The Central Bank
of the Republic of Uzbekistan

Estimating equilibrium real effective exchange rate in Uzbekistan

Author: M. Isroilov

Department of Monetary Policy

Tashkent – 2025

Estimating equilibrium real effective exchange rate in Uzbekistan

Monetary Policy Department

Isroilov Mukhiddin *

Abstract

This paper estimates Uzbekistan's country-specific equilibrium real effective exchange rate (REER) employing the Behavioral Equilibrium Exchange Rate (BEER) approach and Autoregressive Distributed Lag (ARDL) methodology for two sample periods: 2016:I–2024:IV and 2017:IV–2024:IV. The empirical approach is to estimate a broad set of ARDL specifications of macroeconomic fundamentals such as productivity differentials, trade openness, fiscal policy, net foreign assets, and terms of trade. After stringent filtering on the basis of diagnostic tests and cointegration, a subset of models is chosen to estimate the long-run relationship between REER and its determinants. Equilibrium REER estimates are derived by applying the Hodrick–Prescott filter to obtain the long-run trend. Misalignment is measured as the departure of actual REER from this equilibrium path. Results indicate that the REER has tracked its fundamental-based equilibrium quite closely with modest and transitory deviations. The yearly average equilibrium rate of appreciation is 2.2% over the 2016:I-2024:IV period and 2.4% over the post-liberalization 2017:IV–2024:IV period. These results emphasize the increasing contribution made by structural fundamentals to Uzbekistan's exchange rate trajectory and highlight the value of REER monitoring for macroeconomic policy making.[1]

Keywords: Real Effective Exchange Rate, Exchange Rate Misalignment, ARDL, Cointegration, Uzbekistan .

*The views and opinions expressed in this article are solely those of the author and do not necessarily reflect the official position of the Central Bank of the Republic of Uzbekistan. The Central Bank assumes no responsibility for the content of this publication. Reproduction or redistribution of any part of this material in any form is permitted only with the explicit consent of the author.

[1]This research was conducted under the "Bilateral Assistance and Capacity Building for Central Banks (BCC) Programme" of the Swiss State Secretariat for Economic Affairs (SECO).

Contents

1 Introduction **1**

2 Fundamentals of Exchange Rate **2**

3 Estimation Methods **4**
3.1 Error Correction Model 4

4 Overview of Factors **5**
4.1 Determinants of Equilibrium REER 6

5 Estimation results **8**
5.1 Equilibrium level of real effective exchange rate(REER) 9
5.1.1 Estimation results (2016:I–2024:IV) 9
5.1.2 Estimation results (2017:IV–2024:IV) 13

6 Conclusion **15**

Appendix **16**

1 Introduction

The REER represents the price competitiveness of a country's goods and services relative to its trading partners and is defined as:

$$REER = \prod_{i=1}^{N} \left(\frac{P}{E_i P_i^*} \right)^{w_i}, \tag{1}$$

where E_i is the nominal exchange rate against country i, P_i^* is the foreign price level, P is the domestic price level, and w_i is the trade weight assigned to country i. An increase in REER indicates appreciation, making domestic goods relatively more expensive.

The equilibrium level of the real effective exchange rate (REER) is the value of the REER that is consistent with a country's underlying macroeconomic fundamentals — such as productivity, terms of trade, net foreign asset position, fiscal policy, and demographic factors — in the absence of short-term shocks or policy distortions.

Estimation of an equilibrium real effective exchange rate for developing countries plays a crucial role in ensuring economic stability, attracting investment, promoting foreign trade, and formulating effective economic policy. It is an important instrument for interpreting and controlling the forces of the economy, hence promoting sustainable development and growth. Tracking the equilibrium exchange rate helps in preserving exchange rate stability that is crucial in setting an optimal economic environment.

It is especially crucial to estimate the equilibrium exchange rate in developing countries because of some basic reasons:

Importance of Estimating the Equilibrium Level of REER

Measuring the equilibrium level of the real effective exchange rate (REER) is essential for developing countries as it provides a comprehensive view of a country's external competitiveness, adjusted for inflation and trade weights across major partners. Unlike the nominal exchange rate, which reflects market prices, the REER equilibrium captures the sustainable value of the currency relative to its fundamentals. Its accurate estimation helps in several key areas:

- *External Competitiveness:* The equilibrium REER is a benchmark to determine whether the nation's goods and services are appropriately priced in foreign markets. Persistent overvaluation can damage exports, and undervaluation can result in misallocation of resources.
- *Macroeconomic Stability:* Tracking REER misalignments allows pressures in the external sector, i.e., unsustainable current account deficits or capital inflow booms, to be identified, and timely policy responses to be made.
- *Policy Design:* An estimate of the equilibrium REER helps in formulating effective monetary, fiscal, and exchange rate policies. It offers a foundation for central banks and finance ministries to determine if the exchange rate is consistent with long-run fundamentals.
- *Debt Sustainability:* As REER influences the real weight of external debt, particularly for foreign currency-denominated obligations, a declining REER can raise the expense of debt servicing, whereas appreciation can lower it.
- *Investment Climate:* A REER near its equilibrium enhances investor confidence by indicating a stable and predictable macroeconomic environment, stimulating

domestic and also foreign investment.

- *Structural Reform Analysis:* Over time, equilibrium REER changes capture changes in the economy's structure - e.g., increases in productivity or trade openness - so that it is a valuable tool to assess reform progress.

The exchange rate is needed so as to interpret relative prices within an economy. It is most needed in developing and emerging economies, where the volatility of the exchange rate is likely to be greater compared to that of developed nations (Hausmann et al., 2006.) The study of the behavior of the exchange rate is needed because misalignments can have a profound effect on resource allocation through the adjustment of tradable and non-tradable goods profitability. Misalignment in this context is the deviation of the actual or observed exchange rate from the sustainable or equilibrium rate over the long term. It is calculated as the difference between the actual exchange rate and that implied by equilibrium levels of fundamentals. Cointegration methods are typically employed to impose a medium-run relation between the exchange rate and its determinants.

The evaluation of equilibrium exchange rates relies on two primary assessment approaches: The assessment methods for equilibrium exchange rates include structural models which declare internal and external balances must be maintained and direct estimation approaches which calculate reduced-form equations that link exchange rates to fundamental determinants. The Fundamental Equilibrium Exchange Rate (FEER) serves as the main structural method whereas the Behavioral Equilibrium Exchange Rate (BEER) functions as the leading direct estimation technique. The difference between the actual REER and the value predicted by current and equilibrium levels of fundamentals represents the calculation of misalignment. The analysis of medium-run relationships between REER and its determinants typically employs cointegration techniques.

2 Fundamentals of Exchange Rate

This part surveys the literature that applies the BEER (Behavioral Equilibrium Exchange Rate) models to detect long-run relations between the exchange rate (RER) and its fundamentals. Although these studies differ in the exact variables and periods considered, they use largely the same econometric techniques, namely vector error correction models (VECM) and cointegration techniques, to estimate the equilibrium exchange rate.

Ades (1996) employed quarterly data observations on Mexico, South Africa, and Indonesia using the variables of terms of trade openness, external capital flows, and foreign interest rates. The article revealed that these fundamentals were important in determining the RER in these heterogeneous economies.

Broner et al. (1997), in their study of RER in Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela (1960-1995), were interested in the relative price of non-tradable to tradable and net foreign assets.

Soto and Valdes (1998) looked at Chile (1978-1997), using quarterly data and VECM to provide evidence of a long-term relationship between RER and the fundamentals: relative productivity of tradables to non-tradables, net foreign asset position and government expenditure. Surprisingly Terms of trade were not significant in their results, showing the importance of productivity and positions.

The study conducted by Baffes et al. (1999) examines the exchange rate of Burkina Faso and Côte d'Ivoire through annual data analysis in a VECM model. The fundamental

factors that influenced the exchange rate of Burkina Faso between 1970 and 1993 included three main elements: the ratio of output per worker against OECD nations, the import share of GDP and the resource balance expressed as a percentage of GDP. The analysis of Côte d'Ivoire from 1967 to 2003 included the same fundamental factors as Burkina Faso and added the investment-to-GDP ratio which demonstrated statistical significance. This research functions as a methodological framework to apply BEER models specifically for West African nations. Their research findings showed that specific variables held essential value for establishing RER levels in Latin American countries.

Aboal (2002) analyzed Uruguay's RER with quarterly data (1986-2000) and concluded that the most relevant fundamentals were: Ratio of total productivity to industrial productivity, ratio of total consumption to GDP and ratio of consumption expenditure to GDP.Calderón (2004) has estimated Chile's REER using VECM and DLS from quarterly data (1977-2003). His study revealed that depreciation of the Chilean peso in the 1980s were primarily due to increased domestic borrowing and reduced government expenditures. The appreciation during the 1990s with higher productivity in the tradable sector and enhanced external asset positions.

Candelon et al. (2007) apply a panel cointegration methodology to the exchange rates of the Baltic States, with quarterly data for the period 1993-2001. They conclude that the exchange rates on these nations, in relation to the euro, are determined by productivity differentials with the euro area and the level of economic openness. Nevertheless, they do not find clear expression of demand for non-tradable, as represented by government, private, or aggregate consumption playing a major role. The cointegration tests provide inconclusive results, with just a few indicating that the variables are cointegrated. Using the estimated coefficients, the authors calculate the equilibrium exchange rates (REER) of both countries and conclude that there were no significant cases of misalignment between the Baltic States.

Amuedo-Dorantes and Pozo (2004) and Lopez et al. (2007) investigated RER and remittances in Latin America and the Caribbean. Their panel data estimates revealed the statistically significant connection between remittances and RER, especially in countries with a high reliance on remittance flows. Lopez et al. (2007) expanded the analysis to 20 regional countries, validating the robust remittance impact on RER.

The Autoregressive Distributed Lag (ARDL) estimation of equilibrium Real Effective Exchange Rate (REER) serves developing countries by explaining their currency behavior through recent research. Hosni (2021) applies the BEER framework with ARDL to study Egypt's REER from 1965 up to 2018 which shows terms of trade and trade openness determine equilibrium levels while major policy shifts including the 2016 currency floatation caused substantial misalignments.

The ARDL framework applied by Lebdaoui (2013) determines Morocco's REER from 1980 to 2012 through which he found productivity and trade openness to be essential factors while trade policy adjustments generated moderate misalignment.

The ARDL model applied to Indonesia's post-crisis REER demonstrates that productivity and fiscal discipline serve as fundamental elements to sustain equilibrium while terms-of-trade shocks create brief misalignments during this period (Nuryadin (2006)).

Vdovychenko (2021) employs ARDL within the BEER framework to estimate Ukraine's REER from 2005 to 2020, identifying net foreign assets, trade openness, and productivity as key drivers.

To sum up, although the particular basics vary significantly in different countries and studies, the continuous application of cointegration methods and other econometric techniques has obtained strong long-run correlations between the REER and various economic fundamentals, thus opening the door for further empirical analysis in various directions. The different methods employ various parts of macroeconomic theory and highlight the influence of different economic fundamentals.

3 Estimation Methods

Several alternative methods exist to estimate a country's equilibrium exchange rate, each based on a different theoretical approach. These are the internal-external balance approach, behavioral equilibrium exchange rate (BEER), permanent equilibrium exchange rate (PEER), and newer models in the new open economy framework. They all have their weaknesses and strengths, and hence more than one estimate is used by organizations such as central banks to conclude whether or not a currency is overvalued or undervalued. According to Kripfganz and Schneider (2023), ARDL provides strong methodological features which enable it to detect long-term connections within unstable data, making it suitable for exchange rate research. The study establishes ARDL as an effective tool to model REER dynamics while revealing structural elements such as trade openness and productivity, which serve as theoretical foundations for examining Uzbekistan's REER behavior.

3.1 Error Correction Model

An Error Correction Model (ECM) is a modified form ARDL (Autoregressive Distributed Lag) model which fits well for studying non-stationary time series that show cointegration. Cointegration means that the individual time series are non-stationary but still a linear combination of them can be stationary, thus indicating the presence of a long-run equilibrium relationship between the variables (Gujarati, 2004). The ECM setup takes care of not only the long-term relationship between variables but also the short-term changes that are heading towards this equilibrium. Our model describes the exchange rate as depending on the main macroeconomic variables:

$$\Delta Y_t = \beta_0 + \alpha_i \left(Y_{t-1} - \sum_{i=1}^{m} \beta_i X_{i,t-1} \right) + \sum_{i=1}^{m} \sum_{j=1}^{p} \gamma_j \Delta X_{i,t-j} + \mu Z_t + \varepsilon_t \tag{2}$$

In this model, Δ represents the difference operator, while β_0 is a constant term. The vectors β_i and γ_j capture the coefficients that measure the long-run and short-run lagged effects of variables on one another. The parameter α_i reflects the speed at which the i-th endogenous variable adjusts towards the equilibrium. Z_t is an exogenous variable affecting the short-term volatility of the exchange rate with the compatible matrix of coefficients - μ. The term ε_t represents the error term, assumed to follow, $i.i.d$ distribution with zero mean and σ^2 variance. The vector X_{it} consists of m endogenous variables that describe key exchange rate drivers, such as productivity differential,relative price of nontradables, risk premium, trade opennes, terms of trade, and real interest rate p lags of the variables in the model. The ECM approach, as developed by Johansen and Juselius (1990), offers several advantages: it provides a long-run cointegration relationship while accounting for short-run effects, assumes the presence of a cointegrating relationship among I(1) variables, and allows for simultaneous estimation of both long-run and short-run effects.

After estimation of the ECM we use a cointegration equation to measure the equilibrium REER of the following form:

$$\hat{Y}_{t-1} = \sum_{i=1}^{m} \hat{\beta}_i \bar{X}_{i,t-1} \tag{3}$$

Where $\bar{X}_{i,t-1}$ is a vector containing the permanent part of the variables. Exchange rate misalignment is calculated as $\tilde{Y} = Y - \hat{Y}$.

In this configuration of the model, X is the vector including the natural logarithm of export, import, remittance, net foreign assets, terms of trade, and GDP proxy. Y is in the natural logarithm.

4 Overview of Factors

We can estimate the equilibrium real effective exchange rate (REER) by applying the Behavioral Equilibrium Exchange Rate (BEER) method which entails the selection of basic economic variables that have an impact on the exchange rate's movement over a long period of time. These variables represent the major and structural changes in a country's condition that influence its competitive position, investment inflows, foreign trade, and price levels. The next section details each variables' economic justification, how they are related, and the expected directions of their connections with the REER.

In the context of estimating the equilibrium real effective exchange rate (REER), macroeconomic fundamentals are constructed in relative terms to reflect Uzbekistan's position vis-à-vis its trading partners. Since the REER inherently represents a relative price—the price of domestic goods and services compared to those of trading partners—its underlying determinants must also be expressed in a consistent relative framework. Accordingly, for each macroeconomic variable X, a relative indicator is computed as the ratio of the domestic (Uzbekistan's) value, X_h, to a trade-weighted average of the same variable across trading partners, denoted X_f. The foreign component is defined as:

$$X_f = \sum_{i=1}^{N} w_i X_i, \quad \text{where} \quad \sum_{i=1}^{N} w_i = 1 \quad \text{and} \quad w_i \geq 0,$$

with X_i representing the value of the indicator for partner country i, and w_i capturing the corresponding bilateral trade share. The resulting relative indicator is then given by:

$$X = \frac{X_h}{X_f}$$

This formulation ensures coherence between the dependent variable (REER) and its explanatory variables by capturing macroeconomic divergences between Uzbekistan and its external environment.

4.1 Determinants of Equilibrium REER

• *Productivity Differential.* Productivity differential is an important determinant of the equilibrium REER, mainly through the Balassa-Samuelson effect. More rapid productivity growth in the tradable sector relative to trading partners increases wages, which pushes the price level of non-tradable goods higher and results in REER appreciation. We employ two proxy data sources for the productivity differentials:

- *PPP-Adjusted GDP Per Capita:* A rise in PPP-adjusted GDP per capita implies increased productivity and purchasing power, which generates increased demand for goods and services, especially non-tradables, that raises domestic price levels and appreciates REER.

- *Real GDP Per Capita:* Relative GDP per capita growth mirrors productivity growth, rising wages and demand for non-tradables, resulting in a general price level increase and REER appreciation:

$$P_N = wTFP_T \tag{4}$$

where P_N is the price of non-tradables, w is the wage level, and TFP_T is total factor productivity in the tradable sector.

• *Relative price of tradables.* An increase in the relative price of tradables generally leads to a depreciation of the equilibrium REER. When tradable goods become more expensive relative to non-tradables, domestic production costs rise, reducing the competitiveness of exports in international markets. This worsens the trade balance as foreign demand for domestic goods declines, leading to downward pressure on the currency.

-*Nonfood Price/Service Price:* Rising service prices reflect higher labor costs and increased domestic demand, pushing up REER as the economy shifts towards a service-based structure.

- *PPI/CPI:* In an import-dependent country, CPI is heavily influenced by external prices, while PPI reflects domestic inflation. Thus, a rising PPI/CPI ratio reveals that domestic costs are rising faster than external ones — leading to a real appreciation driven by internal price inflation, not by stronger external competitiveness.

• *Net International Investment Position (Excluding Reserves)/GDP:* A positive NIIP indicates strong external financial health which in turn attracts capital inflows and causes currency appreciation. Where a higher NIIP not only helps to improve the current account balance (CA) but also strengthens REER. A robust NIIP is a signal that the country has a net creditor position, thus it can rely less on borrowing from abroad and investors trust it more. Besides that, surplus NIIP decreases the country risk premiums, thus borrowing costs become lower, which then fits higher investment and domestic demand. This, in turn, further pushes up REER through stronger capital inflows and better macroeconomic stability.

• *Relative Government Consumption/GDP:* More government spending results in higher demand for non-tradable goods, which causes domestic prices to go up, thus REER appreciation. The increased governmental expenditure, especially on services and infrastructure, surges aggregate demand, which in turn results in an increase in the prices of non-tradable goods and subsequently an appreciation of the real exchange rate. In the case that government spending is productive, it is able to improve the whole country's economic efficiency, hence investor sentiment will be further boosted and foreign capital inflows attracted. On the other hand, if it is done through too much borrowing, the

long-term consequences may be heavier debt burdens and inflation, the latter of which may cancel out the appreciation.

• *General Government Debt/GDP:* Very high public debt might fuel inflationary expectations and increase the risk premium, thus creating a spiral that can lead to REER depreciation. Moreover, a large debt burden could increase the perceived risk of the country, thus leading to capital flight and a depreciation of the exchange rate. Besides, if debt monetization takes place, the issue of inflation might escalate and the real exchange rate might become even more weakened. On the other hand, high debt levels are commonly linked with high future taxes, which could result in lower investment amounts in the private sector and a decrease in productivity growth. This then leads to further REER decline.

• *Real Interest Rate:* An increase in real interest rates in a country brings in foreign investors who consequently provide more demand for local money which results in the appreciation of currency:

$$REER = f(r - r^*), \tag{5}$$

where r is the domestic real interest rate and r^* is the foreign real interest rate. Higher relative real interest rates make domestic assets more attractive to global investors, which results in larger capital inflows and appreciation of the domestic currency. This phenomenon is especially true for the countries that have no restrictions on capital movement. However, it is worth noting that if interest rates become very high, they might lead to a slowdown in domestic economic growth due to the increased cost of borrowing. This might dampen the effect in the longer term.

• *Trade Openness:* The impact of trade openness on REER is unclear. Greater exports cause appreciation and greater imports cause depreciation pressure. A more open economy enjoys greater efficiency and specialization, and both can result in greater productivity and REER appreciation. Nevertheless, if trade liberalization results in greater imports than exports, then it can deteriorate the trade balance and cause depreciation pressure on the currency. Moreover, greater exposure to international capital flows can cause greater exchange rate volatility.

• *International Investment Position Liability:*Greater external liabilities raise the risk of capital flight and hence depreciation. Economies with large foreign liabilities are exposed to changes in global risk sentiment, which can instigate abrupt capital outflows and depress the REER. Huge external debt-denominated obligations also need to be serviced continuously, which creates additional foreign exchange demand and can put further pressure on the domestic currency. On the contrary, a favorable liability position and better institutional credibility can reduce depreciation risks.

• *Investment/GDP:* Investing more in the economy generates levels of productivity that, in turn, result in increased competitiveness in the long term hence a stronger REER. The economy enjoys greater domestic investment in infrastructure and technology that raises its productive base so that it attains better growth prospects alongside higher capital inflows. Investment environment for productive reasons attracts foreign direct investment (FDI) that serves to boost the REER. When debt-financed investments do not reflect in productivity gains they generate external financial issues which can cause the local currency to depreciate over time.

• *Terms of Trade:* The terms of trade quantify the relative price of exports in terms of

imports:

$$TT = \frac{P_X}{P_M}, \tag{6}$$

where P_X and P_M are export and import prices, respectively. An increase in TT raises national income and appreciates REER. Relative rise in export prices over import prices improves the trade balance which enhances demand for the home currency. REER appreciates because of the rise in foreign currency into the market. Favorable terms of trade raise domestic real incomes which raises demand for non-tradables therefore currency appreciation.

• *Commodity Terms of Trade:* For commodity-exporting nations, appreciation in commodity prices improves trade balances and therefore appreciates the REER. Commodity price appreciation boosts export proceeds, hence the current account balance improves and national income rises. All these things generate more robust domestic demand and capital inflows, hence further appreciating the currency. Commodity dependence can, nevertheless, bring in volatility, a sudden reduction in prices resulting in sharp depreciations in the REER.

These basic variables influence the long-run equilibrium REER via productivity differentials, capital flows, fiscal policy, and trade flows. Their integration within a BEER framework guarantees that there is an overall comprehension of currency appreciation and policy implications.

All relative variables are measured with respect to Uzbekistan's top five trading partners (China, Russia, Kazakhstan, Turkey, and South Korea), taking into account their share in the foreign trade.[2] For the factor X which is weighted average of the trading partners Estimation is quarterly and split into two subsamples. The first is from 2016:I-2024:IV, giving the overall view of the equilibrium REER path. The second one is from 2017:IV-2024:IV, taking into consideration the effects of the liberalization of Uzbekistan's foreign exchange market in September 2017. This split enables the dynamics of the REER before and after the exchange rate regime switch to be contrasted.

5 Estimation results

We estimate the ARDL model using all possible combinations of the specified variables as determinants of the REER. To determine the optimal lag structure, we use the Akaike Information Criterion (AIC), ensuring a balance between model complexity and fit. Given the large number of estimated models, we apply a model selection process based on key statistical criteria. First, we test for serial autocorrelation in the residuals and retain only models with uncorrelated errors. Second, we assess the statistical significance of the long-run coefficients, considering only models where they are significant. Third, we test for cointegration to ensure the existence of a stable long-run relationship. Finally, we keep the models with economically reasonable signs in the cointegration equation. This systematic approach allows us to select models that are both statistically robust and economically meaningful.

[2]Data source: CEIC Global Database, URL https://www.ceicdata.com/en
National Committee of the Republic of Uzbekistan on Statistics, URL https://stat.uz/en/.

5.1 Equilibrium level of real effective exchange rate(REER)

To approximate the equilibrium real effective exchange rate (REER), we use the Autoregressive Distributed Lag (ARDL) bounds testing method of cointegration by quarterly figures from 2016:I to 2024:IV. Key data transformations were carried out prior to estimation: the chosen series, i.e., the REER, were in logarithmic form to stabilize the variance. The X-12-ARIMA eliminated the seasonal components procedure, and trend elements were separated by using the Hodrick-Prescott filter to identify long-run equilibrium behaviour. The ARDL model was used due to its suitability for the integration of mixed variable orders. The REER is the explanatory variable, and the set of possible explanatory variables includes macroeconomic determinants like terms of trade, productivity, trade openness, government expenditure, and net foreign assets. These sets of combinations were generated dynamically via a loop algorithm in EViews. For every specification, the ARDL model was estimated with up to two lags for both the dependent and independent variables. An extensive postestimation diagnostics was used, for instance, the cointegration bounds test, the Lagrange Multiplier test for serial correlation, the Breusch-Pagan-Godfrey test for heteroskedasticity, and the Jarque-Bera test for normality. In addition, the statistical significance of the cointegration parameters was checked for the existence of a long-run relation. Models were only kept for subsequent analysis if they passed all diagnostic checks, exhibited evidence of cointegration (i.e., the bounds test F-statistic exceeded the I(1) critical value at at a 10% level), and had all long-run coefficients significant at a 10% level. The validated models were employed to build summary tables and, finally, to draw the estimated equilibrium REER trajectory.

5.1.1 Estimation results (2016:I–2024:IV)

This section reports the empirical results of estimating the equilibrium real effective exchange rate (REER), which is denoted as *RR*, with quarterly data for the period 2016:I–2024:IV. The Autoregressive Distributed Lag (ARDL) bounds testing method of cointegration is employed because of its small-sample stability and capacity for accommodating regressors with a mix of orders of integration.

Large numbers of ARDL models were estimated using various combinations of macroeconomic fundamentals. Model selection was according to long-run coefficients significance, absence of autocorrelation, and cointegration validity. Nine models passed all the diagnostic tests and were employed for equilibrium REER construction.

Table 1: Long-Run Coefficients of Selected ARDL Models

Variable	RR1	RR2	RR3	RR4	RR5	RR6	RR7	RR8	RR9
GC	0.316				0.264		0.240	0.286	
PC	0.148		0.259	0.192	0.114		0.199		
TT	0.616								
CTT		0.930		0.596		0.486			
TN			-1.461		-0.508	-0.917	-0.792		-1.118
YD1			0.155						
LD					0.465		0.873	0.826	
NF							0.677		
TR						3.631			4.717
Const.	2.786	3.026	4.776	3.056	3.985	2.873	4.174	3.603	3.120

Where:

- RR- Equilibrium level of REER
- GC-Relative Government Consumption/GDP
- PC- Relative PPI/CPI
- TT- Terms of Trade
- CTT- Commodity Terms of Trade
- TN- Relative Nonfood Price/Service Price
- YD1- Relative Real GDP Per Capita
- LD- General Government Debt/GDP
- NF- Net International Investment Position (Excluding Reserves)/GDP
- TR- Relative Trade Openness

The point estimates are mostly in line with theoretical predictions. Government consumption as a share of GDP enters with a positive sign in all specifications, indicating that increased government expenditure—especially if it is directed towards non-tradables—puts upward pressure on the REER. This is indicative of demand pressures and a relative resource reallocation that appreciates the real exchange rate.

As anticipated, the PPI/CPI ratio comes in with a positive and statistically significant coefficient. The implication is that relative hikes in domestic producer costs compared to consumer prices—prevalent in import-dependent economies place upward pressures on the real exchange rate. The outcome captures the underlying cost-push inflation in the domestic producing sector that, in tandem with flat or low foreign consumer prices, results in an appreciation of the REER via increased domestic price levels and changed competitiveness.

The positive coefficients on relative trade openness and terms of trade demonstrate benefits from enhanced export market conditions and superior export pricing. When a country experiences better trade terms or increased openness it builds a stronger current account position which attracts capital inflows that boost the REER value.

The commodity terms of trade, which capture price movements of key export and import commodities, also have a positive effect. Commodity-rich economies tend to experience REER appreciation during booms in global commodity prices.

The relative nonfood/service price index shows negative coefficients because of substitution effects and competitiveness dynamics. When service prices outpace nonfood item prices it indicates inflation or cost pressures that push down the REER.

The positive coefficient of net international investment position as a share of GDP shows that countries which hold stronger external balance sheets will face lower risk premiums leading to currency appreciation. The relative real GDP per capita and PPP-adjusted real income serve as indicators to determine productivity and living standard variations between countries.

The positive coefficient of government debt to GDP appears in multiple models because increased debt spending drives demand, although the effect may turn negative when debt sustainability becomes a concern.

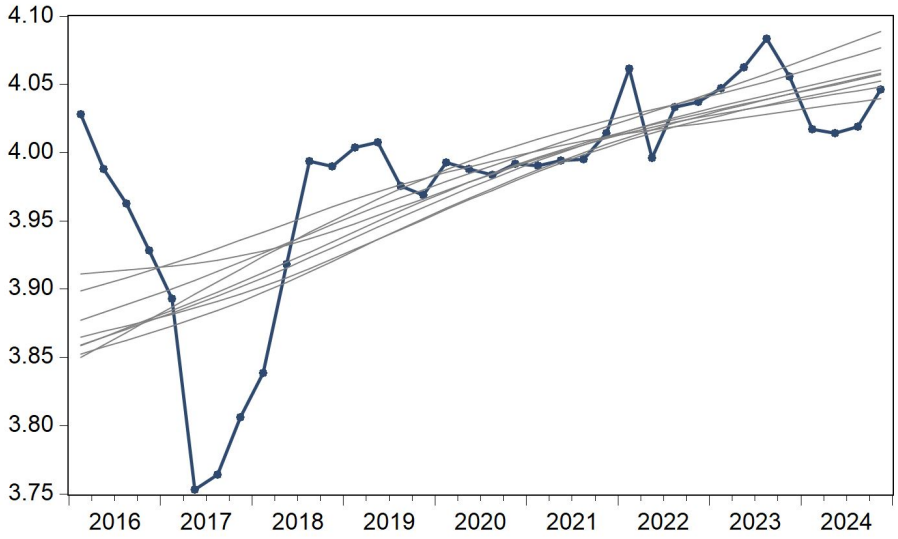

Figure 1: Actual REER and Estimated Equilibrium Paths from Individual Models

The findings validate that REER trends during this period resulted from complex interactions between various structural elements and external forces. The following analysis employs these equations to determine equilibrium REER values while evaluating average appreciation trends and measuring REER deviation across the study period.

The figures in this section show the results obtained from estimated equilibrium values of the real effective exchange rate through ARDL analysis for the period spanning from 2016:I to 2024:IV. The figures display three components, which include individual equilibrium path estimations along with their average path and the deviations between actual REER values and their estimated equilibrium positions.

Figure 1 plots the actual REER series and estimated equilibrium REERs from each of the nine alternative ARDL specifications (RR1 to RR9). The equilibrium series are smoothed by the Hodrick–Prescott (HP) filter to derive their long-run components.

Each line corresponds to an alternative specification founded on a different combination of macroeconomic fundamentals. The equilibrium series is smoother in shape and more persistent than the actual REER, capturing the structural determinants underlying rather than short-run volatility. An upward trend in the equilibrium REER is exhibited by all nine models, consistent with macroeconomic fundamentals having strengthened over the period.

Figure 2 plots the actual REER and the average of the nine filtered equilibrium REER estimates. The average series provides a good proxy for the equilibrium path that is independent of model-specific bias and idiosyncrasies. The equilibrium REER is showing a consistently increasing trend over the sample horizon, reflecting intensifying appreciation pressures fueled by improvements in fundamentals like relative productivity, terms of trade, external positions, and fiscal policy. It is estimated to have appreciated at a rate of approximately 2.2% per annum over the sample horizon. This increasing trend embodies persistent improvement in macroeconomic fundamentals and structural competitiveness. In some periods—especially in 2017 and portions of 2023—the real REER departs substantially from the estimated equilibrium, indicating periods of undervaluation or overvaluation.

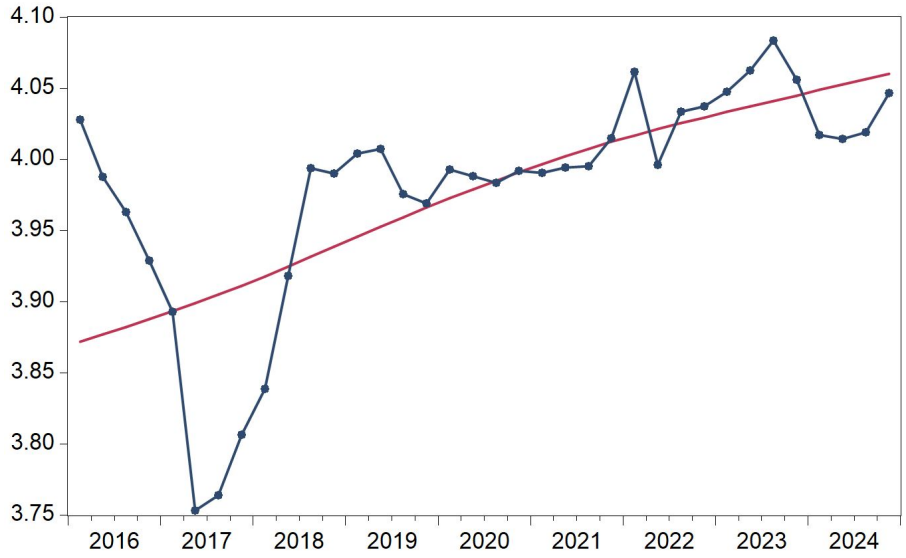

Figure 2: Actual REER vs. Average Equilibrium REER, *in natural logarithm*

The graph in Figure 3 displays the REER misalignment through the calculation of the actual REER differences from the equilibrium average. Values above zero denote that the REER was overvalued, while values below zero suggest the REER was undervalued.

The analysis of misalignment patterns reveals multiple essential tendencies. During the period between 2016 and the beginning of 2018 the REER experienced substantial undervaluation with its lowest point at **-0.145** observed in early 2017. This undervaluation probably shows the process of adjustment after structural changes together with external modifications.

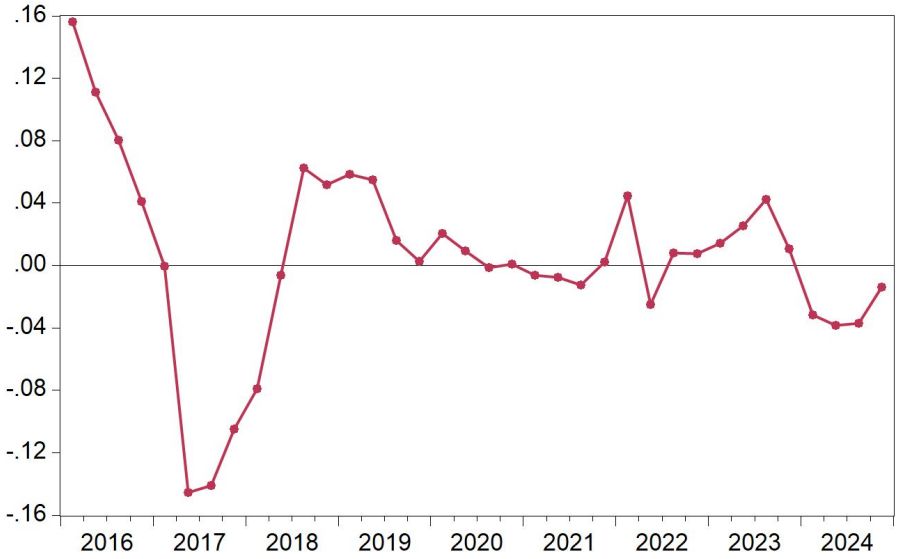

Figure 3: Average REER Misalignment, *expressed in decimal form*

Starting in 2018, the Real Effective Exchange Rate (REER) showed a trend towards approaching equilibrium, with periods of mild overvaluation in between periods of relative stability. The highest level of overvaluation achieved was **0.156**, while the average misalignment for the whole sample was around zero (**0.005**), which implies that in the medium term, the real REER fluctuated around its fundamental value.

These findings highlight that Uzbekistan's exchange rate policy allowed for significant transitional flexibility, and real REER movements generally followed movements in macroeconomic fundamentals. However, there were some short-term misalignments, which highlight the importance of competitiveness monitoring with the aid of structural models.

5.1.2 Estimation results (2017:IV–2024:IV)

This section presents the findings of equilibrium real effective exchange rate (REER) estimation throughout the 2017:IV to 2024:IV period. The study utilized ARDL techniques to investigate how REER connects with multiple macroeconomic fundamentals over extended periods. The equilibrium levels came from the three best-performing ARDL models before being processed through the Hodrick–Prescott (HP) filter. The structural component of the REER becomes the main focus through this approach because it removes short-term market fluctuations.

The following equations were identified as the best-fitting long-run specifications:

Table 2: Long-Run Coefficients of Selected ARDL Models (2017:IV–2024:IV)

Variable	RR1	RR2	RR3
GC		0.141	
PC			0.219
NF			0.565
LX	0.043	0.037	0.056
TR	3.277	2.835	
Const.	2.487	2.584	3.575

These models highlight the significance of trade openness (TR), external balance (NF), fiscal stance (GC), price competitiveness (PC), and foreign investment liabilities (LX) in the determination of the equilibrium level of the real effective exchange rate (REER).

All the coefficients of variables are positive, as economic theory would predict. Trade openness (TR) comes with an increased export potential and foreign investment inflows, both of which result in REER appreciation. GC may be capturing the demand-pull effect positively on non-tradables, whereas NF implies improved net foreign asset positions reducing the currency risk premium. PC is capturing the domestic price pressures, while LX shows that access to foreign liabilities is contemporaneous with confidence in domestic macroeconomic conditions.

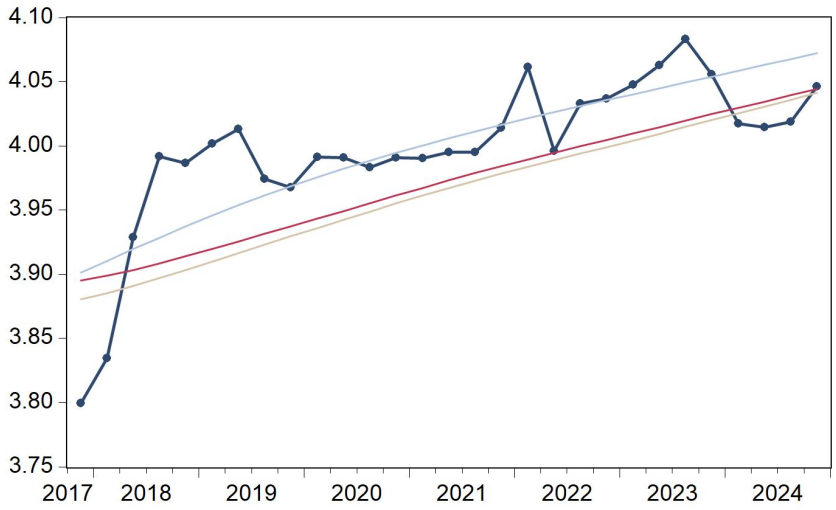

Figure 4: Actual REER vs. Average Equilibrium REER, *expressed in natural logarithm*

Figure 4 displays both actual REER values and three model-based HP-filtered equilibrium REER values. The equilibrium REER estimates reveal a consistent rising pattern which produces an average yearly appreciation of **2.4%**. The country experienced persistent improvements in its economic fundamentals between the specified period. The current REER follows the filtered equilibrium trajectory closely yet shows occasional brief periods of short-term deviations from the equilibrium values.

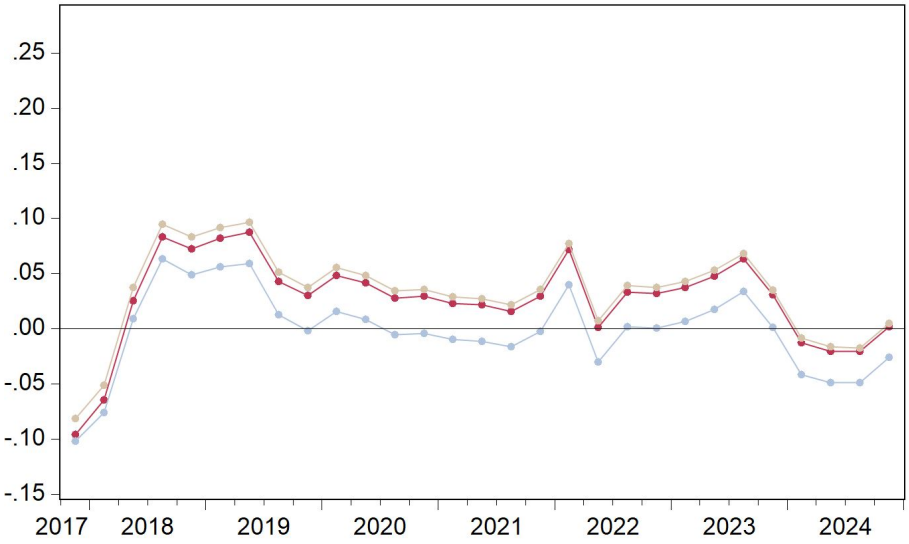

Figure 5: REER Misalignments, *expressed in decimal form*

Figure 5 presents the actual REER deviations from three model equilibrium paths which are identified as MN1, MN2, and MN3. Positive values indicate overvaluation (actual REER above equilibrium), while negative values indicate undervaluation.

The misalignment values never reached extreme levels and stayed within moderate ranges during the entire period. Table 3 summarizes key statistics for each misalignment series:

Table 3: Summary Statistics of REER Misalignment (2017:IV–2024:IV)

	MN1	MN2	MN3
Mean	0.0266	0.0336	-0.0015
Maximum	0.0873	0.0964	0.0633
Minimum	-0.0954	-0.0810	-0.1015

The results reveal that although short-term fluctuations occurred, the REER generally remained close to its fundamental level throughout the period. Misalignments were well-contained within ±10%, supporting the effectiveness of the exchange rate regime in aligning market outcomes with structural fundamentals.

6 Conclusion

This research analyzed the real effective exchange rate of Uzbekistan through Behavioral Equilibrium Exchange Rate (BEER) model estimation combined with ARDL cointegration methods. The research evaluated two timeframes which stretched from 2016:I to 2024:IV as well as from 2017:IV to 2024:IV covering the period after FX market liberalization. The REER exhibits significant sensitivity toward fundamental macroeconomic elements according to the analysis. The long-run equilibrium exchange rate depends heavily on all major variables which include relative productivity measured through GDP per capita alongside trade openness, net international investment position, relative price indicators and government fiscal variables. The estimated coefficients from both time frames maintain theoretical consistency in their signs which proves the economic mechanisms that affect the REER. The equilibrium REER trend is, on average, one of gradual appreciation, 2.2% per annum over the 2016:I-2024:IV sample and 2.4% per annum since liberalization. The trends are indicative of structural strengthening in the economy of Uzbekistan, including better competitiveness, more open trade relations, and greater capital market integration.

The misalignment analysis shows that the REER underwent short-term periods of undervaluation and overvaluation mainly during important policy transitions and external market events but these fluctuations remained small and short-lived. The REER stayed close to its equilibrium level throughout both sample periods which demonstrates that market results maintained consistency with fundamental macroeconomic factors.

Appendix

Distribution of the long-run equation parameters, *vertical lines indicate selected coefficients after the model selection process.*

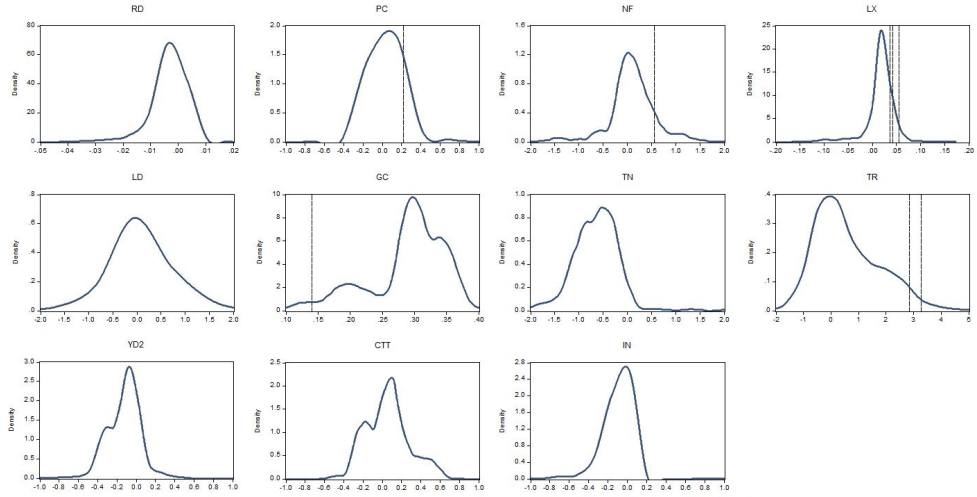

Figure 6: Distribution of the parameters (2017:IV–2024:IV)

	RD	PC	NF	LX	LD	GC	TN	TR	YD2	CTT	IN
Mean	-0.002	-0.045	0.096	0.014	0.263	0.286	-0.717	0.818	-0.127	0.059	-0.052
Median	-0.002	0.011	0.094	0.018	0.073	0.298	-0.678	0.303	-0.106	0.064	-0.050

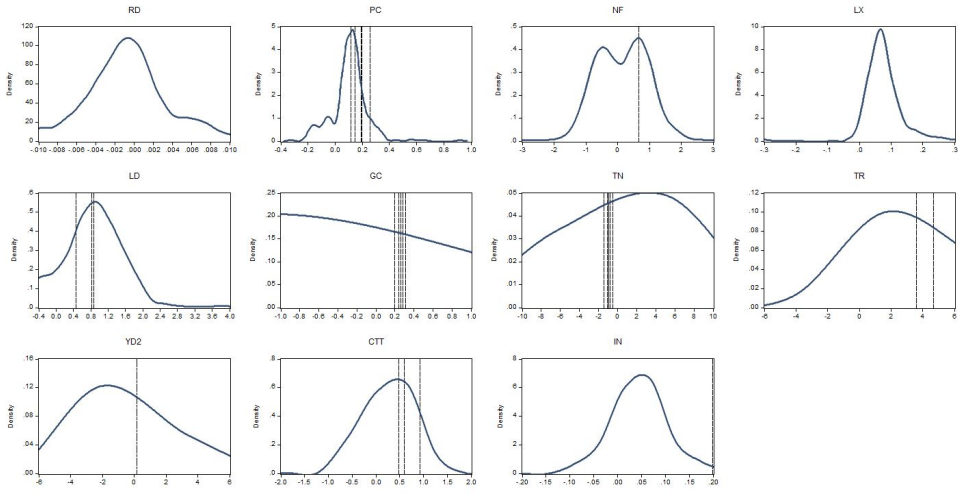

Figure 7: Distribution of the parameters (2016:I–2024:IV)

	RD	PC	NF	LX	LD	GC	TN	TR	YD2	CTT	IN
Mean	-0.001	0.104	0.196	0.076	0.638	-0.527	0.919	3.311	-0.441	0.429	0.043
Median	-0.001	0.112	0.246	0.068	0.767	-0.471	-0.340	2.484	-0.257	0.366	0.044

References

[1] Ades, A. (1996). GSDEEMER and STMPIs: New tools forecasting exchange rates in emerging markets. In Sachs, G. (Ed.), *Economic Research*, Oxford University Press.

[2] Aboal, D. (2002). Real Exchange Rate Equilibrium in Uruguay. *XVII Annual Conference of Economy*, Central Bank of Uruguay.

[3] Amuedo-Dorantes, C., & Pozo, S. (2004). Workers' remittances and the real exchange rate: A paradox of gifts. *World Development*, 32(8), 1407–1417.

[4] Baffes, J., Elbadawi, I., & O'Connell, S. (1999). Single-equation estimation of the equilibrium real exchange rate. In Hinkle, L., & Montiel, P. (Eds.), *Exchange Rate Misalignment: Concepts and Measurement for Developing Countries*. World Bank.

[5] Bitans, M. (2002). Real Exchange Rate in Latvia (1994–2001). *Latvijas Banka*.

[6] Broner, F., Loayza, N., & Lopez, H. (1997). Misalignment and Fundamentals: Equilibrium Exchange Rates in Seven Latin American Countries. *World Bank*, Mimeo.

[7] Calderón, C. (2004). An Analysis of the Behavior of the Real Exchange Rate in Chile. *Working Paper No. 266*, Central Bank of Chile.

[8] Candelon, B., Kool, C., Raabe, K., & Reding, P. (2007). Long-run real exchange rate determinants: Evidence from eight new EU member states. *Journal of Comparative Economics*, 35(1), 87–107.

[9] Clark, P. B., & MacDonald, R. (1998). Exchange Rates and Economic Fundamentals: A Methodological Comparison of BEERs and FEERs. *IMF Working Paper 98/67*.

[10] Égert, B., Halpern, L., & MacDonald, R. (2006). Equilibrium exchange rates in transition economies: Taking stock of the issues. *Journal of Economic Surveys*, 20(2), 257–324.

[11] Fic, T., & Others. (2008). Real exchange rate misalignments in the new EU member states. *National Institute Economic Review*, 204(1), 104–113.

[12] Hinkle, L. E., & Montiel, P. J. (1999). *Exchange Rate Misalignment: Concepts and Measurement for Developing Countries*. Oxford University Press for the World Bank.

[13] Johansen, S. (1995). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford University Press.

[14] Lopez, H., Bussolo, M., & Molina, L. (2007). Remittances and the Real Exchange Rate. *World Bank Policy Research Working Paper No. 4213*.

[15] MacDonald, R. (1998). What determines real exchange rates? The long and the short of it. *Journal of International Financial Markets, Institutions and Money*, 8(2), 117–153.

[16] MacDonald, R. (2002). Modeling the long-run real effective exchange rate of the New Zealand dollar. *Australian Economic Papers*, 41(3), 301–322.

[17] Montiel, P. J. (2007). Equilibrium Real Exchange Rates, Misalignment and Competitiveness in the Southern Cone. *Economic Development Division Series 62*, United Nations.

[18] Soto, C., & Valdés, R. (1998). Misalignment of the Real Exchange Rate in Chile. *Mimeo*, Central Bank of Chile.

[19] Werner, A. (1997). Exchange Rate Targeting and Inflation Targeting in Mexico: An Evaluation. *Banco de México*, Working Paper 9702.