lucrative sectors. Another strand of empirical literature offers statistically evidence which support that both undervaluation and overvaluation are harmful for economic growth (see for instance, Sekkat and Varoudakis, 2000; Aguirre and

Calderón, 2005; MacDonald and Vieira, 2010; Schröder, 2013; among others). Policymakers undergone the relevance of being closer to the long-run equilibrium exchange rate specifically in developing and emerging markets because the adverse impact of RER misalignment is higher than developed countries.

It is important to mention that the RER misalignment is defined as the deviations of the exchange rate from its long-run sustainable equilibrium level. Nevertheless, there is no consensus in the way to determine its equilibrium and for this reason there are several measures of RER equilibrium (see for instance, [Gandolfo et al., 1993](#); [Meese and Rogoff, 1983](#); [Cheung et al., 2010](#) or [Cheung et al., 2017](#); among others). The methodology developed along literature to compute the ERER can be encompassed into two clusters: the structural and the direct approach. The former is relying on a macroeconomic model and the equilibrium is determined based on internal and external balance. On the contrary, the direct approach uses ad-hoc fundamentals to explain the RER. Broadly, there are four main approaches: the PPP introduced by [Cassel \(1918\)](#), the Natural Rate of Exchange Rate (NATREX) proposed by [Stein and Allen \(1998\)](#), the Fundamental Equilibrium Exchange Rate (FEER), introduced by [Williamson \(1994\)](#), the Behavioral Equilibrium Exchange Rate (BEER) proposed by [Clark and MacDonald \(1998\)](#).

The PPP is considered as the most traditional and simplest method in determining the equilibrium RER. Lower levels misalignments are related with higher economic growth applying this procedure ([Cavallo et al., 1990](#); [Ghura and Grennes, 1993](#)). According to this method, the movements in the long run of the equilibrium exchange rates depend on the relative prices. In particular, the PPP theory predicts that the real equilibrium exchange rate is constant over time and equal to 1 because the price levels are equal when measured in the same currency ([Froot and Rogoff, 1995](#); [MacDonald, 1995](#)). Authors such as [Prasad et al. \(2007\)](#) or [Rodrik \(2008a, 2008b\)](#) propose the PPP exchange rate as an important tool to estimate the equilibrium level. However, one of the main criticisms is that if the PPP hypothesis does not hold, as it is proved by [Rogoff \(1996\)](#), [MacDonald \(2000\)](#) and [Taylor and Taylor \(2004\)](#), this strand cannot be considered a valid proxy for the long-run equilibrium. For this reason, alternative methodologies are needed.

The NATREX model was created by [Nurkse \(1945\)](#), developed by [Stein \(1990, 1996\)](#) and provides an equilibrium benchmark applying prevailing real economic fundamentals to determine the exchange rate misalignment. It is understood as a moving equilibrium which varies over time in response to shocks in the current real macroeconomic factors. It ensures the equilibrium of the balance of payments in absence of changes in international reserves, speculative capital movements and cyclical factors. This procedure does not require that actual and its equilibrium are stationary ([Edwards and Savastano, 1999](#)). Several authors have contributed to the empirical literature implementing this technique to examine the transition between the medium-run to long-run equilibrium (see for instance [Gandolfo and Felettigh, 1998](#); [van Eden et al., 2001](#); [Siregar and Rajan, 2006](#); [Detken and Martinez, 2001](#); [Federici and Gandolfo, 2002](#); among others).

Several recent studies have addressed this issue by using the FEER approach developed by [Williamson \(1994\)](#) (see for instance [Zhou, 1993](#); [Barisone et al., 2006](#); [Cline, 2008](#); [Lee et al., 2008](#); [Cline and Williamson, 2010, 2011](#); [Jeong et al., 2010](#); [You and Sarantis, 2011](#); [Carton and Hervé, 2012](#); [Duwicquet et al., 2013](#); [Saadaoui, 2017a, b](#)). The real effective exchange rate fluctuates around a time-varying equilibrium which is defined depending on the relationship with the long-run real factors (the fundamentals). This modeling approach define the equilibrium RER when both internal and external equilibriums are achieved ([Wren-Lewis, 1992](#); [Edwards, 1989](#); [Faruquee et al., 1999](#); [Wren-Lewis, 2003](#)). When the market for non-tradable goods clears at present and in the future given the prices and wages flexibility the

internal equilibrium is reached. The internal equilibrium is achieved when the economy is characterized by full employment and low inflation scenario. The external equilibrium is associated with a scenario in which the current account balance meets a “sustainable” level linked to sustainable capital flows (making equal the capital and the current account balance, [Siregar, 2011](#)). This approach tackles to assess whether a movement of the real effective exchange rate implies a misalignment or by the contrary the equilibrium of the REER has experienced a shift because changes in the macroeconomic fundamentals. In other words, this perspective brings up the possibility of decomposing those factors which can influence on the long-run equilibrium RER with permanent changes (i.e. the fundamentals or the real factors) and the short-run misalignments of the nominal exchange rate derived from policy variables. This methodology is considered as a medium-term approach (or structural approach) given that the equilibrium exchange rate is consistent with the medium-run equilibrium of the macroeconomic factors.

Because the definition of a sustainable current account is highly controversial to define the external equilibrium in the FEER approach ([Siregar and Rajan, 2006](#)) another methodology was introduced. The BEER approach is proposed by [MacDonald \(1997\)](#) and developed by [Clark and MacDonald \(1998\)](#). In this procedure, first, the RER is estimated against its determinants and the second step considers the estimated coefficients from the previous regression and the permanent components of RER factors to compute the corresponding equilibrium. Thereafter, the misalignment is computed as the difference between the actual and the equilibrium RER. In other words, fundamental variables are crucial to determine the behavior of exchange rate and based on the observed fundamental factors or the Hodrick–Prescott filter a long-run cointegration relationship is detected. This method is understood as a direct approach. In contrast to the FEER method, this modeling technique is based on the fact that the equilibrium exchange rate is consistent with prevailing level of economic fundamentals and on the uncovered interest rate parity. This approach has been implemented in the empirical literature by several authors ([Alberola, 2003](#); [Berg and Miao, 2010](#); [Bénassy-Quéré *et al.*, 2009, 2010](#); [Naseem and Hamizah, 2013](#); [Conrad and Jagessar, 2018](#); among others). One of the main advantages is that it captures not only real exchange movements in the medium or long-term equilibrium level but also movements over time.

Comparing different techniques on the determination of the ERER, [Costa \(2005\)](#) and [Driver and Westaway \(2005\)](#) specified that BEER approach is linked with the short-run equilibrium [2], rather than FEER procedure which is associated with the medium-run [3] and NATREX is based on the transition between medium and long-run [4]. For these reasons, these alternative procedures can be seen as complementary methodologies because the REER is determined depending on weights and this fact can lead differences across indexes of misalignments. In compliance with [López-Villavicencio *et al.* \(2012\)](#), the relevant horizon to deal with global imbalances is the medium run, however, the BEER perspective focus on the long run. Another relevant drawback of BEER approach is the strong implicit assumption of misalignments since as in the PPP and the NATREX assume that this variable is stationary by construction.

One of the main shortcomings of the FEER approach is that it is sensitive to trade elasticities, the level of stable capital flows, the returns of net foreign assets and asset prices ([Bayoumi *et al.*, 1994](#); [Costa, 2005](#); [Isard, 2007](#); [Bénassy-Quéré *et al.*, 2009](#); among others). Specifically, [Bénassy-Quéré *et al.* \(2009\)](#) emphasize that BEER method is based on excessive confidence on past behavior of portfolio allocation and another drawback pointed out by [Fidora *et al.* \(2017\)](#) is that the ERER is consistent with the actual values of the real factors. Besides, NATREX and FEER are not based on theory in the exchange rate determination

(Clark and MacDonald, 1998). Couharde *et al.* (2018) point out that FEER and BEER methods are characterized by the statement that the equilibrium value is changing over time adapting to changes in macroeconomic fundamentals.

Other researchers have used alternative econometric techniques to determine the equilibrium of the RER such as Elbadawi and Soto (1994), Montiel (1997), Aron *et al.* (2000) or Imam and Minoiu (2011) which have used the cointegration approach. Panel cointegration and time series estimation techniques are implemented to highlight the long-run relationship. In this perspective, Comunale (2017), Habib *et al.* (2017) and Berg and Miao (2010) determine that undervaluation fosters economic growth. On the contrary, authors such as Aguirre and Calderón (2005) or Schröder (2013) identify that undervaluation does not suppose better economic growth. Single equation models and partial equilibrium models have also been implemented in several studies such as Driver and Wren-Lewis (1997), Montiel (1999) or Ghei and Pritchett (1999), among others.

Analyzing 184 countries, Rodrik (2008a) evolves an index adjusted for the Balassa–Samuelson effect in which it is detected that the more undervalued the RER is the higher the economic growth. Besides, it is identified that undervaluation fosters growth while overvaluation hurts the economic performance. Applying a dynamic panel data based on difference and system GMM techniques on 58 economies during the period 1960–1999, Gala and Lucinda (2006) reflect how real appreciation exchange rate can generate lower growth rates controlling for physical and human capital, output gap and inflation, among others.

In developing countries, it is more frequent that the overvalued RER which contributes depressing production, investment and balance of payment. According to Rodrik (2008b), the magnitude of the undervaluation effect on growth is higher for developing countries due to institutional fragility and market failures. A context characterized by a combination of low volatility and depreciated RER are really crucial for developing and emerging countries (Eichengreen, 2008). Moreover, because the existing empirical evidence that support a positive impact of trade balance on economic growth (see for instance, Kvedaras *et al.*, 2020; Bakari and Tiba, 2019; among others), Mamun *et al.* (2021a) analyze how undervaluation and overvaluation can influence trade balance which explains the behavior of emerging economies. The adverse impact of RER misalignment on economic growth has widely recognized in developing countries (see for instance, Cottani *et al.*, 1990; Dollar, 1992; Ghura and Grennes, 1993; Ali *et al.*, 2015; Akram and Rath, 2017, 2018; among others). Even though Usalan (2018) highlights the lower economic growth associated with overvaluation for developing countries, he does not find significant effect for richer countries. In a more recent study, Mamun *et al.* (2021b) claim that not only overvaluation erode economic growth for emerging economies, but also these authors offer empirical evidence of how undervaluation may hurt these countries due to the adverse impact on domestic consumption by generating income inequality.

In more recent studies, analyzing whether the asymmetric effects are confirmed, some discrepancies are detected. On the one hand, Habib *et al.* (2017), MacDonald and Vieira (2010) and Berg and Miao (2010) detect little evidence of asymmetry analyzing the impact of overvaluation and undervaluation. On the other hand, authors such as Aguirre and Calderón (2005), Bajo-Rubio and Díaz-Roldán (2009) and Schröder (2013) suggest that both positive and negative misalignments can harmful the economy. Applying panel data techniques on 58 countries, McLeod and Mileva (2011) point out the non-linear relationship between misalignments and economic growth because real depreciation involve an expansion on economic growth, nonetheless the higher the misalignment the larger the reduction in economic performance. To account for any possible asymmetric effects, Cuestas *et al.* (2019) estimate a nonlinear model. In particular, it is found that currency overvaluation

is negatively correlated with economic performance and additionally that the impact of overvaluation on economic growth is much stronger than undervaluation. [Ramos-Herrera and Sosvilla-Rivero \(2023\)](#) analyze whether the nexus between per capita economic growth and deviations from its equilibrium exchange rate might differ across different groups of countries applying the Grouped Fixed Effect (GFE) [5] method proposed by [Bonhomme and Manresa \(2015\)](#) identifying heterogenous relationships.

3. Data

Given the purpose of this study, the highest database which offer the ERER and the corresponding exchange rate misalignments for the largest sample of countries provided by [Couharde et al. \(2018\)](#) has been considered. First of all, it is needed to clarify that according to EQCHANGE database the real effective exchange rate of country i in period t is calculated as the weighted average of real bilateral exchange rates against each of its N trading partners j . Therefore, a real appreciation of the domestic currency is captured as a raise in the real effective exchange rate index. Besides, the entire EQCHANGE database applies the BEER approach on 187 countries. The final sample has been conditioned by the availability of data for the macroeconomic control variables, therefore to achieve a balanced panel for some estimation commands this analysis finally use 104 countries [6] during 1995–2022 period. Regarding the dependent variable that in this case is the real economic growth rate have been extracted from the World Development Indicators Database. The explanatory variables implemented in the neoclassical growth model such as the population growth rate, human capital, degree of openness, inflation rate are explained their definitions and their sources in detail in [Appendix](#).

4. Econometric methodology

4.1 Panel ARDL (symmetric effects)

In this section, the general framework of panel Autoregressive distributed lag (panel ARDL) based on the three alternative estimators is reviewed. First of all, it is important to mention that the standard panel models are usually associated with some drawbacks related to the imposed restrictions. To name a few, the pooled ordinary least square (OLS) is a highly restricted model because this method imposed the same intercept and slope for all cross-sections or the fixed effects model establishes common slopes and variance. Additionally, [Campos and Kinoshita \(2008\)](#) point out the bias that can be found in the fixed effects model when some regressors are endogenous and correlated with the error terms. Moreover, although the random effects model does not offer so many problems in terms of degrees of freedom, it does not guarantee the strict exogeneity ([Arellano, 2003](#)).

On the other hand, dynamic panel models such as the generalized method of moments (GMM)-difference estimator proposed by [Arellano and Bond \(1991\)](#) or the GMM-system estimator proposed by [Arellano and Bover \(1995\)](#) overcome some weaknesses. Nevertheless, according to [Roodman \(2006\)](#), the GMM estimators could provide spurious results in cases in which N is small and T is large for two reasons: first, due to the unreliable autocorrelation test and second, because this condition can affect the validity of the Sargan test of over-identification restriction.

For these reasons, to overcome these shortcomings and due to the fact that panel ARDL methodology is able to determine coefficients of a short- and long-term nature simultaneously ([Thampanya et al., 2021](#)), this paper implements the panel ARDL applying three different estimators: Mean Group (MG) estimator, Dynamic Fixed Effects (DFE) estimator and the Pooled Mean Group (PMG) estimator. The following generalized empirical ARDL (1, 1, 1, 1) equation in the panel form is given below:

$$\begin{aligned}\Delta g_{it} = & \beta_{0i} + \beta_{1i}g_{it-1} + \beta_{2i}Mis_{it-1} + \beta_{3i}Pop_{it-1} + \beta_{4i}HK_{it-1} + \beta_{5i}INF_{it-1} + \beta_{6i}OPEN_{it-1} \\ & + \beta_{7i}GKF_{it-1} + \sum_{j=0}^{M-1} \gamma_{ij}\Delta g_{it-j} + \sum_{j=0}^{N-1} \gamma_{ij}\Delta Mis_{it-j} + \sum_{j=0}^{O-1} \gamma_{ij}\Delta Pop_{it-j} \\ & + \sum_{j=0}^{P-1} \gamma_{ij}\Delta HK_{it-j} + \sum_{j=0}^{Q-1} \gamma_{ij}\Delta INF_{it-j} + \sum_{j=0}^{R-1} \gamma_{ij}\Delta OPEN_{it-j} + \mu_i + \varepsilon_{it}\end{aligned}\quad (1)$$

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where g_{it} refers real economic growth rate, Mis_{it} are exchange rate misalignments (both Mis_{186} or Mis_{30} [7]), Pop_{it} is the population growth rate, HK_{it} represents the human capital, INF_{it} is the inflation rate measured by the consumer price index, $OPEN_{it}$ captures the degree of openness, $i = 1, 2, \dots, N$ and time by $t = 1, 2, \dots, T$; μ_i represents the fixed effects and ε_{it} denotes the error term.

One of the main advantages is that panel ARDL does not force the variables to have the same order of integration to corroborate a long-run relationship. In other words, the panel ARDL estimation can efficiently perform regardless of the level of integration of the variables (Fang *et al.*, 2015; Kim *et al.*, 2010). To be more specific, it means that this approach is appropriate for variables that are integrated or order 0 or of order 1 or a mixed of them. Therefore the unit root pre-testing is only needed to rule out the possibility of I(2) variables since Pesaran and Pesaran (1996) claim that it will generate spurious regression because the computed F-statistic of the bounds test are rendered invalid (Chigusiwa *et al.*, 2011) [8]. Additionally, according to Pesaran *et al.* (1999), PMG and MG estimators are consistent even in the presence of endogeneity, because they include lags of dependent and independent variables.

First, the MG estimator was developed by Pesaran and Smith (1995) and it is characterized by estimating a regression for each country and then it computes the coefficients using unweighted means. All coefficients are allowed to be country-specific (i.e. heterogeneous) and time-varying in the short- and in the long-run. One of the necessary requirements to implement this approach is that time-series need to be large. In particular, in the study is crucial to consider at least 20 countries. Second, the PMG estimator assumes homogeneity for the long-term slope coefficients across economies, however, it allows heterogeneity across countries for short-term coefficients, the speed of adjustment, error variances and the intercepts. One of the basic assumptions is that the error correction term (ECT) is not correlated with regressors and it is normally distributed meaning that the explanatory factors can be treated as exogenous variables. Finally, Pesaran *et al.* (1999) developed the DFE technique, which is similar to PMG estimator, nonetheless, the DFE assumes that the slope coefficient and the error variances are the same across countries in the long run. The speed of adjustment and the short-run coefficient are also homogeneous while the intercepts are country-specific.

Given that the time in this study is 28 years, the MG estimator has not enough degrees of freedom, therefore PMG estimations become more important for the analysis. Nevertheless, to determine more formally which is the best method to estimate the model, the Hausman (1978) test is applied. The purpose of this test is to throw light on whether there is a significant difference between the estimators. In the case of a rejection of the null hypothesis (i.e. the difference between PMG and DFE or between PMG and MG is not significant [9]), the best option is to estimate applying the PMG estimator given that it is more efficient than others [10].

4.2 Panel NARDL (asymmetric effects)

Given that overvaluation and undervaluation RER can lead different effects on economic growth, an asymmetric panel methodology should be applied. In other words, this study implements the panel Nonlinear ARDL to distinguish whether positive and negative shocks can imply different reactions on economic performance. Following [Shin et al. \(2014\)](#), the [equation \(1\)](#) is rewritten as a non-linear equation:

$$\begin{aligned}\Delta g_{it} = & \beta_{0i} + \beta_{1t}g_{it-1} + \beta_{2t}^{-}Mis_{it-1}^{-} + \beta_{2t}^{+}Mis_{it-1}^{+} + \beta_{3t}Pop_{it-1} + \beta_{4t}HK_{it-1} + \beta_{5t}INF_{it-1} \\ & + \beta_{6t}OPEN_{it-1} + \beta_{7t}GKF_{it-1} + \sum_{j=0}^{M-1}\gamma_{ij}\Delta g_{it-j} + \sum_{j=0}^{N-1}(\gamma_{ij}^{-}\Delta Mis_{it-j}^{-} + \gamma_{ij}^{+}\Delta Mis_{it-j}^{+}) \\ & + \sum_{j=0}^{O-1}\gamma_{ij}\Delta Pop_{it-j} + \sum_{j=0}^{P-1}\gamma_{ij}\Delta HK_{it-j} + \sum_{j=0}^{Q-1}\gamma_{ij}\Delta INF_{it-j} + \sum_{j=0}^{R-1}\gamma_{ij}\Delta OPEN_{it-j} \\ & + \mu_i + \varepsilon_{it}\end{aligned}\quad (2)$$

where Mis^{-} and Mis^{+} represent the negative and positive shock of deviations of the RER from its long-run sustainable equilibrium level, respectively. The long-run coefficients are computed as $Mis^{-} = \frac{-\beta_{2i}^{-}}{\beta_{1i}}$ and $Mis^{+} = \frac{-\beta_{2i}^{+}}{\beta_{1i}}$. These shocks are estimated based on negative and positive partial sum decomposition of misalignment as follows:

$$\begin{cases} Mis_i^{-} = \sum_{k=1}^t \Delta Mis_{ik}^{-} = \sum_{K=1}^T \text{Min}(\Delta Mis_{ik}, 0) \\ Mis_i^{+} = \sum_{k=1}^t \Delta Mis_{ik}^{+} = \sum_{K=1}^T \text{Max}(\Delta Mis_{ik}, 0) \end{cases}\quad (3)$$

The error correction version of [equation \(2\)](#) is as follows:

$$\begin{aligned}\Delta g_{it} = & \omega_{1i}\phi_{it-1} + \sum_{j=0}^{M-1}\gamma_{ij}\Delta g_{it-j} + \sum_{j=0}^{N-1}(\gamma_{ij}^{-}\Delta Mis_{it-j}^{-} + \gamma_{ij}^{+}\Delta Mis_{it-j}^{+}) + \sum_{j=0}^{O-1}\gamma_{ij}\Delta Pop_{it-j} \\ & + \sum_{j=0}^{P-1}\gamma_{ij}\Delta HK_{it-j} + \sum_{j=0}^{Q-1}\gamma_{ij}\Delta INF_{it-j} + \sum_{j=0}^{R-1}\gamma_{ij}\Delta OPEN_{it-j} + \varepsilon_{it}\end{aligned}\quad (4)$$

The ECT reflects the speed of adjustment to the long-run equilibrium. It means how long it needs to reach the long-run equilibrium in the presence of shocks in the short run.

5. Empirical results

In this section, it is performed panel regression estimation assuming symmetry and asymmetry relationship between RER misalignments and real economic growth rate by applying panel ARDL and NARDL estimation.

[Table 1](#) exhibits the estimation results of PMG, MG and DFE for all countries. Applying the Hausman test, the efficiency of the PMG estimator is revealed over the other estimators,

	Pooled mean group		Mean group		Dynamic fixed effects	
	Coef.	Std. error	Coef.	Std. error	Coef.	Std. error
<i>Long-run coefficients</i>						
Mis_186	-1.9618***	0.4723	-0.7001***	2.7031	-1.1758*	0.6368
Pop	0.5380***	0.0860	0.4133	1.7159	0.4354***	0.1196
HK	0.4559***	0.0802	0.7704	0.6420	0.0776	0.0647
INF	-0.0862***	0.0118	-0.2322***	0.0662	-0.0242***	0.0048
OPEN	0.0138***	0.0052	0.0846***	0.0239	-0.0027	0.0094
UN	-0.0862**	0.0118	-1.4384**	0.6247	-0.0094	0.0404
<i>Error-correction coefficient</i>						
ECT (-1)	-0.8789***	0.0310	-1.1586***	0.0312	-0.8456***	0.0342
ΔMis186	-0.6686	2.1087	4.2609	2.7846	2.2195*	1.2480
ΔPop	0.4552	1.1303	1.7979	1.9106	-0.1361*	0.0751
ΔHK	0.4826	0.3827	-0.1593	0.6369	0.4796***	0.1044
ΔINF	0.0277	0.0273	0.1274***	0.0478	0.0015	0.0021
ΔOPEN	0.1143***	0.0178	0.0621***	0.0258	0.0554***	0.0119
Δ	-1.7488***	0.2946	-0.3973	0.6089	-1.3305***	0.0973
Intercept	-24.0796***	1.0813	-51.3916	44.0457	-0.7777	3.7228
BIC	9,799.67		9,865.45		9,980.21	
AIC	9,711.92		9,817.60		9,880.48	
Observations	2,566		2,566		2,566	
Hausman test			6.25 ⁽ⁱ⁾		8.96 ⁽ⁱⁱ⁾	
			(0.3953)		(0.5698)	

Notes: * ** and *** indicate significance at 10, 5 and 1%, respectively. ^aUnder the null hypothesis, PMG is more efficient estimation than MG; ^bPMG is more efficient estimation than DFE under the null hypothesis. In brackets are the associated *p*-values

Source: Authors' own elaboration

Panel ARDL
and panel
NARDL
approach

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Table 1.
Panel ARDL results
(Misalignment_186)

because it does not have statistically significant evidence to reject the null hypothesis of the homogeneity assumption on the regressors in the long term. In other words, the PMG is the most efficient estimator with respect to MG and DFE and for this reason, the interpretations are based on this method [11]. In particular, the RER misalignments have a negative but not significant effect on the short-run, nevertheless, a negative and highly significant impact on real economic growth rate is detected on the long-run.

As expected, analyzing the macroeconomic control variables, the human capital, the population growth and the degree of openness are the most important factors which positively contribute to higher economic growth rate in the long run. On the contrary, inflation rate along with unemployment rate are negatively related with the standard of living in the long term. As expected, a positive and highly significant effect on real economic growth is generated by the degree of openness and indirect effect is generated by unemployment rate in the short run. Furthermore, it can be concluded that any shock in the short run could achieve the long run equilibrium at a speed of 88% per year, given that the ECT is negative and statistically significant at 1% significance level. The same conclusion is achieved by Table 2 in which misalignments are measured considering 30 partners instead 186 analyzed. Therefore, these results are robust.

Attending to the asymmetric or non-linear panel ARDL and controlling for the usual macroeconomic explanatory factors on real growth, the results confirm that positive and negative shocks in the main variable do not produce the same impact. Table 3 shows the long-run and short-run coefficients along with the long-run and short-run symmetric test

Notes: *, ** and *** indicate significance at 10, 5 and 1%, respectively; ^aUnder the null hypothesis, PMG is more efficient estimation than MG; ^bPMG is more efficient estimation than DFE under the null hypothesis. In brackets are the associated *p*-values
Source: Authors' own elaboration

According to the Gross National Income (GNI) per capita, The World Bank classify the economies into four income groups: high income, upper-middle income, lower-middle income and low income. The next purpose of this study is to analyze whether there are differences in the asymmetric effect depending on the different income level economies. The main result is that the long-run symmetry test is strongly rejected laying special emphasis in the existence of asymmetric effects of misalignments on economic growth for the high, upper-middle and lower-middle and low-income economies in the long run. Specifically, an overvalued RER above its long-run sustainable equilibrium level erodes the economic activity, whereas

	Full sample (Mis_186)		Full sample (Mis_30)		Low income		Lower Middle income		Upper Middle income		High income	
	Coef.	Std. error	Coef.	Std. error	Coef.	Std. error	Coef.	Std. error	Coef.	Std. error	Coef.	Std. error
<i>Long-run coefficients</i>												
Mis186 ⁺	-3.7425***	1.4154	-5.2663***	1.4270	-10.8596***	2.4467	-5.8189**	2.5381	-9.5129***	3.7895	-6.4005***	2.4982
Mis186 ⁻	2.3422***	1.3059	4.2680***	1.3206	6.9833***	2.0317	3.3737**	2.5626	1.2553**	3.7862	3.9484**	2.1411
Pop	0.5986***	0.0818	0.5653***	0.0847	0.4946***	0.1172	1.3443***	0.2086	0.9297***	0.2769	0.1608*	0.2259
HK	0.3741***	0.0793	0.2916***	0.0789	0.1500***	0.1480	0.5043***	0.1268	1.1176***	0.2282	0.4281***	0.1425
INF	-0.0605***	0.0110	-0.0211***	0.0239	-0.0196***	0.0028	-0.0196***	0.0243	-0.1294***	0.0279	-0.0422***	0.0342
OPEN	0.0133***	0.0050	0.0084*	0.0048	0.0039	0.0074	0.0723***	0.0124	-0.0128	0.0099	0.0314***	0.0096
UN	-0.0684***	0.0247	-0.0711***	0.0242	-0.3007***	0.0571	-0.0503	0.0511	-0.1623***	0.0434	-0.1404***	0.0537
<i>Error-correction coefficient</i>												
ECT (-1)	-0.8787***	0.0324	-0.8894***	0.0323	-0.8561***	0.0765	-0.9238***	0.0584	-0.9585***	0.0520	-0.8422***	0.0740
Δ Mis186 ⁺	-3.5792	2.8218	-2.5530	3.0551	2.7302	7.3987	-6.6384	5.5552	-3.3182	5.0690	-2.8876	4.6343
Δ Mis186 ⁻	-0.5224	1.5495	-0.9148	1.6007	-0.3661	2.9128	3.7766*	2.0063	1.4035	2.1023	-5.7987	4.2656
Δ Pop	0.5804	1.1293	0.3646	1.1549	1.4042	2.3491	-3.0001	2.1592	3.2022	2.9509	0.5381	0.8188
Δ HK	0.4916	0.3889	0.5607	0.4070	1.2333**	0.6004	0.3228	0.4716	0.6644	1.0880	0.8052	0.6903
Δ INF	-0.0292	0.0277	0.0205	0.0280	-0.0055	0.0373	0.0408	0.0655	0.0543	0.0558	0.0486	0.0537
Δ OPEN	0.1089***	0.0175	0.1130***	0.0179	0.1132***	0.0305	0.1540***	0.0383	0.0934***	0.0356	0.0776***	0.0305
Δ UN	-1.7665***	0.2931	-1.7464***	0.2860	-2.2508***	0.7264	-1.7290***	0.3819	-1.8268***	0.4402	-1.1823*	0.6355
Intercept	-19.1761***	0.9153	-14.3291***	0.7031	-0.9639	1.2175	-33.4585**	2.4115	-67.8055**	4.2103	-23.7481**	2.4914
BIC	9,810.16		9,767.93		2,497.50		2,197.13		2,606.69		2,696.55	
AIC	9,710.48		9,668.25		2,422.06		2,122.41		2,529.94		2,619.18	
Log likelihood	-4,838.24		-4,817.13		-1,194.03		-1,044.21		-1,247.97		-1,292.59	
Observations	2,600		2,600		625		600		675		700	
<i>Symmetry tests</i>												
Long run symmetry test	5.43 (0.0198)		13.03 (0.0003)		17.77 (0.0000)		4.01 (0.0452)		2.30 (0.0132)		4.59 (0.0321)	
Short run symmetry test	1.16 (0.2809)		0.25 (0.6156)		0.22 (0.6389)		2.67 (0.1022)		1.13 (0.2887)		0.24 (0.6248)	
Notes: *, ** and *** indicate significance at 10, 5 and 1%, respectively. In brackets are the associated <i>p</i> -values												
Source: Authors' own elaboration												

Table 3.
Panel NARDL
results (full sample
and WB's income
classification)

deviations below its equilibrium is able to enhance the economic performance. These results are robust applying the International Monetary Fund income (IMF) 's classification [12]. Mbaye (2013) emphasizes that there are two channels through undervalued exchange rate can foster economic growth: "the capital accumulation channel" and "the total factor productivity growth channel". The former is related to the increment on capital stock motivated by undervaluation and the latter refers to the fact that productivity would rise given the shift in production to tradable sector due to its benefits are higher. On the contrary, deviations in either direction cannot lead any significant effect on economic growth regardless the income classification used, because the short-run symmetry test is not rejected.

6. Concluding remarks

One of the main contributions of this study related to previous research studies is that it focuses not only on the symmetric impact of deviations from the long-run sustainable RER equilibrium on real economic growth applying panel ARDL but also examines the asymmetric effects. This analysis is based on the largest sample of countries provided by Couharde *et al.* (2018), considering 104 economies during 1995–2022 period thank to the EQCHANGE database which applies the BEER approach to determine the equilibrium RER.

The results suggest that after controlling for the usual macroeconomic factors on economic growth such as human capital, population growth rate, inflation and unemployment, among others, the RER misalignments have a negative but not significant effect on the short-run, nevertheless, a negative and highly significant impact on real economic growth rate is detected on the long-run.

To distinguish whether overvaluation and undervaluation RER can suppose a different reaction on economic performance, the panel Non-linear ARDL is implemented based on Shin *et al.* (2014) specification. Notwithstanding the fact that the short-run symmetry tests are not able to be rejected, in the long-run the asymmetric relationship between RER misalignment and economic growth rate is supported considering all countries. Specifically, in the long run is detected that undervaluation can promote economic growth rate, rather than overvaluation which can harm the economic performance.

Based on these results, from the policy perspective, policymakers should advocate appropriate exchange rate policies to prevent large deviations from the equilibrium path. In other words, they should implement a proper policy to keep the exchange rate as close as possible to what fundamentals suggest. It is crucial to avoid long-lasting periods characterized by RER appreciations and in place adopting economic policies associated with higher competitiveness which most time it is linked to a more depreciated RER compared to its equilibrium level.

Finally, this study tries to bring to light whether there are differences in the asymmetric effect depending on the different income level economies. For this goal, it is considered the World Bank income classification which rank the economies into four income groups according to the GNI per capita: high income, upper-middle income, lower-middle income and low income. The main result is that the long-run symmetry test is strongly rejected laying special emphasis in the existence of asymmetric effects of misalignments on economic growth regardless the income group in the long run. Specifically, an overvalued RER above its long-run sustainable equilibrium level erodes the economic activity, whereas deviations below its equilibrium is able to enhance the economic performance. These results are robust applying also the IMF income's classification.

Notes

1. See Lee *et al.* (2008) for a recent survey on this topic.

2. It is called short-run equilibrium exchange rate for which macroeconomic factors are at their current setting once the random effects have been discounting. In other words, [Driver and Westaway \(2005\)](#) highlight that it is compatible with the current situation after ruling out the financial shocks.
3. In this case, the medium-run equilibrium exchange rate must be compatible with internal and external equilibrium.
4. According to [Driver and Westaway \(2005\)](#), once the stock-flow equilibrium is reached for all agents in the economy and therefore capital movements are not justified, the long-run equilibrium is achieved.
5. This estimator does not impose the same time trend for all countries and requires only that all economies within a group follow the same time pattern over time.
6. This study considers the following countries: Algeria, Austria, Bahrain, Barbados, Belarus, Belgium, Belize, Bolivia, Brazil, Bulgaria, Burkina Faso, Cape Verde, Cameroon, Canada, Chile, China, Colombia, Comoros, Congo Democratic Republic, Congo Republic, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, Estonia, Fiji, Finland, France, Gabon, Gambia, Germany, Ghana, Greece, Guatemala, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea Republic, Kyrgyz Republic, Latvia, Lithuania, Madagascar, Malaysia, Mali, Malta, Mauritius, Mexico, Moldova, Morocco, Namibia, Nepal, Netherlands, New Zealand, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Rwanda, Saudi Arabia, Senegal, Seychelles, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Tanzania, Thailand, Tunisia, Turkey, Uganda, Ukraine, the UK, the USA and Uruguay.
7. A negative sign of the misalignment means an undervaluation which implies that the real exchange rate must appreciate to converge toward its long-run equilibrium value. Moreover, the EQCHANGE database offers methodological options in terms of number of trade partners and weighting schemes. For this reason, given that the effective exchange rates indices are computed for two panels of trade partners (186 and top 30), this study also consider real exchange rate misalignment with 186 or 30 trading partners as a robustness check.
8. The panel unit root tests ruled out the existence of I(2) variables (these results are available upon request).
9. For instance, testing whether there exists significant difference between PMG and MG, if the null hypothesis (difference between PMG and MG estimations is not significant) is not rejected, it can be concluded that it should be apply PMG estimator since it is efficient, not only consistent. In the opposite case, in which the null hypothesis is rejected, this means that there is significant difference between MG and PMG which translate into the fact that it should be apply the average estimator. In other words, according to [Pesaran et al. \(1999\)](#), under the null hypothesis, homogeneity of long-term coefficients is assumed versus heterogeneity of the long-run coefficients in the alternative hypothesis.
10. For more details, see for instance [Bakry et al. \(2023\)](#), [Yuldoshboy et al. \(2023\)](#) or [Rafindadi and Yosuf \(2013\)](#), among others.
11. The other estimators (MG and DFE) offer qualitatively the same results in terms of the estimated sign and significance, especially in the long run, although since the PMG is more efficient than both of them the PMG estimations are considered the most appropriate.
12. These results are available from the author upon request.

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Further reading

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Appendix

Panel ARDL
and panel
NARDL
approach

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Variable	Description	Source
Real economic growth rate (g)	Growth rate of real gross domestic product (annual %)	World Development Indicators (World Bank)
Population growth rate (POPGR)	Population growth (annual %). Annual population growth rate for year t is the exponential rate of growth of midyear population from year $t-1$ to t	World Development Indicators (World Bank)
Inflation rate (INF)	Inflation measured by the consumer price index (annual %)	World Development Indicators (World Bank)
Human capital (HK)	Human capital using life expectancy at birth (years) as a proxy. This variable is considered by World Bank to elaborate the Human Capital Index, however its data availability is scarce to the database, so for this reason I use life expectancy at birth	World Development Indicators (World Bank)
Degree of openness (OPEN)	It is the sum of exports and imports of goods and services (% of GDP)	World Development Indicators (World Bank)
Misalignment (MIS_186)	It is the difference between the real effective exchange rates and their equilibrium real effective exchange rates which is calculated against 186 trading partners based on the behavioral equilibrium exchange rate (BEER) approach	Couharde <i>et al.</i> (2018)
Misalignment (MIS_30)	It is the difference between the real effective exchange rates and their equilibrium real effective exchange rates which is calculated against 30 trading partners based on the behavioral equilibrium exchange rate (BEER) approach	Couharde <i>et al.</i> (2018)

Table A1.
Definition of the
explanatory
variables in the panel
regression and data
sources

Source: Authors' own elaboration

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