Chapter 12
Testing the Balassa Hypothesis in Low- and Middle-Income Countries

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Abstract This study analyses the long-run relationship between economic growth and real exchange rate for a group of 15 low- and middle-income countries for the period 1950–2011. Co-integration between growth and exchange rate is established by means of an augmented pooled mean group estimation method (which controls for heterogeneity and cross-sectional dependence). Unlike previous studies, cross-sectional dependence is accounted for which implies that the productivity effect of the Balassa term is expected to be estimated consistently and without bias. Moreover, our results indicate that the effect of the Balassa term depends more on the income group (level of per capita income) than the rate of economic growth. In general, the power of the effect is stronger for higher income countries in the long run. The study clearly indicates that the Balassa hypothesis holds for middle-income countries, while this is not the case for low-income countries. However, fiscal policy and exchange rate volatility rather clearly explain the variations in the real exchange rate.

Keywords Productivity · Growth · Real exchange rate · Balassa hypothesis · Panel data

12.1 Introduction

The Balassa hypothesis tests the impact of productivity growth on the real exchange rate. It states that for a growing economy, the real exchange rate is expected to appreciate in the long run. Our study is based on a finding by Baylie (2008). The real effective exchange rate is an important policy parameter and among the most determining factors of growth in Ethiopia (Baylie 2008). Though Baylie recommends depreciation of the domestic currency for promoting economic growth in the short run, the author discovered that it is healthier to allow appreciation in the long

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run to encourage sustainable economic growth. Hence, he provided (an exchange rate) policy recommendations which promote appreciation of the domestic currency for sustainable growth in the long run.

Both depreciation and appreciation are not welcomed effortlessly by the monetary authority. As suggested by Baylie (2008), depreciation in particular is not favored by the monetary authority as it increases the burden on the importing capacity for a developing country like Ethiopia. In contrast, by the time it is recommended that a country allows appreciation, all advantages of depreciation have been exhausted while prospects of appreciation are pending. Depreciation may initially help promote exports and generate sufficient foreign earnings. Once this objective is met, there arises a need to promote imports of capital goods by allowing appreciation to establish import-substituting industries to transform the economy. The only issue to consider in this case is the 'timing' of switching policy. The solution to this dilemma is provided by the Balassa hypothesis.

At the time when the Balassa hypothesis holds in a particular economy, depreciation is not gainful. In short, it states that if economic growth is accompanied in appreciation of the domestic currency (Balassa hypothesis), the monetary authority should not constrain the appreciation for the simple reason that it may discourage exports. If economic growth by itself brings appreciation, it can be sustained as the latter further puts inertia on the former. There is a possibility of one driving the other in the long run when the hypothesis holds.

In short, the hypothesis states that the impact of growth on the exchange rate is positive; that is, there is appreciation of the domestic currency. The main purpose of our study, therefore, is to show whether this analysis can be extended to a group of low- and middle-income countries on various continents. While there is evidence in favor of the hypothesis, there are also some anti-Balassa results in some studies. The negative results could be associated with different reasons specific to each study.

Tica and Druzic's (2006) survey shows that since its discovery in 1964, the hypothesis has been tested 58 times in 98 countries in time series or panel analyses and in 142 countries in cross-country analyses. In these analyzed estimates, country-specific Balassa hypothesis coefficients have been estimated 164 times. The first empirical test of the theory was carried out by Balassa (1964) himself. Kravis and (1983) and Bhagwati (1984) were also among the forerunners. The conclusions from all these studies confirm the difficulty in ignoring the significance of the hypothesis in general. The strongest empirical support in favor of the relationship between productivity and exchange rate is found in cross-sectional and panel empirical studies.

Chuoudhri and Kahn (2004) found evidence of Balassa–Samuelson effects in a panel of 16 developing countries. They found the traded and non-traded productivity differential to be a significant determinant of the relative prices of non-traded goods, and the relative price in turn exerted a significant effect on the real exchange rate. Similarly, Guo and Hall (2010) and Jabeen et al. (2011) also show that productivity differences directly explained changes in the real exchange rate by using the Johansen co-integration approach for China and Pakistan, respectively.

A positive relationship between productivity and the real exchange rate is not, however, a common fact in all studies. There are a number of studies that show anti-Balassa results. Drine and Rault (2002, 2004), for example, tested the Balassa hypothesis for 20 Latin American (middle-income) and six Asian (low-income) developing countries separately. They applied Pedroni's co-integration techniques in both the studies. Though they were able to find evidence for the hypothesis in the first study for middle-income countries, they failed to replicate the result in the second study for low-income countries. The reason given for the failure is a break in the relationship between productivity and relative price, one of the assumptions of the hypothesis. Asea and Mendoza (1994a, b), Harberger (2003), Hassan (2011), Isard and Symansky (1996), Miyajima (2005), and Wilson (2010) also found anti-Balassa results in their studies on developing countries.

The study that comes the closest to our study is Chuah's (2012). This study found mixed results from a panel study of 142 developing (middle- and low-income) and developed (high-income) countries. The estimation of the fixed effect model showed that productivity growth in developed economies resulted in real appreciation of domestic currencies, while the relationship was nonlinear in developing economies. In the latter group, the real exchange rate initially depreciated and then appreciated after per capita income jumped to a higher level (above $2200), the main reason being a level of development.

Our study makes three improvements over Chuah's (2012) study in terms of data quality, methodology, and variables. First, our study uses data from the latest version of the Penn World Table (PWT), version 8. Data from this version address shortcomings associated with previous versions. In particularly, Chuah (2012) used an expenditure-based measure of GDP from version 7, while our study uses the output-based measure of GDP from version 8. Feenstra et al. (2013) suggested using the second measure for studies interested in an economy's productive capacity. Second, our study accounts for cross-sectional dependence and heterogeneity by applying the common correlated effect approach of Pesaran (2013) and pooled mean group estimation, respectively. Third, our study controls for important supply- and demand-side factors.

The remaining paper is organized as follows. Section 12.2 provides the theoretical background of the hypothesis. Section 12.3 discusses the methodology. The findings are presented in Sects. 12.4 and 12.5 gives the conclusion and policy implications derived from the findings.

12.2 Theoretical Framework of the Model: The Balassa–Samuelson Hypothesis[1]

The Balassa hypothesis demonstrates the relationship between exchange rate, purchasing power parity (PPP), and inter-country income comparisons in general. The hypothesis emanates from the PPP theory. It explains the reason why the PPP theory of exchange rate is imperfect. In the absence of all frictions, the prices of a common basket of goods in two countries measured in the same currency should be the same at all times for absolute PPP to hold, that is, $P/\varepsilon P^{*} = 1$. The Balassa–Samuelson effect, first formulated by Harrod in 1934 and later by Balassa and Samuelson in 1964 separately, says that distortions in purchasing power parity are the result of international differences in relative productivity growth between the tradable goods sector (mainly manufacturing and agriculture) and the non-tradable goods sector (mainly services) (Herberger 2003; Tica and Druzic 2006). In contrast to the PPP theory, price levels are higher in rich countries than poor ones when converted to a common currency. This may be associated with higher productivity growth in the tradable sector in rich countries (Rogoff 1996).

A nation's prosperity is mainly associated with productivity growth in the tradable goods sector. This has an effect of reducing costs in the same sector and increasing real wages in the economy and puts an upward pressure on relative prices of non-tradable goods where productivity has not grown by the same magnitude. This distorts the PPP relationship and results in appreciation of the real exchange rate. The same effect holds true across nations. A more prosperous nation experiences higher productivity growth in the tradable goods sector than a poor nation. Thus, an increase in the prices of non-tradable goods will be higher in a rich country. As a result, a rich country's real exchange will appreciate compared to a poor's nation currency (Asea and Corden 1994a, b).

The Balassa hypothesis may be tested in two forms: external and internal versions. The external version analyzes the impact of productivity growth on the real exchange rate. The internal version analyzes the impact of productivity on relative prices. If one fails to prove a relationship between productivity and the real exchange rate, it is most likely that the hypothesis is functioning through the internal version; that is, the relationship between relative prices and the real exchange rate or relative prices and productivity growth should be tested. The main objective of our study is to examine the validity of the external version of the hypothesis.

The core idea of the Balassa hypothesis is related to the concept of convergence (beta-β-convergence) in growth theories. Both describe features of developing economies. Convergence between economies may be roughly defined as the

[1]Though the idea has been mentioned by several authors (like Ricardo 1911; Harrod 1933; Viner 1937), the contribution of other authors is not as bold as Paul A. Samuelson and Bela Balassa and hence the name Balassa-Samuelson hypothesis (Tica and Druzic 2006). The term 'Balassa hypothesis' is used in this study.

tendency for levels of per capita income or productivity to equalize over time. Growth theories[2] state that countries with low capital-to-labor ratios (high marginal productivity of capital) in general and with advantages of elements such as innovation ability, human capital formation, technical progress, and economies to scale in particular grow faster than others (Kumo 2011; Orlik 2003; Soukiazis 1995).

According to these growth theories, there is a tendency for developing countries to grow faster than developed countries if some conditions in particular are satisfied. Given that the Balassa hypothesis is related to the impact of economic (productivity) growth on the real exchange rate, there should be a greater probability of finding evidence for the hypothesis in converging economies as compared to developed ones. The convergence process, thus, may be used as a criterion for identifying candidate countries for a sample study.

12.3 Methodology

12.3.1 Data Type and Collection Methods

Data for all countries and variables are from Penn World Table for the period 1950–2011. The variables include exchange rate, per capita GDP, and government expenditure. While the choice of the study period for each country depends on data availability, countries are selected on the basis of the convergence criterion which suggests that the fastest growing economies are mainly the developing economies.

According to IMF's World Economic Outlook Report (2015), all 15 countries in our sample are developing countries. However, for comparison purposes, the sample is divided into two categories on the basis of the size of economies (relative GDP). The first group represents the top five largest economies in the sample—BRICS (Brazil, Russia, India, China, and South Africa). They are from the (upper) middle-income countries' category (except India) which together nearly represent 90% of the US economy. The second group consists of 10 low-income countries (Angola, Ethiopia, Ghana, Indonesia, Kenya, Nigeria, the Philippines, Rwanda, Tanzania, and Uganda). Lower middle-income countries (with per capita income lower than $4125) are included in the second group in our sample.

[2]There are three main theoretical approaches to explain the convergence phenomenon: the neoclassical approach, endogenous growth theory, and demand-orientated approach. While (absolute) convergence is the inherent nature of diminishing returns to reproducible capital in the first approach, it is conditional on different factors and elements such as innovation ability, human capital formation, technical progress, and economies to scale in the second and third approaches (Soukiazis 1995).

12.3.2 Model Specification

The original Balassa model was designed for a fully employed small open economy; a $2 \times 2 \times 2$ system (two countries, two commodities, two factors); an inter-sector mobile labor (scarce factor) and inter-nation mobile capital; law of one price for factors within a nation and for tradables across nations; a constant return to scale production frontier; perfect competition in both markets (goods and factors); neural technical progress; and constant terms of trade (Podkaminer 2003).

A derivation of the Balassa–Samuelson model may be considered as a three-stage process. The first is to derive the relationship between the productivity differential and relative price. The second is to derive the relationship between relative price and exchange rate. The third is to derive the relationship between productivity differential and exchange rate.

STEP 1: The original Balassa–Samuelson model is framed on the basis of the traditional Ricardian trade model (Asea and Corden 1994a, b). It is a supply-side model defined by constant return to scale Cobb-Douglas style production functions in two sectors as (Podkaminer 2003):

$$Y_T = A_T L_T^{\alpha} K_T^{1-\alpha} \tag{12.1}$$

$$Y_N = A_N L_N^{\beta} K_N^{1-\beta} \tag{12.2}$$

where T and N refer to traded and non-traded sectors, and α and β represent the share of labor in each sector, respectively, with $\beta \geq \alpha$.

In a perfectly competitive market, factor prices must equal their respective value of marginal products at equilibrium for both sectors:

$$P_T A_T \alpha \left(\frac{K_T}{L_T}\right)^{1-\alpha} = w \tag{12.3}$$

$$P_T A_T (1-\alpha) \left(\frac{K_T}{L_T}\right)^{-\alpha} = r \tag{12.4}$$

$$P_N A_N \beta \left(\frac{K_N}{L_N}\right)^{1-\beta} = w \tag{12.5}$$

$$P_N A_N (1-\beta) \left(\frac{K_N}{L_N}\right)^{-\beta} = r \tag{12.6}$$

Combing the two factor markets for each sector independently and taking the logarithm of both sides for each equation yields:

$$\log(P_T) = (1-\alpha)\log(\mathrm{r}) - (1-\alpha)\log(1-\alpha) + \alpha\log(\mathrm{w}) - \log(A_T) \quad (12.7)$$

$$\log(P_N) = (1-\beta)\log(\mathrm{r}) - (1-\beta)\log(1-\beta) + \beta\log(\mathrm{w}) - \log(A_N) \quad (12.8)$$

Recalling the assumption that price of tradables (*numeraire*) and interest rate (not technology) are the same across boundaries, differentiation of the above with respect to time yields:

$$\frac{\left(\frac{\mathrm{d}P_T(\tau)}{\mathrm{d}\tau}\right)}{P_T(\tau)} = 0 = \frac{\alpha\left(\frac{\mathrm{dw}(\tau)}{\mathrm{d}\tau}\right)}{\mathrm{w}(\tau)} - \frac{\left(\frac{\mathrm{d}A_T(\tau)}{\mathrm{d}\tau}\right)}{A_T(\tau)} \quad (12.9)$$

$$\frac{\left(\frac{\mathrm{d}P_N(\tau)}{\mathrm{d}\tau}\right)}{P_N(\tau)} = \frac{\beta\left(\frac{\mathrm{dw}(\tau)}{\mathrm{d}\tau}\right)}{\mathrm{w}(\tau)} - \frac{\left(\frac{\mathrm{d}A_N(\tau)}{\mathrm{d}\tau}\right)}{A_N(\tau)} \quad (12.10)$$

Substituting Eq. (12.9) into Eq. (12.10) helps define the relative price of non-tradables in terms of productivity differentials for home and foreign country ($\hat{A}$ represents growth rate):

$$\frac{\left(\frac{\mathrm{d}P_N(\tau)}{\mathrm{d}\tau}\right)}{P_N(\tau)} = \frac{\beta}{\alpha}\frac{\left(\frac{\mathrm{d}A_T(\tau)}{\mathrm{d}\tau}\right)}{A_T(\tau)} - \frac{\left(\frac{\mathrm{d}A_N(\tau)}{\mathrm{d}\tau}\right)}{A_N(\tau)} \quad (12.11)$$

$$\hat{p}_N = \left(\frac{\beta}{\alpha}\right)\hat{A}_T - \hat{A}_N \quad (12.12)$$

$$\hat{p}_N^* = \left(\frac{\beta}{\alpha}\right)^* \hat{A}_T^* - \hat{A}_N^* \quad (12.13)$$

The difference between Eqs. (12.12) and (12.13) defines price differentials across countries:

$$\hat{p}_N - \hat{p}_N^* = \left[\left(\frac{\beta}{\alpha}\right)\hat{A}_T - \hat{A}_N\right] - \left[\left(\frac{\beta}{\alpha}\right)^* \hat{A}_T^* - \hat{A}_N^*\right] \quad (12.14)$$

This means that the price differential between sectors and across countries can be explained by productivity differentials between sectors and across nations.

STEP 2: We follow Ahn (2009) to link the exchange rate and productivity differential through the price index. The real exchange rate is defined in a log-linear form as (increase shows appreciation):

$$\begin{aligned} Q &= P/\varepsilon P^* \\ q &= p - e - p^* \end{aligned} \tag{12.15}$$

Price indices are defined as weighted averages of prices in tradable and non-tradable sectors in both domestic and foreign markets:

$$P = P_N^{\delta} P_T^{1-\delta} \quad \text{and} \quad P^* = P_N^{*\theta} P_T^{*(1-\theta)}$$

In log-linear form:

$$p = \delta p_N + (1-\delta) p_T \tag{12.16}$$

$$p^* = \theta p_N^* + (1-\theta) p_T^* \tag{12.17}$$

δ and θ represent the share of non-tradables in the consumer basket at home and abroad, respectively. Substituting Eqs. (12.16) and (12.17) into Eq. (12.15) helps define the real exchange rate as a function of price differential:

$$q = \left[\delta(p_N - p_T) - \theta\left(p_N^* - p_T^*\right)\right] + p_T - e - p_T^* \tag{12.18}$$

Since $p_T = e + p_T^*$ (law of one price for tradables), Eq. (12.18) will be:

$$q = \left[\delta(p_N - p_T) - \theta\left(p_N^* - p_T^*\right)\right] \tag{12.19}$$

STEP 3: Eq. (12.19) defines the real exchange rate as a function of the relative price differential between countries. Substituting Eq. (12.14) into Eq. (12.19) helps define the exchange rate as a function of the productivity differential. We assume that the share of non-tradables in the foreign consumer basket (θ) is the same as home (δ). Hence:

$$\hat{q} = \delta\left(\left[\left(\frac{\beta}{\alpha}\right)\hat{A}_T - \hat{A}_N\right] - \left(\frac{\beta}{\alpha}\right)^* \hat{A}_T^* - \hat{A}_N^*\right) \tag{12.20}$$

If the home market grows faster than the foreign one, then the domestic currency appreciates and vice versa.

In order to avoid the assumption of neutral technical progress, we introduced an intercept in the econometric model (Kohler 1998). We also introduced demand-side factors as the Balassa model is not complete by itself (De Gregorio and Wolf 1994).

Therefore, the econometric model used in our study is derived from Eq. (12.20) (see Annexure 1 for derivation). It includes two more factors (demand and supply sides):

$$(\ln Q)_{it} = \alpha_i + \beta_{1i}\ln(Y/Y^*)_{it} + \beta_{2i}\ln(G/G^*)_{it} + \beta_{3i}\mathrm{vol}(E)_{it} + e_{it} \tag{12.21}$$

where Q and E are real and nominal exchange rates.

$(\ln Q)_{it}$ is log of the real exchange rate of each country measured against the US dollar. Increase implies appreciation. '*it*' refers to *i*th country in period *t*. $\ln(Y/Y^*)_{it}$ is log of real GDP per capita relative to the US economy. It is a proxy for the productivity growth differential in each country. The Balassa hypothesis declares that productivity growth has a positive impact on the real exchange rate.

$\ln(G/G^*)_{it}$ is log of relative real government expenditure. It is a proxy for fiscal policy. Kohler (1998) argues that government expenditure accounts for demand shifts toward non-tradables which results in appreciation of the real exchange rate in the short run. In the long run, it does not have an impact unless financed by distortionary taxes. Distortionary taxes reduce real wages and relative prices of non-tradables, and this leads to the depreciation of the real exchange rate in the long run.

$vol(E)_{it}$ is exchange rate volatility measured as the absolute value of percentage change in the nominal exchange rate. It is a supply-side factor. The impact of volatility on the real exchange rate may be positive or negative; it depends on the time horizon and type of regime. Kohler (1998) shows that the impact of volatility is smaller in the short run and in poor countries due to greater nominal rigidities. In relatively fixed exchange rate regimes (mainly poor economies), movements in nominal exchange rate are restricted. In this case, growing economies experience inflation in both sectors with relative prices of non-tradables falling. This leads to a depreciation of the real exchange rate. In contrast, there is smaller rigidity in freely floating exchange rate regimes (mainly rich economies). With productivity growth, inflation in the non-tradable sector is balanced by deflation in the tradable sector (as a result of a nominal appreciation). Relative prices of non-tradables increase, and this leads to the real exchange rate appreciation.

12.3.3 Cross-sectional Dependence Test

Cross-sectional dependence is a problem associated with panel data that mixes information from different cross sections and leads to a difficulty in interpreting the individual effects of each section. It may be caused by socioeconomic network effects, spatial effects, or the influence of a dominant unit or common unobserved factors. When the problem is ignored, estimates are badly biased and the tests may be misleading (Shin 2014). Factor models are used to filter out cross-sectional dependence due to unobserved common factors. We used the Pesaran cross-sectional independence test in our study as it is the most powerful test (Eberhardt 2011). It is given by CD (cross-sectional dependence) which is $N(0,1)$.

$$CD = \sqrt{\left(\frac{2}{N(N-1)}\right)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\sqrt{T_{ij}}\hat{\rho}_{ij}\right) \tag{12.22}$$

12.3.4 Panel Unit Root Tests

Six types of panel unit root tests are available: Levin-Lin-Chu (LLC), Hariss-Tzavalis (HT), Breitung, Im-Pesaran-Shin (IPS), Fisher type, and Hadri LM. The panel data for our study are unbalanced, and N is fixed and smaller relative to T. It also assumes that the auto-regressive parameter, ρ, is panel specific. Hence, the candidate panel unit root tests that fit these criteria are the IPS and Fisher-type tests. Another advantage of these tests is that they can be used to test a series which is not serially independent across cross sections.

(a) **The Im–Pesaran–Shin test**

The following is a panel unit root test as proposed by Pesaran (2007) which accounts for cross-sectional dependence. The standard Augmented Dickey–Fuller (ADF) regressions are further augmented with cross-sectional averages of lagged levels and first differences of individual series. Let $y_{i,t}$ be the observation on the ith cross-sectional unit at time t, and suppose that it is generated according to the simple dynamic linear heterogeneous panel data model:

$$y_{i,t} = (1-\phi_i)\mu_i + \phi_i y_{i,t-1} + e_{it} \tag{12.23}$$

$$\text{where} \quad e_{it} = \gamma_i f_t + \varepsilon_{it};\, i = 1\ldots N; \quad t = 1\ldots T.$$

The initial value, $y_{i,0}$, has a given density function with a finite mean and variance, and the error term, e_{it}, has a single-factor structure. f_t is the unobserved common effect, and ε_{it} is an individual-specific (idiosyncratic) error. The unit root hypothesis of interest is expressed as:

$$H_0\colon \phi_i = 1 \text{ for all } i \text{ against the possibly heterogeneous alternatives}$$

$$H_1\colon \phi_i < 1, i = 1, 2, \ldots N_1, \phi_i = 1, i = N_1 + 1, N_2 + 2, \ldots, N$$

N_1/N, a fraction of the individual processes that are stationary, is nonzero and tends to the fixed value δ such that $0 < \delta < 1$ as $N \to \infty$. This condition is necessary for the consistency of unit root tests.

(b) **Fisher-type tests**

Maddala and Wu (1999) provide a Fisher-type panel unit root test which accounts for cross-sectional dependence. Like the IPS test, the Fisher-type test is a way of combining evidence on the unit root hypothesis from the N unit root tests performed on N cross-sectional units. The fisher-type test makes this approach more explicit. It combines p values from panel-specific unit root tests using four methods. Three of the methods differ in whether they use inverse chi-square, inverse-normal, or inverse-logit transformation of p values, and the fourth is a modification of the inverse Chi-square transformation. The inverse-normal Z statistic offers the best trade-off between size and power.

Let G_{i,T_i} be a unit root test statistic for the *ith* group, and assume that as $T_i \to \infty$, then $G_{i,T_i} = \; > G_i$. Let p_i be the p value of a unit root test for cross section i, that is, $\mathrm{p_i} = 1 - \mathrm{F}(G_{i,T_i})$, where $F(\cdot)$ is the distribution function of random variable G_i. In Chen (2013), the Fisher-type test is given as:

$$P = -2\sum_{i=1}^{N} \ln p_i \tag{12.24}$$

P is distributed as χ^2 with $2N$ degrees of freedom as $T \to \infty$ for all N. p_i value closer to zero ($\ln p_i$ closer to $-\infty$) implies large value of P, and then, the null hypothesis of the existing panel unit root is rejected. p_i value closer to 1 ($\ln p_i$ closer to zero) implies that the panel unit root does exist.

12.3.5 Panel Co-integration Tests

There are two possibilities to deal with nonstationary variables in a given model after the stationarity test. First, to test whether the linear combination of nonstationary variables is stationary by using the co-integration test. If they are co-integrated, then we proceed to a long-run analysis with the nonstationary variables. Otherwise, we difference the stationary variables for a short-run analysis.

Engle and Granger (1987) noted that 'a test for co-integration can be thought as a pretest to avoid "spurious regression" situations.' If regression of one nonstationary variable over another nonstationary variable yields a stationary series, it is known as a co-integrating regression and the slope parameter in such a regression is known as a co-integrating parameter.

We employ a residual-based Pedroni co-integration test which is simply a unit root test applied to the residuals obtained from a co-integrating regression. If variables are co-integrated, then the residuals should be $I(0)$. If the variables are not co-integrated, then the residuals are not $I(0)$ (Pedroni 2004). The test allows for heterogeneous intercepts and trend coefficients across cross sections. It is based on a residual obtained from a regression:

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i}x_{1i,t} + \beta_{2i}x_{2i,t} + \cdots + \beta_{Mi}x_{Mi,t} + e_{i,t} \tag{12.25}$$

for $t = 1, \ldots, T$; $i = 1, \ldots, M$; $m = 1, \ldots, M$; and x and y are assumed to be integrated of order 1, $I(1)$. The parameters α_i and δ_i are individual and trend effects. Pedroni proposes seven different statistics to test panel data co-integration: panel v-statistic, panel rho-statistic, panel PP-statistic, panel ADF-statistic, group rho-statistic, group PP-statistic, and group ADF-statistic. The first four are based on pooling or the 'within' dimension, and the last three are based on the 'between' dimension. The null hypothesis is no co-integration for both. However, the alternative hypothesis is $\rho_i = \rho < 1$ for all i in the former, and it is $\rho_i < 1$ for all i in the latter (Pedroni 2004).

12.3.6 Estimation Method

The choice of estimation method mainly depends on the results of preliminary tests of data. In our case, we looked for a method that helped an analysis of nonstationary variables which were co-integrated. We considered a method that provides estimated coefficients for individual countries. Therefore, we are not supposed to consider traditional estimators such as Pooled OLS, fixed effect, and first-difference OLS models which assume homogeneous technology parameters and factor loadings (common slope). Eberhardt et al. (2011) and others have suggested using the *pooled mean group estimation* method for analyzing nonstationary variables which are co-integrated in a long panel setting. This method is helpful for heterogeneous technology parameters and factor loadings in particular.

The pooled mean group (PMG) estimator involves averaging and pooling. It restricts long-run coefficients to be homogenous over cross sections, but allows for heterogeneity in intercepts, short-run coefficients (including the speed of adjustment), and error variances. It is argued that country heterogeneity is particularly relevant in short-run relationships given that countries may be affected by over-lending, borrowing constraints and financial crises in short-time horizons. Homogenous long-run relationships may be assumed for reasons such as budget or solvency constraints, arbitrage conditions, or common technologies (Cavalcanti et al. 2011).

The relationship in pooled mean group estimation may be defined by an ARDL model as:

$$\Delta q_{it} = \alpha_i + \beta_i \Delta x_{it} + \lambda_i \left(q_{i,t-1} - \theta x_{i,t-1} \right) + e_{it} \tag{12.26}$$

where $q = lnQ$ and $x = lnX$. β_i are short-run parameters, which like σ_i^2 differ across countries. Error correction term¸ λ_i, also differs across i, long-run parameter; θ, however, is constant across the groups. This estimator is quite appealing when studying small sets of arguably ‘similar’ countries. In $I(1)$ panels, this estimator allows for a mix of co-integration ($\lambda_i > 0$) and non-co-integration ($\lambda_i = 0$). $x_{i,t}$ represents the set of explanatory variables defined in Eq. (12.21).

To account for cross-sectional dependence which may result from any common unobserved factor incorporated in the error term, we follow Pesaran’s (2013) common correlated effect approach. Unlike de-meaning, the approach handles multiple factors which can be correlated with regressors and serial correlation in errors and lagged dependent variables (Shin 2014). It does not require prior knowledge of the number of unobserved common factors and can be applied to dynamic panels with heterogeneous coefficients and weakly exogenous regressors (Pesaran 2013). The procedure consists of approximating the linear combinations of unobserved common factors by cross-sectional averages of the dependent and explanatory variables and then running standard panel regressions augmented with these cross-sectional averages.

The PMG estimator for a cross-sectionally dependent series may be explicitly defined as:

$$\Delta q_{it} = \alpha_i + \beta_i \Delta x_{it} + \lambda_i \left(q_{i,t-1} - \theta x_{i,t-1} \right) + \gamma_{it} f_t + \varepsilon_{it} \tag{12.27}$$

$$\text{where } \gamma_i' f_t + \varepsilon_{it} = e_{it}$$

f_t is a vector of unobserved common shocks which captures the source of error term dependencies across countries. It may be stationary or nonstationary. The impacts of these factors on each country are governed by the idiosyncratic loadings in γ_{it}. The individual-specific errors, ε_{it}, are distributed independently across i and t; they are not correlated with the unobserved common factors or the regressors; and they have zero mean, variance greater than zero, and finite fourth moments (Cavalcanti et al. 2011). The augmented pooled mean group estimator is, therefore, defined by substituting cross-sectional averages for the unobserved common factors, f_t.

$$\Delta q_{it} = \alpha_i + \beta_i \Delta x_{it} + \lambda_i \left(q_{i,t-1} - \theta x_{i,t-1} \right) + \frac{1}{N} \sum_{l=1}^{PT} \delta \bar{z}_{w,t-l} + \varepsilon_{it} \tag{12.28}$$

where $\bar{z}_{w,t}$ represents a set of cross-sectional averages of the dependent and independent variables and their lagged values which approximate/proxy the unobserved common factors (f_t). The focus of this estimator is on obtaining consistent estimates of parameters related to observable variables, while the estimated coefficients on cross-sectionally averaged variables are not interpretable in a meaningful way: They are merely present to alter the biasing impact of unobservable common factors (Eberhardt 2012).

12.3.7 Error Correction Mechanism (ECM)

If two/more variables are co-integrated or prove to have a long-run relationship, then one needs to go for an error correction mechanism. The error correction mechanism (ECM) is a method used to correct any short-run deviations of variables from their long-run equilibrium; that is, it corrects for short-run disequilibrium. An important theorem, the Granger representation theorem, states that if two variables Y and X are co-integrated, then the long-term or equilibrium relationship that exists between the two can be expressed as ECM (Engle and Granger 1987). This means that one shall go for the construction of an error correction model if the two variables are co-integrated. ECM is given as follows in Bhattarai (2011) for ARDL (1,1) with $\beta_i = 0$:

$$q_{it} = \alpha_i + \gamma_i q_{it-1} + \beta_i x_{it} + \theta_i x_{i,t-1} + \varepsilon_{it}$$

$$\Delta q_{it} = \alpha_i + \beta_i \Delta x_{it} + \lambda_i u_{i,t-1} + \varepsilon_{it} \tag{12.29}$$

Δ denotes the first-difference operator, ε_{it} is a random error term, and $u_{i,t-1} = \left(q_{i,t-1} - \theta x_{i,t-1}\right)$ is one-period lagged value of error term from a co-integrating regression.

This ECM equation states that δq_{it} depends on δx_{it} and also on the equilibrium error term. If the error term is nonzero, the model is out of equilibrium. Suppose δx_{it} is zero (Bhattarai 2011) and $u_{i,t-1}$ is positive, it means q_{it-1} is too high (above) to be in equilibrium. Since λ_i is expected to be negative, the term $\lambda_i u_{i,t-1}$ is negative, and therefore, δq_{it} will be negative to restore equilibrium. That is, if q_{it} is above its equilibrium value, it will start falling in the next period to correct the equilibrium error. Similarly, if $u_{i,t-1}$ is negative (i.e., q_{it} is below its equilibrium value), $\lambda_i u_{i,t-1}$ will be positive, which causes δq_{it} to be positive, leading q_{it} to rise in the next period. The absolute value of λ_i determines how quickly the equilibrium is restored (Engle and Granger 1987).

12.4 Empirical Results

12.4.1 Test Results

This analysis begins by performing different econometric tests. Since not all unit roots provide the appropriate results, a cross-sectional independence test was performed to decide the type of panel unit root test to be considered. Using the Pesaran CD test, and possibly all other tests, the null hypothesis of cross-sectional independence was rejected for the original data. Hence, the series for our data was initially cross-sectionally dependent. However, after the data were augmented for cross-sectional averages to eliminate unobserved common factors, the Pesaran CD test, and possibly two other tests, failed to reject the null hypothesis of cross-sectional independence. The test results are given in Annexure 2.

IPS and Fisher-type tests are panel unit root tests which account for cross-sectional dependence. The results of the tests with different assumptions are given in Annexure 2. All the variables are nonstationary at the 1% level of significance.

The next step is to test for co-integration—whether there is a long-run relation between our nonstationary variables. The test for co-integration is residual based. We used two Pedroni type tests (ADF and PP tests) and the IPS test. In all the cases, we strongly reject the null hypothesis of no co-integration for both types of models (augmented and non-augmented) (see Annexure 2). Augmented models include cross-sectional averages of dependent and independent variables to account for cross-sectional dependence.

We propose three types of augmented models for the model selection criterion: models I, II, and III with one, two, and three explanatory variables, respectively. Even though the model selection criterion suggests that a model with three variables is our 'best model' in terms of log-likelihood ratio and Akaike information criteria (see Annexure 2), we present the results of the other models as well for comparison.

12.4.2 Estimation Results

Unlike most previous studies, the results of our study were not uniform across all developing countries. The impact of productivity growth on the real exchange rate differed by income group or per capita income. Productivity growth led to an appreciation in middle-income countries and depreciation in low-income countries in the long run. Our results substantiate the findings of Drine and Rault (2002, 2004) and Chuah (2012). Drine and Rault (2002, 2004) found evidence for the hypothesis in a study for middle-income countries (MICs) in 2002 and failed to arrive at the same conclusion for low-income countries (LICs) in another study in 2004. Our findings also seem to be in implicit confirmation of Chuah's (2012) results. He calculated a turning point ($2200) below which change in income resulted in depreciation of the real exchange rate. Almost all LICs in our study had a per capita income less than $2200. The conclusions of Chuah's (2012) study coincide with our conclusions for LICs such as Indonesia, Kenya, Nigeria, Tanzania, and Uganda.

Table 12.1 shows the long-run results of the panel co-integration estimation using the augmented PMG estimator for different groups of countries and models in the sample. We follow the tradition of presenting estimated coefficients of only observable variables as cross-sectionally averaged variables are not directly interpretable in a meaningful way. Estimated coefficients of full models (with observable and unobservable variables) are reported in Annexure 3.

Basically, we consider three types of models in comparing three types of groups: the *all countries* group (15 countries), country groups by income (middle-income countries (*MICs),* 5 countries; low-income countries (*LICs),* 10 countries), and

Table 12.1 Panel co-integration estimation: the augmented PMG estimator

Sample [# of countries]	Type of model	Long-run coefficients		
		$\ln Q$ = dependent variable		
		$\ln(Y/Y^{*})$	$\ln(G/G^{*})$	$\mathrm{vol}(E)$
All countries [15]	Model I	0.378296*** (0.108540)		
	Model II	0.246642*** (0.075056)	0.170621*** (0.037414)	
	Model III	0.388355*** (0.092802)	0.110547** (0.045996)	−0.021531** (0.010345)
MICs (BRICS) [5]	Model I	0.109014 (0.151776)		
	Model II	0.382324** (0.160930)	0.220887* (0.120288)	
	Model III	0.344657** (0.149000)	0.252061*** (0.092608)	0.024845** (0.012602)
LICs [10]	Model I	0.320488* (0.132415)		
	Model II	0.211173** (0.098594)	0.140663*** (0.041793)	
	Model III	−0.287286*** (0.086673)	0.010920 (0.049502)	−3.21610*** (0.419248)
Africa [9]	Model I	0.366216** (0.144702)		
	Model II	0.239056** (0.103439)	0.168407*** (0.043046)	
	Model III	−0.247591*** (0.071625)	0.077565** (0.038439)	−2.56978*** (0.285754)
Asia [4]	Model I	0.248016 (0.258474)		
	Model II	0.519768** (0.216328)	−0.179409** (0.078622)	
	Model III	0.771434* (0.439197)	−0.339890 (0.207397)	−7.71735*** (2.826821)

Note Q and E are real and nominal exchange rates, Y/Y^* = real GDP of home relative to foreign (US), G/G^* = real government expenditure of home relative to foreign (US), and vol(E) exchange rate volatility

***, **, and * refer to significance level at 1, 5, and 10%. Standard errors in parentheses

MICs refers to middle-income countries of the BRICS group (Brazil, Russia, India, China, and South Africa)

LICs refers to low-income countries (Angola, Ethiopia, Ghana, Indonesia, Kenya, Nigeria, the Philippines, Rwanda, Tanzania, and Uganda)

Africa refers to African countries (Angola, Ethiopia, Ghana, Kenya, Nigeria, Rwanda, Tanzania, Uganda, and South Africa)

Asia refers to Asian countries (China, India, Indonesia, and the Philippines) country groups by region (*Africa*, 9 countries; *Asia*, 4 countries). For each group in Table 12.1, the first row shows a model with one explanatory variable (productivity); the second row shows a model with two explanatory variables (productivity and government expenditure); and the third row shows a model with three explanatory variables (productivity—$\ln(Y/Y^*)$, government expenditure —$\ln(G/G^*)$, and exchange rate volatility—$\mathrm{vol}(E)$). The center of our discussion is Model III (shaded rows) for each group below.

In general, the results in Table 12.1, in general, show that the Balassa hypothesis holds for *all countries* as a group in the sample in the long run; that is, a 1% improvement in productivity leads to an appreciation of domestic currencies in the developing countries in the group by 0.388% on average. We find a different result, however, when the sample is categorized into different groups. When categorized by level of per capita income, the results show that the Balassa hypothesis holds only for middle-income countries (*MICs*). The same fact holds when countries are categorized by region; that is, the Balassa hypothesis holds only for *Asian* countries. This may be related to the fact that in our sample, most middle-income countries are from Asia and poor countries are from Africa. In both the cases, a 1% increase in productivity appreciates the domestic currencies of countries in *MICs* and *Asia* groups nearly by 0.34 and 0.77%, respectively (though only at the 10% level of significance for the latter). For *LICs* and *Africa* groups, a 1% increase in productivity depreciates domestic currencies of countries in the groups by nearly 0.287 and 0.247%, respectively.

The long-run relationship between government expenditure and the real exchange rate shows that expansionary fiscal policies result in appreciation of domestic currencies in all cases except for the *LICs* and *Asia* groups. This may not be surprising as the major countries with 'big economies' in both the groups are almost similar (Indonesia and the Philippines are members of both groups). The results of these groups are in line with Kohler's (1998) argument who states that government expenditure does not have an impact in the long run unless financed by distortionary taxes.

Exchange rate volatility has the impact of depreciating the real exchange rate for all countries in all groups except the middle-income group in the long run. This confirms theoretical arguments which associate relatively fixed or highly managed exchange rate systems (mainly in poor countries) to depreciation and flexible regimes to appreciation in the real exchange rate.

Table 12.2 presents the results of short-run dynamics of the same groups of countries and models as given in Table 12.1. The discussion that follows focuses on Model III (the shaded rows). Short-run dynamics show that the impact of change in productivity on change in the real exchange rate is significant but negative; that is, it has the impact of depreciating the real exchange rate for all countries in all groups in the short run.

Fiscal policy does not significantly explain the variations in the real exchange rate. Exchange rate volatility has an impact only in *MICs* and *all countries* groups. It negatively impacts the real exchange rate in the short run. This may be due to greater rigidity in the short run.

Table 12.2 Short-run dynamics of panel co-integration estimation: the augmented PMG estimator

Sample [# of countries]	Type of model	Adjustment coefficient	Short-run coefficients		
			$\Delta \ln Q$ = dependent variable		
			$\Delta\ \ln(Y/Y^{*})$	$\Delta\ \ln(G/G^{*})$	$\Delta\,\mathrm{vol}(E)$
All countries [15]	Model I	−0.109894*** (0.022462)	−0.327721*** (0.081918)		
	Model II	−0.142981*** (0.032498)	−0.359401*** (0.091545)	−0.046910* (0.027791)	
	Model III	−0.122432*** (0.037203)	−0.397465*** (0.082479)	−0.057736* (0.030909)	−0.161279*** (0.038693)
MICs (BRICS) [5]	Model I	−0.167326*** (0.068251)	−0.300195*** (0.082509)		
	Model II	−0.193645*** (0.102726)	−0.408364*** (0.133144)	−0.082710 (0.073367)	
	Model III	−0.12243*** (0.037203)	−0.3974*** (0.082479)	−0.057736* (0.030909)	−0.161279*** (0.038693)
LICs [10]	Model I	−0.111716*** (0.027206)	−0.352239*** (0.118025)		
	Model II	−0.141304*** (0.036735)	−0.364848*** (0.136587)	−0.042973 (0.032613)	
	Model III	−0.086261*** (0.024822)	−0.423972*** (0.099213)	−0.016775 (0.028716)	−0.020308 (0.031332)
Africa [9]	Model I	−0.098028*** (0.031963)	−0.427619*** (0.104199)		
	Model II	−0.131601*** (0.041812)	−0.427570*** (0.122564)	−0.058400** (0.031572)	
	Model III	−0.107015*** (0.032358)	−0.408247*** (0.100776)	−0.032190 (0.029437)	−0.034526 (0.046803)
Asia [4]	Model I	−0.127473*** (0.041693)	−0.213683 (0.193959)		
	Model II	−0.165803* (0.092356)	−0.229174 (0.192154)	0.035224 (0.067468)	
	Model III	−0.052518*** (0.019297)	−0.458148*** (0.162181)	−0.013347 (0.067688)	−0.044258* (0.023795)

Note Δ ln Q = log of real exchange rate differenced, Δ ln Y/Y^{*} = log of real GDP relative to foreign (US) differenced, Δ ln G/G^{*} = log of real government expenditure relative to foreign (US) differenced, and vol(E) exchange rate volatility differenced

***, **, and * refer to the significance level at 1, 5, and 10%. Standard errors in parenthesis

MICs refers to middle-income countries of the BRICS group (Brazil, Russia, India, China, and South Africa)

LICs refers to low-income countries (Angola, Ethiopia, Ghana, Indonesia, Kenya, Nigeria, the Philippines, Rwanda, Tanzania, and Uganda)

Africa refers to African countries (Angola, Ethiopia, Ghana, Kenya, Nigeria, Rwanda, Tanzania, Uganda, and South Africa)

Asia refers to Asian countries (China, India, Indonesia, and the Philippines)

The (negative) signs and statistical significance of the error correcting terms show that the system is stable. A stable co-integrating relationship adjusts short-run deviations by the extent of the error correcting term. The rate of adjustment is, however, higher (12%) in *MICs* than *LICs* (8%). This means *MICs* have a faster rate of adjustment and achieve equilibrium earlier than *LICs*. This may be associated with better conditions to fulfill assumptions of the model in the former group.

Tables 12.3 and 12.4 present the short-run dynamics for individual countries in two income groups (*MICs* and *LICs*), respectively. The results are for Model III.

The short-run dynamics show that the impact of productivity on the real exchange rate was significant and negative for all countries except Brazil and South Africa. Productivity did not have an impact on the real exchange rate in these countries in the short run. Expansionary fiscal policies resulted in depreciation of the real exchange rate in Brazil, Russia, and China. The role of exchange rate volatility was significant in all countries. However, the effect was exceptionally positive in Russia.

The rate of adjustment was the highest in Russia (56.25%) followed by Brazil (22.76%). This may be associated with the size and features of these economies. These are the two biggest economies in the group which account for 40 and 20% of the US economy, respectively. A faster rate of adjustment means that they can achieve equilibrium earlier than others.

Table 12.4 presents the short-run dynamics for *LICs*. The short-run dynamics shows that the impact of productivity on the real exchange rate was significant and negative for all countries except Indonesia and Uganda. Productivity did not impact

Table 12.3 Short-run dynamics by country: middle-income group (BRICS): Model III

Cases	Adjustment coefficient	Short-run coefficients		
		$\Delta \ln Q$ = dependent variable		
		$\Delta \ln(Y/Y^*)$	$\Delta \ln(G/G^*)$	$\Delta \mathrm{vol}(E)$
All countries	−0.12243*** (0.037203)	−0.3974*** (0.082479)	−0.057736* (0.030909)	−0.161279*** (0.038693)
Brazil	−0.227627*** (0.004377)	0.228636* (0.096920)	−0.088359*** (0.006094)	−0.002061*** (1.62E−05)
China	−0.064666*** (0.000587)	−0.5913*** (0.012107)	−0.101536*** (0.006333)	−0.354891*** (0.007472)
India	−0.046854*** (0.000797)	−0.4483*** (0.026819)	0.015571 (0.008586)	−0.301000*** (0.006721)
Russia	−0.562507*** (0.015174)	−0.4439*** (0.045163)	−0.451463*** (0.010053)	0.006537*** (3.27E−05)
South Africa	−0.078684*** (0.001472)	−0.194967 (0.151551)	0.039537 (0.058783)	−0.373313*** (0.009758)

Note $\Delta \ln Q$ = log of real exchange rate differenced, $\Delta \ln Y/Y^*$ = log of real GDP relative to foreign (US) differenced, $\Delta \ln G/G^*$ = log of real government expenditure relative to foreign (US) differenced, and vol(E) exchange rate volatility differenced

MICs refers to middle-income countries of the BRICS group (Brazil, Russia, India, China, and South Africa)

Table 12.4 Short-run dynamics by country: low-income group

Cases	Adjustment coefficient	Short-run coefficients		
		$\Delta \ln Q$ = dependent variable		
		$\Delta \ln(Y/Y^*)$	$\Delta \ln(G/G^*)$	$\Delta \text{vol}(E)$
All countries	−0.086261*** (0.024822)	−0.423972*** (0.099213)	−0.016775 (0.028716)	−0.020308 (0.031332)
Angola	−0.001548*** (4.27E−07)	−0.372509*** (0.025896)	−0.171725** (0.003968)	−0.005968*** (7.06E−06)
Ethiopia	−0.136337*** (0.000650)	−0.816907*** (0.015748)	−0.03830*** (0.002945)	0.065656*** (0.007485)
Ghana	−0.094831*** (0.000562)	−0.691301*** (0.035033)	0.03351*** (0.002317)	−0.042398*** (0.002733)
Indonesia	−0.000108*** (1.02E−05)	−0.006073 (0.086557)	0.06723*** (0.010901)	−0.017159 (5.17E−05)
Kenya	−0.248868*** (0.001492)	−0.121422*** (0.012865)	0.11217*** (0.000995)	0.164651*** (0.003452)
Nigeria	−0.042414*** (0.000194)	−0.632917*** (0.009143)	−0.02030*** (0.000807)	−0.125337*** (0.002453)
The Philippines	−0.145762*** (0.000584)	−0.647025*** (0.022619)	0.05421*** (0.003975)	−0.089533*** (0.002379)
Rwanda	−0.075394*** (0.000518)	−0.345743*** (0.005333)	−0.012847** (0.002458)	−0.028748*** (0.002997)
Tanzania	−0.107271*** (0.000337)	−0.665093*** (0.013354)	−0.04128*** (0.002109)	−0.177574*** (0.003046)
Uganda	−0.010293*** (5.76E−05)	0.059272 (0.032875)	−0.15042*** (0.007855)	0.053328*** (0.002087)

Note Δ ln Q = log of real exchange rate differenced, Δ ln Y/Y^* = log of real GDP relative to foreign (US) differenced, Δ ln G/G^* = log of real government expenditure relative to foreign (US) differenced, and vol(E) exchange rate volatility differenced

***, **, and * refer to significance level at 1, 5, and 10%. Standard errors in parentheses

LICs refers to low-income countries (Angola, Ethiopia, Ghana, Indonesia, Kenya, Nigeria, the Philippines, Rwanda, Tanzania, and Uganda)

the real exchange rate in the short run in these countries. The role of fiscal policy was significant in all countries even though the effect was different. The increase in government expenditure resulted in a depreciation of the real exchange rate in all countries except in Ghana, Kenya, Indonesia, and the Philippines. The strongest impact of the fiscal policy was shown by Uganda (0.15%). The impact of exchange rate volatility was significant in all countries except Indonesia.

The rate of adjustment was the highest in Kenya (24.89%) followed by the Philippines (14.58%) and Ethiopia (13.63%). These three countries may achieve equilibrium earlier than others in the group.

12.5 Conclusions and Policy Implications

12.5.1 Conclusions

Unlike most previous studies, the results of our study are not uniform across all the developing countries in our sample. The impact of productivity growth on the real exchange rate varied by income group or per capita income. Productivity growth led to an appreciation of the real exchange rate in middle-income countries and depreciation of the real exchange rate in low-income countries in the long run. In general, the results of our study confirm that the relationship between the real exchange rate and productivity does exist and is stronger for higher income countries in the long run. Real per capita income matters more than the rate of economic growth in explaining the effects of the Balassa term in our study.

In the short run, however, we find almost uniform results across income groups. Productivity growth (possibly of non-tradables), expansionary fiscal policies, and high exchange rate volatility result in the real exchange rate depreciation. More specifically:

- Improvements in productivity and expansionary fiscal policies both have the impact of depreciating the real exchange rate in almost all the countries, both middle and low incomes.
- The impact of exchange rate volatility is significant only in m*iddle-income countries*. This may be associated with the type of exchange rate policy/regime adopted. It is mainly fixed (unchanged) in *low-income countries* in which case it may not be useful to explain variations in the real exchange rate in the short run.

The reasons for the anti-Balassa hypothesis results in low-income countries in our study may be associated with a failure to satisfy the basic assumptions of the model. The relationship between the real exchange rate and productivity in the external version of the hypothesis assumes a positive relationship between productivity and relative prices as well as relative prices and the real exchange rate in the internal version. In addition, the law of one price must hold in the tradable sector.

12.5.2 Policy Implications

On the basis of our findings, we recommend the following policy options for MICs and LICs:

- The Balassa hypothesis holds for *middle-income countries* in our sample. Economic growth leads to an appreciation in the real exchange rate in these countries. Hence, countries in this group may promote growth by increasing productivity in the tradable sector.

- Since the Balassa hypothesis does not hold for *low-income countries* in our sample, economic growth does not lead to the real exchange rate appreciation in these countries. Hence, countries in this group may continue to grow by promoting productivity growth in the non-tradable sector.
- Depreciation of the real exchange rate can be associated with improvements in the productivity of the non-tradable sector for *low-income countries* and should be used accordingly.
- The role of fiscal policy may not last long in *low-income countries* and so should be used accordingly.

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Annexure 1

1.1 Model Derivation (Scott Hacker's Contribution)

Suppose that the growth rate of the real exchange rate is defined as a function of productivity differential between the non-tradable and tradable sectors as in:

$$\hat{Q} = \delta\left(\left[\left(\frac{\beta}{\alpha}\right)\hat{A}_T - \hat{A}_N\right] - \left(\frac{\beta}{\alpha}\right)^{*}\hat{A}_T^{*} - \hat{A}_N^{*}\right) \tag{1}$$

with $\hat{Q} \equiv \hat{p} - \hat{p}^{*}$.

This is the same as:

$$\hat{Q} = \delta\left(\left[\left(\frac{\beta}{\alpha}\right)\hat{A}_T - A_T^{*}\right] - \hat{A}_N - \hat{A}_N^{*}\right) \tag{1.1}$$

If we let $\hat{M}_0 = -\delta\left(\hat{A}_N - \hat{A}_N^{*}\right)$ and $m_1 = \delta\left(\frac{\beta}{\alpha}\right)$, then:

$$\hat{Q} = \hat{A}_0 + m_1\left(\hat{A}_T - \hat{A}_T^{*}\right) \tag{1.2}$$

In levels form, this is equivalent to:

$$Q = M_0 \left(A_T / A_T^* \right)^{m_1} \tag{1.3}$$

and in log-levels, it is

$$q = m_0 + m_1 ln \left(A_T / A_T^* \right) \tag{1.4}$$

where $q \equiv \ln Q \, and \, m_0 \equiv \ln M_0$

We proxy A_T / A_T^* with Y/Y^* where Y is the home real GDP per capita and Y^* is the foreign (US) real GDP per capita, so we get Eq. (2.23).

$$q = m_0 + m_1 (lnY/Y^*) \tag{1.5}$$

Annexure 2

See Tables 12.5, 12.6, 12.7, 12.8, 12.9, and 12.10

Table 12.5 Descriptive statistics (all countries)

Statistics	$\ln(Q)$	$\ln(Y/Y^*)$	$\ln(G/G^*)$	vol(E)
Mean	−0.6737	−2.7011	0.9462	0.4726
Median	−0.6646	−2.7219	1.1813	0.0424
Maximum	0.4235	−0.4348	2.8605	45.552
Minimum	−1.6263	−4.6914	−2.2488	0.0000
Std. dev.	0.3675	0.7907	0.9795	2.8547
Skewness	0.2293	0.0585	−0.7068	11.761
Kurtosis	2.7686	2.5192	2.9466	164.64
Jarque−Bera	9.1598	8.4988	69.465	909407
Probability	0.0102	0.0143	0.0000	0.0000
Sum	−561.22	−2250.0	788.16	386.62
Sum sq. dev.	112.38	520.19	798.28	6658.1
Observations	833	833	833	818

Table 12.6 Descriptive statistics (by country)

Country	$\ln(Q)$		$\ln(Y/Y^*)$		$\ln(G/G^*)$		$\mathrm{Vol}(E)$		Obs.
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	
Angola	−0.4650	0.2996	−2.2869	0.4128	1.5568	0.5088	3.4174	10.3081	41
Brazil	−0.3824	0.3295	−1.8292	0.2390	0.4919	0.6321	1.8454	4.5140	61
China	−0.8927	0.3308	−2.7127	0.4237	1.4123	0.2741	0.0474	0.0861	59
Ethiopia	−0.6491	0.3398	−3.8203	0.3501	1.0952	0.4464	0.0434	0.1172	61
Ghana	−0.4949	0.2539	−2.7498	0.4530	−0.0584	1.0071	0.2148	0.2427	56
India	−0.9066	0.2218	−2.9414	0.2323	1.1495	0.5007	0.0528	0.0688	61
Indonesia	−0.9281	0.2891	−2.5105	0.1529	1.0049	0.7692	0.6411	2.5342	51
Kenya	−0.6909	0.2801	−2.8806	0.3690	0.5182	0.6943	0.0628	0.1158	61
Nigeria	−0.4329	0.5292	−2.7153	1.0063	0.9769	1.0085	0.1322	0.2678	61
The Philippines	−0.6683	0.3533	−2.3381	0.1450	0.7938	0.7134	0.0769	0.1468	61
Russia	−0.9519	0.2779	−1.1607	0.3472	1.7785	0.3746	1.5517	3.5475	21
Rwanda	−0.9272	0.2395	−3.3872	0.3605	1.5705	0.9514	0.0867	0.1667	51
South Africa	−0.4349	0.1711	−1.4829	0.2699	−0.8529	0.4004	0.0757	0.1007	61
Tanzania	−0.7518	0.2005	−3.3301	0.4605	2.0835	0.4700	0.1328	0.2058	51
Uganda	−0.7283	0.3749	−3.4294	0.4039	1.6334	0.2242	0.2552	0.4379	61
All	−0.6737	0.3675	−2.7011	0.7907	0.9462	0.9795	0.4726	2.8547	818

Table 12.7 Cross-sectional dependence tests

Tests	Non-augmented model	Augmented model
Breusch-Pagan LM	235.4183***	145.5989***
Pesaran scaled LM	7.964616***	1.766490*
Bias-corrected scaled LM	7.837498***	1.639371
Pesaran CD	11.56950***	−0.781383

Note Null hypothesis: no cross-sectional dependence (correlation)
Note ***, and * refer to significance level at 1, and 10%.

Annexure 3

See Tables 12.11 and 12.12

Table 12.8 Panel unit root tests (IPS and Fisher-type tests)

Variables	Specifications	Pesaran statistics	Fisher statistics	Order of integration
$\ln(Q)$	Constant	−1.0567	32.73	*I*(1)
	Constant and trend	1.6161	21.13	
$\Delta \ln(Q)$	Constant	−21.07***	401.23***	*I*(0)
	Constant and trend	−20.07***	344.39***	
$\ln(Y/Y^{*})$	Constant	−0.3133	34.84	I(1)
	Constant and trend	3.3929	21.69	
$\Delta \ln(Y/Y^{*})$	Constant	−16.22***	296.62***	*I*(0)
	Constant and trend	−19.43***	327.62***	
$\ln(G/G^{*})$	Constant	−0.9245	32.50	*I*(1)
	Constant and trend	0.6120	26.57	
$\Delta \ln(Y/Y^{*})$	Constant	−19.99***	377.62***	*I*(0)
	Constant and trend	−19.23***	350.83***	
$\mathrm{vol}(E)$	Constant	−13.74***	246.72***	*I*(0)
	Constant and trend	−16.07	230.49	

Note *** indicates the rejection of the null hypothesis (unit root) at 1%

Table 12.9 Results of co-integration tests

Model	IPS test		ADF test		PP test	
	Non-augmented	Augmented	Non-augmented	Augmented	Non-augmented	Augmented
Model I	−19.15***	−22.18***	356.99***	427.72***	353.95***	430.16***
Model II	−18.13***	−22.00***	339.99***	426.95***	351.52***	499.48***
Model II	−17.36***	−20.75***	314.36***	392.64***	317.27***	409.21***

Note *** indicates rejection of the null hypothesis (unit root/no co-integration) at 1%

Table 12.10 Model selection criteria

Model type	Log *L*	AIC*	BIC	HQ	Specification
I	822.9247	−1.8213	−1.3725	−1.6491	ARDL (1, 1)
II	858.6465	−1.8304	−1.1975	−1.5875	ARDL (1, 1, 1)
III	920.9778	−1.9800	−1.2444	−1.6975	ARDL (1, 1, 1, 1)

Note * refer to significance level at 10%.

Table 12.11 Panel co-integration estimation: pooled mean group estimator (*MICs* = 5 countries)

Cases	Model type	Adjustment coefficient	Long-run coefficients					
			$\ln(Q)$ = dependent variable					
			$\overline{\ln(Q)}$	$\ln(Y/Y^*)$	$\overline{\ln(Y/Y^*)}$	$\ln(G/G^*)$	$\overline{\ln(G/G^*)}$	vol(E)
All countries	I		0.7986 (0.3929)	0.1090 (0.1518)	−0.2792 (0.4087)			
	II		2.5721*** (0.6182)	0.3823** (0.1609)	−2.0355** (0.7849)	0.2209* (0.1203)	−1.0014*** (0.2819)	
	III		3.0730*** (0.5858)	0.3447** (0.1490)	−2.2913*** (0.7061)	0.2521*** (0.0926)	−0.8858*** (0.2532)	0.0248** (0.0126)
Short-run coefficients								
			$\Delta \ln(Q)$ = *dependent variable*					
			$\Delta\overline{\ln(Q)}$	$\Delta \ln(Y/Y^*)$	$\overline{\Delta \ln(Y/Y^*)}$	$\Delta \ln(G/G^*)$	$\overline{\Delta \ln(G/G^*)}$	Δ vol(E)
All countries	I	−0.1673*** (0.0682)	1.1840*** (0.2976)	−0.3002*** (0.0825)	0.1930 (0.1433)			
	II	−0.1936*** (0.10272)	0.9115*** (0.1791)	−0.4084*** (0.1331)	0.2804 (0.2339)	−0.0827 (0.0734)	0.1863*** (0.0612)	
	III	−0.1224*** (0.0372)	0.8424*** (0.1041)	−0.3974*** (0.0825)	0.1953** (0.0869)	−0.0577* (0.0309)	0.0648 (0.0663)	−0.1613*** (0.0387)
Brazil	I	−0.0940*** (0.0026)	1.5177*** (0.0929)	0.0801 (0.0812)	−0.1346 (0.0974)			
	II	−0.1458*** (0.0044)	1.2512*** (0.1148)	0.0152 (0.0927)	−0.1126 (0.0964)	−0.0096 (0.0059)	0.0453 (0.0435)	
	III	−0.2276*** (0.0044)	1.0306*** (0.1047)	0.2286* (0.0969)	−0.0875 (0.0865)	−0.0883*** (0.0060)	0.2952** (0.0529)	−0.0021*** (0.0001)

(continued)

Table 12.11 (continued)

Cases	Model type	Adjustment coefficient	Long-run coefficients					
			$\ln(Q)$ = dependent variable					
			$\overline{\ln(Q)}$	$\ln(Y/Y^*)$	$\overline{\ln(Y/Y^*)}$	$\ln(G/G^*)$	$\overline{\ln(G/G^*)}$	vol(E)
China	I	−0.0625*** (0.0012)	0.7314*** (0.0440)	−0.5448*** (0.0166)	0.1722* (0.0610)			
	II	−0.0933*** (0.0011)	0.5149*** (0.0416)	−0.5655*** (0.0143)	0.1126 (0.0523)	−0.1301*** (0.0076)	0.2787*** (0.0293)	
	III	−0.0647*** (0.0006)	0.5464*** (0.0344)	−0.5913*** (0.0121)	0.1947** (0.0438)	−0.1015*** (0.0063)	0.2244*** (0.0242)	−0.3549*** (0.0075)
India	I	−0.0883*** (0.0019)	0.6518*** (0.0235)	−0.4247*** (0.0294)	0.1166** (0.0267)			
	II	−0.0488*** (0.0011)	0.6234*** (0.0301)	−0.3918*** (0.0327)	0.1173** (0.0271)	0.0029 (0.0091)	0.1059*** (0.0129)	
	III	−0.0468*** (0.0008)	0.5813*** (0.0267)	−0.4483*** (0.0268)	0.1445*** (0.0229)	0.0156 (0.0086)	0.0836*** (0.0112)	−0.3010*** (0.0067)
Russia	I	−0.4328*** (0.0122)	2.2026*** (0.1078)	−0.2004*** (0.0308)	0.7271* (0.3085)			
	II	−0.5998*** (0.0173)	1.4202*** (0.2234)	−0.7845*** (0.0570)	1.2003** (0.3171)	−0.3464*** (0.0124)	0.3769** (0.1013)	
	III	−0.5625*** (0.0152)	1.3547*** (0.1719)	−0.4439*** (0.0452)	1.1735** (0.3029)	−0.4515*** (0.0100)	0.3237** (0.0646)	0.0065*** (0.0001)
South Africa	I	−0.1589*** (0.0051)	0.8167*** (0.0582)	−0.2509* (0.1060)	0.0837 (0.0756)			
	II	−0.0806*** (0.0015)	0.7475*** (0.0622)	−0.3152 (0.1463)	0.0843 (0.0773)	0.0696 (0.0426)	0.1248** (0.0356)	
	III	−0.0787*** (0.0015)	0.6452*** (0.0548)	−0.1949 (0.1515)	−0.0028 (0.0679)	0.0395 (0.0588)	0.2259*** (0.0306)	−0.3733*** (0.0097)

Note ***, **, and * refer to significance level at 1, 5, and 10%. Standard errors in parentheses

Table 12.12 Panel co-integration estimation: pooled mean group estimator (*LICs* = 10 countries)

Cases	Model type	Adjustment coefficient	Long-run coefficients					
			$\ln(Q)$ = dependent variable					
			$\overline{\ln(Q)}$	$\ln(Y/Y^*)$	$\overline{\ln(Y/Y^*)}$	$\ln(G/G^*)$	$\overline{\ln(G/G^*)}$	vol(E)
All countries	I		0.3168 (0.2237)	0.3205* (0.1324)	0.8329*** (0.2129)			
	II		0.6872*** (0.2259)	0.2112** (0.0986)	0.3854 (0.2512)	0.1407*** (0.0418)	−0.3507*** (0.0959)	
	III		1.0669*** (0.2127)	−0.2873*** (0.0867)	0.2720 (0.2552)	0.0109 (0.0495)	−0.0182 (0.1282)	−3.2161*** (0.4192)
			Short-run coefficients					
			$\Delta \ln(Q)$ = *dependent variable*					
			$\overline{\Delta \ln(Q)}$	$\Delta \ln(Y/Y^*)$	$\overline{\Delta \ln(Y/Y^*)}$	$\Delta \ln(G/G^*)$	$\overline{\Delta \ln(G/G^*)}$	Δ vol(E)
All countries	I	−0.1117*** (0.0272)	0.7647*** (0.1003)	−0.3522*** (0.1180)	0.2879** (0.1313)			
	II	−0.1413*** (0.0367)	0.7635*** (0.1032)	−0.3648*** (0.1366)	0.2653** (0.1351)	−0.0429 (0.0326)	−0.0144 (0.1094)	
	III	−0.0863*** (0.0248)	0.5631*** (0.1294)	−0.4239*** (0.0992)	0.1896 (0.1162)	−0.0168 (0.0287)	0.0173 (0.0951)	−0.0203 (0.0313)
Angola	I	−0.1021*** (0.0129)	0.8559** (0.2088)	−0.2539** (0.0445)	0.6178** (0.3376)			
	II	−0.1835*** (0.0105)	1.0438*** (0.1673)	−0.2890*** (0.0349)	0.6206** (0.2624)	−0.1326*** (0.0049)	−0.7164*** (0.0993)	
	III	−0.0015*** (0.0001)	0.9369*** (0.1255)	−0.3725*** (0.0259)	0.4225 (0.1812)	−0.1717** (0.0039)	−0.5855** (0.0886)	−0.0059*** (0.0001)

(continued)

Table 12.12 (continued)

Cases	Model type	Adjustment coefficient	Long-run coefficients					
			$\ln(Q)$ = dependent variable					
			$\overline{\ln(Q)}$	$\ln(Y/Y^*)$	$\overline{\ln(Y/Y^*)}$	$\ln(G/G^*)$	$\overline{\ln(G/G^*)}$	vol(E)
Ethiopia	I	−0.3364*** (0.0034)	0.5018*** (0.0332)	−0.9714*** (0.0187)	0.3830*** (0.0419)	0.3830*** (0.0419)		
	II	−0.4113*** (0.0031)	0.4470*** (0.0291)	−1.1079*** (0.0161)	0.4443*** (0.0334)	−0.1390*** (0.0028)	0.1123*** (0.0161)	
	III	−0.1363*** (0.0006)	0.3654*** (0.0279)	−0.8169*** (0.0157)	0.3477*** (0.0343)	−0.038*** (0.0029)	0.1337*** (0.0192)	0.0657*** (0.0075)
Ghana	I	−0.1228*** (0.0032)	0.3116** (0.0722)	−0.7780*** (0.0433)	0.7832*** (0.0938)			
	II	−0.2304*** (0.0046)	0.2622** (0.0696)	−0.8854*** (0.0518)	0.6431*** (0.0870)	−0.0894*** (0.0034)	0.1710** (0.0427)	
	III	−0.0948*** (0.0006)	0.0931 (0.0470)	−0.6913*** (0.0350)	0.3100** (0.0622)	0.0335*** (0.0023)	−0.079616* (0.025340)	−0.0424*** (0.0027)
Indonesia	I	−0.1386*** (0.0043)	0.8098*** (0.1281)	0.2978** (0.0631)	0.5774** (0.1625)			
	II	−0.1571*** (0.0050)	0.8070*** (0.1307)	0.3864** (0.0765)	0.4926* (0.1635)	0.0454** (0.0103)	−0.0530 (0.0744)	
	III	0.0001*** (0.0001)	0.8071*** (0.1249)	−0.0061 (0.0866)	0.6202** (0.1609)	0.0672*** (0.0109)	0.0295 (0.0685)	−0.0172 (0.0001)
Kenya	I	−0.1036*** (0.0025)	1.0582*** (0.0396)	−0.4606*** (0.0340)	0.1793** (0.0450)			
	II	−0.1197*** (0.0033)	1.0269*** (0.0374)	−0.4043*** (0.0334)	0.1692** (0.0443)	0.0740*** (0.0037)	−0.1535*** (0.0211)	
	III	−0.2489*** (0.0015)	0.2617*** (0.0133)	−0.1214*** (0.0129)	−0.0381* (0.0124)	0.1122*** (0.0009)	−0.0537*** (0.0074)	0.1646*** (0.0034)

(continued)

Table 12.12 (continued)

Cases	Model type	Adjustment coefficient	Long-run coefficients					
			$\ln(Q)$ = dependent variable					
			$\overline{\ln(Q)}$	$\ln(Y/Y^*)$	$\overline{\ln(Y/Y^*)}$	$\ln(G/G^*)$	$\overline{\ln(G/G^*)}$	vol(E)
Nigeria	I	−0.0364*** (0.0002)	0.8468*** (0.0885)	−0.4929*** (0.0112)	0.8597*** (0.1219)			
	II	−0.0277*** (0.0002)	0.7961*** (0.0832)	−0.5074*** (0.0106)	0.9467*** (0.1138)	−0.0155*** (0.0011)	0.5019*** (0.0436)	
	III	−0.0424*** (0.0002)	0.7329*** (0.0613)	−0.6329*** (0.0091)	0.7799*** (0.0850)	−0.0203*** (0.0008)	0.5929*** (0.0378)	−0.1253*** (0.0024)
The Philippines	I	−0.1089*** (0.0036)	0.6733*** (0.0759)	−0.2433** (0.0713)	−0.1986* (0.0830)			
	II	−0.1138*** (0.0045)	0.7101*** (0.0724)	−0.3810** (0.0716)	−0.1423 (0.0821)	0.1328*** (0.0141)	−0.3828*** (0.0469)	
	III	−0.1458*** (0.0006)	0.3199*** (0.0226)	−0.6470*** (0.0226)	0.1060** (0.0239)	0.0542*** (0.0039)	−0.0446* (0.0158)	−0.0895*** (0.0024)
Rwanda	I	−0.0665*** (0.0008)	0.8509*** (0.0487)	−0.4273*** (0.0069)	−0.0079 (0.0531)			
	II	−0.1001*** (0.0018)	0.7458*** (0.0559)	−0.4331*** (0.0071)	−0.0645 (0.0540)	−0.0098* (0.0035)	−0.0204 (0.0313)	
	III	−0.0754*** (0.0005)	0.7087*** (0.0363)	−0.3457*** (0.0053)	−0.1616** (0.0416)	−0.0128** (0.0024)	0.0278 (0.0235)	−0.0287*** (0.0029)
Tanzania	I	−0.0505*** (0.0019)	0.3739*** (0.0578)	−0.2922*** (0.0151)	−0.0059 (0.0659)			
	II	−0.0359*** (0.0024)	0.4408*** (0.0572)	−0.0900** (0.0263)	−0.0628 (0.0658)	−0.1428*** (0.0058)	0.1009** (0.0306)	
	III	−0.1073*** (0.0003)	0.0668** (0.0195)	−0.6651*** (0.0133)	−0.1276** (0.0238)	−0.0412*** (0.0021)	−0.1234*** (0.0102)	−0.1776*** (0.0030)

(continued)

Table 12.12 (continued)

Cases	Model type	Adjustment coefficient	Long-run coefficients					
			$\ln(Q)$ = dependent variable					
			$\overline{\ln(Q)}$	$\ln(Y/Y^*)$	$\overline{\ln(Y/Y^*)}$	$\ln(G/G^*)$	$\overline{\ln(G/G^*)}$	vol(E)
Uganda	I	−0.0512*** (0.0005)	1.3649*** (0.0555)	0.0995* (0.0325)	−0.3089** (0.0661)			
	II	−0.0335*** (0.0004)	1.3547*** (0.0526)	0.0635 (0.0314)	−0.3939*** (0.0651)	−0.1529*** (0.0069)	0.2964*** (0.0228)	
	III	−0.0103*** (0.0001)	1.3388*** (0.0542)	0.0593 (0.0329)	−0.3629** (0.0673)	−0.1504*** (0.0078)	0.2763*** (0.0276)	0.0533*** (0.0021)

$\ln(Q)$ = log of real exchange rate, $\ln(Y/Y^*)$ = log of real GDP relative to foreign (US), $\ln(G/G^*)$ = log of real government expenditure relative to foreign (US), vol(E) exchange rate volatility, $\overline{\ln(Q)}$ = log of real exchange rate demeaned, $\overline{\ln(Y/Y^*)}$ = log of real GDP relative to foreign (US) demeaned, and $\overline{\ln(G/G^*)}$ = log of real government expenditure relative to foreign (US) demeaned

***, **, and * refer to significance level at 1, 5, and 10. Standard errors in parentheses

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