Measuring Exchange Rate Misalignment in Turkey*

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Abstract

We propose a new methodology to measure exchange rate misalignment for Turkey, which has already undergone a severe economic crisis. We estimate the real exchange rate within a time varying parameter model, where a return-to-normality assumption about the parameters are assumed.

Contrary to common belief, it is found that, except the initial four months of the stabilization program, the Turkish Lira remained structurally undervalued for most of 2000. Also, we observe a pattern where Lira has been structurally overvalued after the crisis in 1994 until 1998, and has displayed structural undervaluation after then.

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1 Introduction

Turkey initiated an extensive disinflation program in December 1999, backed and supervised by the International Monetary Fund (IMF). The program exclusively relied on a nominally anchored exchange rate basket and fiscal austerity. In February 2001, however, in the midst of its implementation, Turkey experienced a sudden currency crisis, which deepened into a severe recession and continued to-date. In what followed, the Central Bank was forced to sell a large portion of its foreign reserves in an attempt to support the Turkish Lira (TL), and finally declared the surrender of the pegged exchange rate system on February 22, thereby unconditionally switching to an exchange system of free float.

An important line of criticism on the 1999 Turkish disinflation program was that it overlooked the structurally fragile characteristics of the banking system, and relied excessively on the short-term capital flows for liquidity generation[1]. It further ignored the fact that the Lira was already overvalued (by as much as 18 percent in purchasing parity terms[2]) on the eve of the program's implementation in late 1999.

The Lira's experience of free float throughout the rest of 2001 followed the general pattern of overshooting succeeded by stabilization, as was also witnessed during much of the currency crisis episodes of the emerging market economies

[1] The underlying elements of the disinflation program and the succeeding crises are discussed in detail in Ertuğrul and Yeldan (2002), Akyüz and Boratav (2002), Yeldan (2002), Boratav and Yeldan (2002), Ertuğrul and Selçuk (2001), Eichengreen (2001), Gencay and Selçuk (2001), and Alper (2001).

[2] Using the wholesale price index (WPI) (1989=100). The PPP comparison is carried directly vis-a-vis the conversion rate of the TL against US$.

in the 1990's. The nominal conversion rate of the Lira vis-à-vis the US$ depreciated by 86% by August 2001. Yet, after mild fluctuations until October, it virtually stabilized displaying a nominal still. This occurred against the ongoing inflationary pressures with an average monthly rate of 3.7% in consumer prices, and 4.2% in producer prices between October 2001 and the time of writing.

This observation set forth a new line of argument claiming that the TL was again "overvalued" and that competitiveness of the Turkish exportables was at stake. Setting the ill-founded issue of the meaning of "over"- or "under"-valuation of a currency under the workings of market-determined free float aside, the question is not trivial, as the currency crises witnessed among the emerging economies throughout the 1990's clearly underscored the need for avoiding exchange rates that are incompatible with maintaining sustainable external accounts. After the Mexican, East Asian, and the Argentinean crises in particular, international economists intensified their efforts to understand the behavior and determinants of the real exchange rate in emerging market economies.

Conventionally, the real exchange rate is regarded as "misaligned" if its realized value exhibits a persistent departure from its long run equilibrium trend. The long run equilibrating value, in turn, is taken to be that rate which, for a given set of "structural fundamentals" is compatible with simultaneous achievement of internal and external equilibrium[3]. It is clear that such an assessment has to go beyond the simple PPP calculations which are wrought with issues of the choice of a relevant price index and a proper base year.

[3] Edwards(2001). See also Fischer (2001) on the formal statement of the problem within the context of a finer classification of the exchange rate systems.

In fact, as noted by Evans and Lyons (1999), exchange rate economics has already been in crisis following the seminal papers of Meese and Rogoff (1983a, 1983b). Also, the empirical findings on exchange rate misalignment (ERM henceforth) are controversial themselves and suffer from limitations of simplistic assumptions, as mentioned in Edwards and Savastano (1999). As a result, the literature on exchange rate determination, which would serve us to come up with a model to measure ERM in a developing country such as Turkey has potential conflicts. Therefore, there is need for unconventional approaches to find out the determinants of the real exchange rate and to measure ERM.

In this paper, we attempt to measure ERM in a dynamic time series setting by employing a mean reverting time-varying parameter model. To our knowledge, such a methodology has not been employed before in the literature of ERM. The advantages of such a model will be discussed when the model is introduced in the fourth section.

Another noble idea in this paper is to use data from the field of microstructure finance to determine the real exchange rate. Flood and Rose (1995) argue that the models, that rely on macroeconomic dynamics to determine real exchange rate perform poorly. Evans and Lyons (2002) move in an original direction and introduce the microeconomics of asset pricing. They use order flow data as one of the determinants of the exchange rate and argue that such a specification significantly improves the explanatory power of the model. In our paper we use lagged exchange rate volatility and banking sector's foreign capital flows to account for the dynamics of microeconomic structure of the economy.

We also employ conventional macro-based variables to acquire an appropriate structural picture for the Turkish economy.

The plan of the paper is as follows. In the next section, we briefly summarize the literature on ERM and single equation models, which dominated the field of ERM in the recent years. Following a brief review of the salient characteristics of the foreign exchange market in Turkey in section 3, the model is introduced, and its advantages are discussed in section 4. After presentation of the estimation results, we conclude in section 5.

2 Literature Review

As Kaminsky et al. (1998) mentions, the overvaluation of exchange rates has been a potential predictor of currency crisis in emerging economies. Also Cottani et al. (1990) and Ghura and Grennes (1993) find evidence for strong positive relationship between ERM and lower economic growth. These findings suggest that there are potential gains from analyzing the dynamics of ERM.

The literature on ERM follows two distinct paths: PPP-based models and single equation models. Models using the PPP-based definitions of the equilibrium exchange rate are known to suffer from their lack of empirical fit in the short and medium term horizons (Frenkel 1981, Meese and Rogoff 1983a, 1983b). Therefore, in the recent years, more emphasis is based on single equation models. Such models start with choosing a group of variables (often called fundamentals) that are assumed to affect the real exchange rate. Time series techniques are then used to estimate a real exchange rate equation, with the most common estimation method being a vector error correction model. Next, the fundamentals are decomposed into transitory and permanent components, usually by an appropriate filter. After permanent components of the fundamentals are inserted into the estimated exchange rate equation, the resulting fitted time series is interpreted as the equilibrium real exchange rate. Finally, deviations between the estimated equilibrium rate and the actual real exchange rate yield the degree of structural misalignment of the model.

Although single equation models dominated the field of ERM in the recent years, they also have serious shortcomings. These are discussed at length by Edwards (2001) and Edwards and Savastano (1999). First, these models implicitly assume that the real exchange rate is in a stable equilibrium during the period under the study, which need not be the case. Second, the role of debt accumulation and current account dynamics are often ignored. Third, most of these models do not specify any relationship between the real exchange rate and other key macroeconomic variables. Fourth, as mentioned in Baum and Barkoulas (2001), Error Correction Models, which are widely used in single equation models may not be appropriate due to fractional behavior in the disequilibrium term. Finally, as emphasized in Evans and Lyons (1999), most of the empirical studies on exchange rate economics rely on macroeconomic data, and ignore some of the key micro-based data, like the order flow, which reflect the buying/selling pressure on the exchange rate. Moreover, the banking sectors in many emerging countries breed volatile capital movements, which may significantly affect the exchange rate dynamics in the domestic asset markets.

This study takes the above mentioned criticisms as its starting point and introduces a dynamic time series model to explain the exchange rate misalignment in Turkey within a single-equation framework. The advantages and possible shortcomings of employing such a model and the variables used will be discussed in section four below. We now turn to a brief discussion of the recent developments of the Turkish economy.

3 Patterns of the Turkish Exchange Rate over the 1990s.

Turkey adopted convertibility of the *Lira* in early 1990. By then all foreign exchange transactions on the capital account were already liberalized. In retrospect, this move is regarded to be pre-mature and over-hasty. Without correcting for macro fundamentals and without taking the necessary steps to ensure prudential regulation of the banking sector, the domestic goods and asset markets felt undue strains in adjusting the volatile conditions of open international competition. Boratav, Yeldan and Köse (2002), Cizre-Sakallıoğlu and Yeldan (2001), Öniş and Aysan (2000), and Yentürk (1999) for instance, point out that important fragility indicators such as the ratio of short term foreign debt to Central Bank reserves, and the standard ratios of financial deepening revealed that the Turkish foreign exchange market was not yet ready for graduation for opening up to the speculation of international arbiters.

We report the main parameters affecting the Turkish foreign exchange market in Table 1. As can be seen, Turkey continued to display significant fragility with short term foreign debt to CB reserves [4] exceeding 100%, and M2Y to CB reserves over 300%.

To this fragile picture, an added set of pressures originated from the public sector's increased borrowing requirements (PSBR). In fact, with the advent of full-fledged financial liberalization after 1989, the PSBR financing relied exclusively on issues of government debt instruments (GDIs) to the internal market, especially the banking sector. The stock of domestic debt was only 6% of the GNP in 1989. It grew rapidly and reached to 42.8% in 1995, and to 59.1% in 2000 (Table 1).

⟨Insert Table 1⟩

The underlying characteristic of the domestic debt management was its extreme short-termism. Net new domestic borrowings, as a ratio of the stock of domestic debt continued at a pace of above 50% for most of the decade. Thus, the public sector has been trapped in a short term rolling of debt, a phenomenon characterized as Ponzi-financing in the fiscal economics literature. For this scheme to work, however, domestic financial markets necessitated the continued inflow of short-term capital inflows. Thus, the episode of hot money inflows should be interpreted, in the Turkish context, as the long arm of fiscal policy, overcoming credit restraints and monetary constraints of the monetary authority.

[4] Rodrik and Velasco (1999) regard this ratio as the most robust indicator of a currency crisis. For comparison, at the outbreak of the financial crisis in Asia in 1997, this ratio was 60% in Malaysia; 90% in Philippines; 150% in Thailand; and 170% in Indonesia.

In fact, with the implementation of positive interest rates, and the new possibility of foreign exchange accounts, the advance of financial deepening for the private households has meant increased foreign exchange deposits with substantial currency substitution. Thus, it can be stated that the "pioneers of financial deepening" in Turkey in the 1980's and 90's have been the public sector securities and the foreign exchange deposits. The major brunt of the costs of this fragile environment, however, fell on the productive sphere of the economy, especially the traded sectors. High real interest rates and overvaluation of the domestic currency generated dis-incentives to exporters, productive entrepreneurs and contributed to a widening trade deficit.

Finally in December 1999 the government adopted another disinflation program, aiming at decreasing the inflation rate to a single digit by the end of 2002. Aided with the supervision and technical support of the IMF, the new program relied on exchange rate based disinflation and monetary control by setting upper limits to net domestic asset position of the Central Bank (CB). Accordingly the CB committed itself to a policy of no sterilization, whereby changes in the monetary base would directly reflect changes in the net foreign assets of its balance sheet. The program further entailed a series of austerity measures on fiscal expenditures and set specific targets for the balance on non-interest, primary budget.

In what follows, the program announced that the rate of currency depreciation would be set according to a pre-announced calendar, thereby setting the course for the evolution of the exchange rate throughout the year. For this purpose, the CB declared an exchange rate basket consisting of 1US$ + 0.77 Euro, and announced a daily calendar of depreciation rate which adds up to a cumulative 20 percent by the end of 2000. The pre-announcement of the exchange rate depreciation according to such a tablita was regarded as the backbone of the program in its attempt to break the inflationary inertia of three decades.

The Turkish disinflation program suffered further from the unavoidable appreciation of the Lira, and together with the elimination of exchange rate risk, it was regarded as a clear sign for increased foreign borrowing. The rapid escalation of the stock of foreign debt mostly originated from increased short term borrowing which, as under most circumstances, was exercised at a rate exceeding the social optimum. Given the fragile environment it was set in, the unsustainable character of short term indebtedness, with the widening of the current account deficit throughout 2000, led to a sudden capital outflow and the surrender of the pegged exchange rate system in February 2001.

Lira's experience under the free float since February had been a significant depreciation until October, followed by nominal stabilization since then. The nominal stabilization of the Lira against an ongoing price inflation averaging 3% on a monthly basis brought questions of "over"-valuation. With the Central Bank's declaration of instrument independence for controlling inflation, and given its clear stance that it would not set targets for the exchange rate, traded sectors' producers raised concerns of losing competitiveness. Yet, given that the purchasing power parity (PPP) comparisons of exchange rate misalignment offer poor guidance, such claims had become a matter of unresolved controversy.

A particularly important unresolved issue in analyses of the PPP measure has been the choice of the proper base year. For instance, given the wholesale price index, choosing October 2001 as the base year reveals an "overvaluation" of the TL by 27%. If February 2001 is regarded as the base, the rate of overvaluation becomes 5.7%. Per contra, using the consumer rather than producer prices, we observe that Lira is still "under"-valued in comparison to its February 2001 value by 5.2%. On a broader time horizon, if we look at the state of the Lira in comparison to 1989 -the year of capital account liberalization, we calculate an overvaluation of 18%.

The Figures below display the paths of the index of the nominal value of the TL against the US$ together with alternative price indexes assuming different base periods.

⟨Insert Figures 1-2-3 here⟩

Our message from this exercise is clear: given a high inflationary embedded within financial and fiscal fragility, measuring exchange rate misalignment through simplistic PPP calculations are of little use. For this task one needs the guidance of a proper structural model. It is to this task we turn in the next section.

4 The Model

A mean-reverting time-varying parameter model is employed to measure ERM for Turkey. Such an approach has several desirable characteristics: The coefficients of the variables which determine the equilibrium real exchange rate are allowed to deviate from their sample mean over time. Therefore, the real exchange rate need not be in a stable equilibrium over the period considered. Such an approach will not face the criticism that Edwards (2001) and Edwards and Savastano (1999) note for single-equation models. The unpleasant characteristics of Error Correction Models mentioned in Baum and Barkoulas (2001) are also avoided in such a formulation. Finally, conventional macro models along with micro-based variables such as order flow and short-term capital movements are used, resulting in a compact model to determine the equilibrium real exchange rate. Consequently, most of the important criticisms that authors bring for single equation models are not faced in our model.

4.1 Time-Varying Parameter Models

Time-varying parameter models have been extensively used in the macroeconomics and finance literature (See Hamilton (1994) for a detailed discussion and literature survey). These models are extensions of state space models where a powerful recursive algorithm, Kalman Filter, is used for estimation purposes. The general form of such models are presented in the Appendix.

As discussed before, the model that will be employed to measure exchange rate misalignment is a mean-reverting time-varying parameter model, where the variables that are assumed to affect equilibrium real exchange rate have varying coefficients over time. Such a formulation allows us to track the changing effects of different micro-based and macro-based variables on the real exchange rate. Moreover, the difference between the estimated real exchange rate with changing parameters each period and the real exchange rate itself will give us a measure of the exchange rate misalignment. The model can be defined as:

$$y_t = X_t^{'}\beta_t + w_t \tag{1}$$

$$\left(\beta_{t+1} - \bar{\beta}\right) = F\left(\beta_t - \bar{\beta}\right) + v_{t+1} \tag{2}$$

where y_t is the real exchange rate, X_t is $(k \times 1)$ vector that includes the regressors. These regressors are lagged values of the real exchange rate, exchange rate volatility, short-term capital movements, and conventional macro variables. The regressors are independent of w_τ for all τ. The second equation is the state equation in state space models and implies that the deviations of the coefficients of the regressors from their sample means (their steady state values) follow an AR(1) process[5].

If the eigenvalues of $(k \times k)$ matrix F are inside the unit circle, then $\bar{\beta}$ is the average (steady state) value for the coefficient vector. It is also assumed that

$$\left[\begin{array}{c} v_{t+1} \\ w_t \end{array} |X_t, Y_{t-1}\right] \sim N\left(\left[\begin{array}{c} 0 \\ 0 \end{array}\right], \left[\begin{array}{cc} Q & 0 \\ 0 & \sigma^2 \end{array}\right]\right)$$

Then the last three equations are recognized as a state space model of the form with state vector $\xi_t = \beta_t - \bar{\beta}$. The regression can be written as

$$y_t = X_t^{'}\bar{\beta} + X_t^{'}\xi_t + w_t$$

[5] Note that we can also generalize the state equation to a p^{th} order Vector Autoregression (VAR) for the coefficient vector β_t by defining $\xi_t^{'} \equiv \left[\left(\beta_t - \bar{\beta}\right)^{'}, \left(\beta_{t-1} - \bar{\beta}\right)^{'}, ..., \left(\beta_{t-p+1} - \bar{\beta}\right)^{'}\right]$ and replacing the state equation accordingly.

which is the observation equation of the form $y_t = a(X_t) + [H(X_t)]^{'} \xi_t + w_t$ with $a(X_t) = X_t^{'}\overline{\beta}$, $H(X_t) = X_t$ and $R(X_t) = \sigma^2$. Then, these values can be used in the Kalman Filter equations described before.

In this case, the log-likelihood function to be maximized will be as:

$$\sum_{t=1}^{T} \log f(y_t|X_t, Y_{t-1}) = -\frac{T}{2}\log(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\log(X_t^{'}P_{t|t-1}X_t + \sigma^2) -\frac{1}{2}\sum_{t=1}^{T}(y_t - X_t^{'}\overline{\beta} - X_t^{'}\hat{\xi}_{t|t-1})^2/(X_t^{'}P_{t|t-1}X_t + \sigma^2)$$

4.2 Data and The Estimation Technique

Our data consist of two parts: micro-based variables and conventional macro variables. All of the variables are monthly observations. The variables that we used in performing the analysis include exchange rate volatility (used as a proxy for the order flow data that Evans and Lyons(1999) use in their study), short term capital movements, industrial production, inflation based on consumer price index, monthly budget balance of the public sector, openness, and lagged values of these variables.

Exchange rate volatility is obtained as the standard deviation of daily exchange rate observations in a month. Openness is the ratio of the sum of exports and imports in the gross domestic product. For the short term capital flows, (CREDIT) we have implemented two alternative data specifications: monthly volume of *gross* versus *net* short term foreign credit obtained by the banking sector. The distinction between gross versus net flows of foreign capital is not trivial, and our underlying motivation is to capture their differential impact of the CREDIT variable on the agents' perceptions of availability of short term capital as well as the fragility embedded in its volatility. This distinction is convincingly emphasized in Tobin (2000: 1101-1102) where he argues that "(i)t is only the net transfers that carry the economic benefits. (Yet) it is the gross, speculative transactions which carry with them the destabilizing effects leading to financial crises and severe real economic downturns. Given that exchange rate volatility is directly affected from the gross volume of capital flows and that currency appreciation is regarded as one of the key indicators of a culminating financial crisis (see, e.g. Calvo and Vegh, 1999, Kaminsky, Lizondo, and Reinhart, 1998), we find it important to address both considerations by distinguishing two alternative modeling specifications over the CREDIT variable. For robustness check, we used alternative measures for inflation, output and short term capital movements. Finally, the sample period is between January 1992 and December 2001.

The first step in the estimation process is to select the appropriate model to estimate real exchange rate. Akaike Information Criteria (AIC) and Schwarz Information Criteria (SIC) were used for this purpose. Among many models estimated, the best model, which gave the lowest AIC and SIC values is found as:

$$\begin{aligned} rer_t &= \beta_{1t} rer_{t-1} + \beta_{2t} rer_{t-12} + \beta_{3t} ervol_{t-1} + \beta_{4t} ip_t + \\ & \quad \beta_{5t} ip_{t-1} + \beta_{6t} ip_{t-12} + \beta_{7t} cpi_t + \beta_{8t} cpi_{t-12} + \beta_{9t} Creditnet_{t-1} + \varepsilon_t \end{aligned} \tag{3}$$

where rer_t is the real exchange rate at time t , $ervol$ is the exchange rate volatility, *ip* is the industrial production, *cpi* is the inflation based on consumer price index, *Creditnet* is the short-term net capital flows.

The simple OLS estimates for this equation along with the test statistics can be seen in Table 2.

Table2 states that all variables employed are significant except the first lagged value of the industrial production. Other than the first lagged value of the real exchange rate, the most important variable in determining the real exchange rate is exchange rate volatility, which also has the expected sign. An increase in the volatility of the real exchange rate in the last period leads to a depreciation of Turkish Lira in the next period, most probably through an expectations channel. It is worth remembering that one of the most important determinant of the exchange rate in Evans and Lyons (1999) was order flow data, for which we used exchange rate volatility as a proxy. Another surprising result is the unimportance of net short term capital movements. Although it is statistically significant at 10% significance level, its effect on real exchange rate is negligible.

The next step is to formulate the state space system and obtain time series for each coefficient. The state space system can be written as:

$$rer_t = X_t^{'}\beta_t + w_t \tag{4}$$

$$\left(\beta_{t+1} - \bar{\beta}\right) = F\left(\beta_t - \bar{\beta}\right) + v_{t+1} \tag{5}$$

where X_t is the 9×1 vector of regressors. As mentioned above, we assume return to normality assumption for the evolution of the coefficients.

After the state space system is estimated via Kalman Filter, the series for each of the nine coefficients are obtained. However, since we use lagged values in estimating the real exchange rate equation we have less than 120 observations for the coefficient series.

The next step is to generate an implied real equilibrium exchange rate. This can be done simply by multiplying each period's coefficient vector with the regressor vector. Then, in the final phase, the difference between the real exchange rate and the generated (implied) real exchange rate gives the level of the exchange rate misalignment based on the structure of our model.

Formally, $erm_t = rer_t - grer_t$, where erm denotes the exchange rate misalignment. If $erm \prec 0$, then it means that The Turkish Lira is structurally undervalued. It is structurally overvalued when $erm \succ 0$. The graph for erm can be seen in Figure 4 at the end of the text. Also, the generated erm series is presented in Appendix 2.

Our results indicate that following the crisis in 1994, The Turkish Lira remained mostly overvalued until the beginning of 1998, in the aftermath of the Asian crisis. After then, we mostly observe an undervalued Lira until the end of 1999. At that point, the negative effect of the Russian crisis and the earthquake are worth mentioning. In December 1999, the IMF-backed disinflation program was introduced. An overvalued currency was targeted to reduce inflation at early stages of the program. However, we find that the Lira was structurally overvalued during the first 4 months of the 2000 disinflation program, while the rest of 2000 witnessed structural undervaluation of the domestic currency. This finding is contrary to the common wisdom based on simple PPP calculations. The sizable devaluation of the Turkish Lira can easily be seen in February 2001, when the currency crisis took place and the disinflation program was officially abandoned. The degree of undervaluation was at its peak during July and August of 2001. Finally, in our latest observation, we see that the Lira began to appreciate and entered into an overvaluation period. It seems that the nominal stabilization of the Lira following October of 2001 has revealed itself as a structural misalignment (overvaluation) late in December.

4.2.1 Robustness Check and Alternative Specifications

To understand whether the results presented above is sensitive to alternative specifications, we performed the analysis using several other variables. We used monthly GDP, and monthly inflation based on wholesale price index, as alternatives to variables *ip* and *cpi*. Moreover, we included two other measures of net short term capital movements.

One important result of this exercise regards the significance of short term *gross* capital inflows, as an alternative to *net* capital flows. Such a finding supports the hindsight put forth by Tobin (2000). Also, it is worth mentioning that the effect of exchange rate volatility has decreased and its significance was reduced dramatically when gross capital inflows was used in the regressor vector. The state space system is estimated also by taking the model in Table 3 as the observation equation. However, the log-likelihood of the model was found to be much lower than the original specification and most of the coefficients turned out to be not statistically significant.

Furthermore, two alternative specifications about the evolution of the parameters of the model were estimated. These specifications assume "random walk", and "constant mean", respectively. These can be formulated as:

$$\begin{aligned} \text{Random Walk} \quad &: \quad \beta_{t+1} = F\beta_t + \eta_t \\ \text{Constant Mean} \quad &: \quad \beta_{t+1} = F\bar{\beta} + \eta_t \end{aligned}$$

After the system is estimated with each of these specifications, it is observed that the system with random walk assumption had a very high negative likelihood value, which makes it inferior to the original model. Also, the estimated exchange rate misalignment using the "random walk" assumption predicted deviations of very small magnitude than the real exchange rate, which reduces its plausibility. On the other hand, the estimation with the "constant mean" assumption was cumbersome, and no reasonable results could be obtained due to a singular matrix in the Kalman Filter updating equation.

As a consequence, the above analysis reveals that the original specification presented in the previous subsection is robust to the usage of several alternative variables, and it gives the most reasonable results when compared with other models assuming "random walk" and "constant mean" assumptions about the evolution of the parameters over time.

5 Conclusion

The purpose of this paper was to come up with a measure for real exchange rate misalignment for Turkey, which has already undergone a severe economic crisis.

However,the conventional PPP models can not successfully explain the dynamics of exchange rate, at least in the short and medium run. Single equation models are proposed as an alternative to have a measure for exchange rate misalignment. However, these models also have shortcomings, as highlighted in the literature. This paper takes these criticisms as its starting point and employs a time-varying parameter model within a single equation framework for Turkey. We assume a return-to normality assumption about the parameters, generate an implied real exchange rate series by multiplying the parameter vector with the regressor vector for each period. Then, the difference between the real exchange rate and the implied rate gives a measure of exchange rate misalignment.

It is found that, following the economic crisis in 1994, the Turkish Lira was overvalued for four consecutive years. Then, excluding the first four months of 2000 and the short period of April 2001 and May 2001, we observe a structurally undervalued Turkish Lira. The nominal standstill of the Lira starting October 2001 gave way to structural overvaluation only late in the year, by December 2001. It is a matter of availability of new data to answer whether Turkish Lira continues to be undervalued in 2002.

Finally, the results remained robust to usage of alternative variables. The alternative specifications about the behavior of time-varying parameters gave inferior results.

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Appendix1: Time-Varying Parameter Models

Time-Varying parameter models can be written as:

$$\begin{aligned} \xi_{t+1} &= F(X_t)\xi_t + v_{t+1} \\ y_t &= a(X_t) + [H(X_t)]' \xi_t + w_t \end{aligned}$$

where the first equation is called as the state equation and the second one is the observation equation. $F(X_t)$ is $r \times r$ matrix, whose elements are functions of X_t ; $a(X_t)$ is an $n \times 1$ vector-valued function, and $H(X_t)$ is an $r \times n$ matrix-valued function. Let $Y_{t-1} \equiv (y'_{t-1}, y'_{t-2}, ..., y'_1, X'_{t-1}, X'_{t-2}, ..., X'_1)'$. Then, the disturbance vector $(v'_{t+1}, w'_t)'$ has the following distribution:

$$\left[\begin{pmatrix} v_{t+1} \\ w_t \end{pmatrix} | X_t, Y_{t-1} \right] \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} Q(X_t) & 0 \\ 0 & R(X_t) \end{bmatrix} \right)$$

It follows from the above equations that

$\left[\begin{pmatrix} \xi_t \\ y_t \end{pmatrix} | X_t, Y_{t-1} \right]$ is normally distributed as:

$$N\left(\begin{array}{c} \begin{bmatrix} \hat{\xi}_{t|t-1} \\ a(X_t) + [H(X_t)]' \hat{\xi}_{t|t-1} \end{bmatrix}, \\ \begin{bmatrix} P_{t|t-1} & P_{t|t-1}H(X_t) \\ H'(X_t)P_{t|t-1} & [H(X_t)]' P_{t|t-1}H(X_t) + R(X_t) \end{bmatrix} \end{array} \right)$$

Finally, in order to estimate the parameters of the system, we execute the Kalman Filter, which can be defined by the following updating equations:

$$\hat{\xi}_{t|t} = \hat{\xi}_{t|t-1} + \left\{ \begin{array}{c} P_{t|t-1}H(X_t) \left[[H(X_t)]' P_{t|t-1}H(X_t) + R(X_t) \right]^{-1} \\ \times \left[y_t - a(X_t) - [H(X_t)]' \hat{\xi}_{t|t-1} \right] \end{array} \right\}$$

$$P_{t|t} = P_{t|t-1} - \left\{ P_{t|t-1} H(X_t) \left[[H(X_t)]^{'} P_{t|t-1} H(X_t) + R(X_t) \right]^{-1} \left[H^{'}(X_t) P_{t|t-1} \right] \right\}$$

Since $\overset{\wedge}{\xi}_{t+1|t}|y_t \sim N(\overset{\wedge}{\xi}_{t+1|t}, P_{t+1|t})$ where

$$\begin{aligned} \overset{\wedge}{\xi}_{t+1|t} &= F(X_t)\overset{\wedge}{\xi}_{t|t} \\ P_{t+1|t} &= F(X_t) P_{t|t} \left[F(X_t) \right]^{'} + Q(X_t) \end{aligned}$$

These last four equations constitute the Kalman Filter equations.

Appendix 2: ERM Series

1994:07	-2.90	1994:08	-0.84
1994:09	-1.13	1994:10	2.76
1994:11	2.53	1994:12	6.39
1995:01	2.07	1995:02	11.87
1995:03	10.16	1995:04	4.12
1995:05	7.80	1995:06	10.26
1995:07	13.43	1995:08	13.28
1995:09	14.58	1995:10	9.75
1995:11	4.86	1995:12	3.13
1996:01	9.15	1996:02	3.08
1996:03	2.60	1996:04	5.37
1996:05	2.29	1996:06	-0.09
1996:07	-1.71	1996:08	2.06
1996:09	1.31	1996:10	1.01
1996:11	-0.40	1996:12	-0.71
1997:01	0.69	1997:02	6.48
1997:03	2.25	1997:04	4.27
1997:05	-0.31	1997:06	-0.95
1997:07	3.52	1997:08	1.80
1997:09	0.98	1997:10	1.78
1997:11	0.89	1997:12	1.49
1998:01	5.93	1998:02	1.43

1998:03	-2.42	1998:04	0.53
1998:05	-2.59	1998:06	-2.98
1998:07	-2.69	1998:08	-2.35
1998:09	-0.66	1998:10	-4.22
1998:11	-3.57	1998:12	-3.84
1999:01	0.08	1999:02	-0.35
1999:03	-0.29	1999:04	0.73
1999:05	-2.29	1999:06	-1.29
1999:07	-0.83	1999:08	0.81
1999:09	-0.76	1999:10	-0.74
1999:11	-2.83	1999:12	2.86
2000:01	5.76	2000:02	4.18
2000:03	1.72	2000:04	-0.93
2000:05	-0.69	2000:06	-6.43
2000:07	-2.36	2000:08	-3.15
2000:09	-3.21	2000:10	-5.40
2000:11	-1.48	2000:12	-2.16
2001:01	0.40	2001:02	-5.08
2001:03	-4.71	2001:04	3.99
2001:05	3.22	2001:06	-3.80
2001:07	-8.56	2001:08	-8.44
2001:09	-4.51	2001:10	-4.57
2001:11	-1.84	2001:12	3.64

Table 1. Basic Characteristics of the Turkish Foreign Exchange Market, 1995-2001

	1995	1996	1997	1998	1999	2000	2001
Rate of Change of the Nominal Exchange Rate (TL/$)	54.0	77.0	86.6	71.7	60.6	49.3	95.8
Macroeconomic Prices							
Inflation (WPI)	86.0	75.9	81.8	71.8	53.1	51.4	61.6
Inflation (CPI)	89.1	79.3	85.7	84.6	64.9	54.9	54.4
Real Interest Rate on GDIs	18.1	31.1	22.1	29.5	36.8	-8.8	21.4
Real Wage Growth Rates[a]							
Public Sector	-17.1	-25.0	19.1	-1.3	42.0	6.9	-11.5
Private Sector	-8.3	1.9	-3.0	16.9	11.6	1.0	
Real Rate of Growth							
GDP	7.2	7.0	7.5	3.1	-5.0	7.2	-9.5
Exports	19.5	7.3	13.1	2.7	-1.4	4.5	12.3
Imports	53.5	22.2	11.3	-5.4	-11.4	34.0	-26.0
As Ratio to the GNP (%)							
Current Account Balance	-1.4	-1.3	-1.4	1.0	-0.7	-4.8	1.4
Stock of Foreign Debt	42.8	46.2	47.8	47.2	55.7	59.1	74.3
Budget Balance	-4.0	-8.3	-7.6	-7.0	-11.6	-10.9	-15.6
PSBR	5.2	8.8	7.6	9.2	15.1	12.5	15.9
Fragility Indicators							
Short Term Foreign Debt / CB International Reserves (%)	128.7	104.2	95.1	105.4	98.9	127.6	85.9
M2Y / CB Inter. Reserves (%)	354.0	314.1	287.8	321.8	329.4	381.4	380.6
Currency Substitution[b]	54.8	50.9	48.6	45.1	45.2	44.1	56.2
Interest Paym. on Dom. Debt / Total Tax Revenues (%)	43.9	59.2	41.7	61.0	66.4	63.7	103.4
Interest Paym. on Dom. Debt / Net New Dom. Borrowing (%)	93.7	83.1	63.5	97.9	87.5	137.8	47.2
Net New Dom. Borrowing / Domestic Debt Stock (%)	52.4	57.8	52.4	49.5	49.3	37.1	70.2

Sources: SPO *Main Economic Indicators* ; Undersecreteriat of Treasury, *Main Economic Indicators; Central Bank A*

a. Data compiled from the Turkish Employers Association and the Confederation of Public Employers Unions, as reported in the Central Bank Annual Reports. Nominal wages are deflated using the CPI (1994=100).

b. (Rate of Dollarization): Ratio of foreign exchange deposits to total deposits of residents.

TABLE 2. OLS ESTIMATES FOR THE MODEL

Variable	Coefficient	Std. Error	t-stat
$\mathbf{rer}_{t-1}$	0.78	0.0489	15.92
$\mathbf{rer}_{t-12}$	0.164	0.0462	3.55
$\mathbf{ervol}_{t-1}$	-0.519	0.2260	-2.29
$\mathbf{ip}_{t}$	0.131	0.0587	2.23
$\mathbf{ip}_{t-1}$	-0.046	0.0475	0.96
$\mathbf{ip}_{t-12}$	-0.111	0.0557	-1.99
cpi	-0.392	0.1147	-3.41
$\mathbf{cpi}_{t-12}$	0.227	0.1168	1.94
$\mathbf{creditnet}_{t}$	0.001	0.0008	1.87

$R - Squared : 0.87$

$Adjusted\ R - Squared : 0.86$

$AIC : 5.09$

$SIC : 5.31$

$F - Statistic : 84.98$

TABLE 3. ALTERNATIVE MODEL

Variable	Coefficient	Std. Error	t-stat
$\mathbf{rer}_{t-1}$	0.826	0.0486	16.97
$\mathbf{rer}_{t-12}$	0.113	0.0453	2.50
$\mathbf{ervol}_{t-1}$	-0.260	0.2378	-1.09
$\mathbf{ip}_{t}$	0.105	0.0596	1.76
$\mathbf{ip}_{t-1}$	0.049	0.0475	1.04
$\mathbf{ip}_{t-12}$	-0.086	0.0569	-1.51
$\mathbf{cpi}_{t}$	-0.385	0.1157	-3.32
$\mathbf{cpi}_{t-12}$	0.332	0.1111	2.98
$\mathbf{credits}_{t}$	0.302	0.1399	2.16
$\mathbf{credits}_{t-1}$	-0.338	0.1418	-2.38

$R - Squared : 0.71$

$Adjusted\ R - Squared : 0.69$

$AIC : 6.09$

$SIC : 6.31$

$F - statistic : 84.98$

Figure 1
Indexes of the Exchange Rate (TL/$) and Prices (1989 = 100)

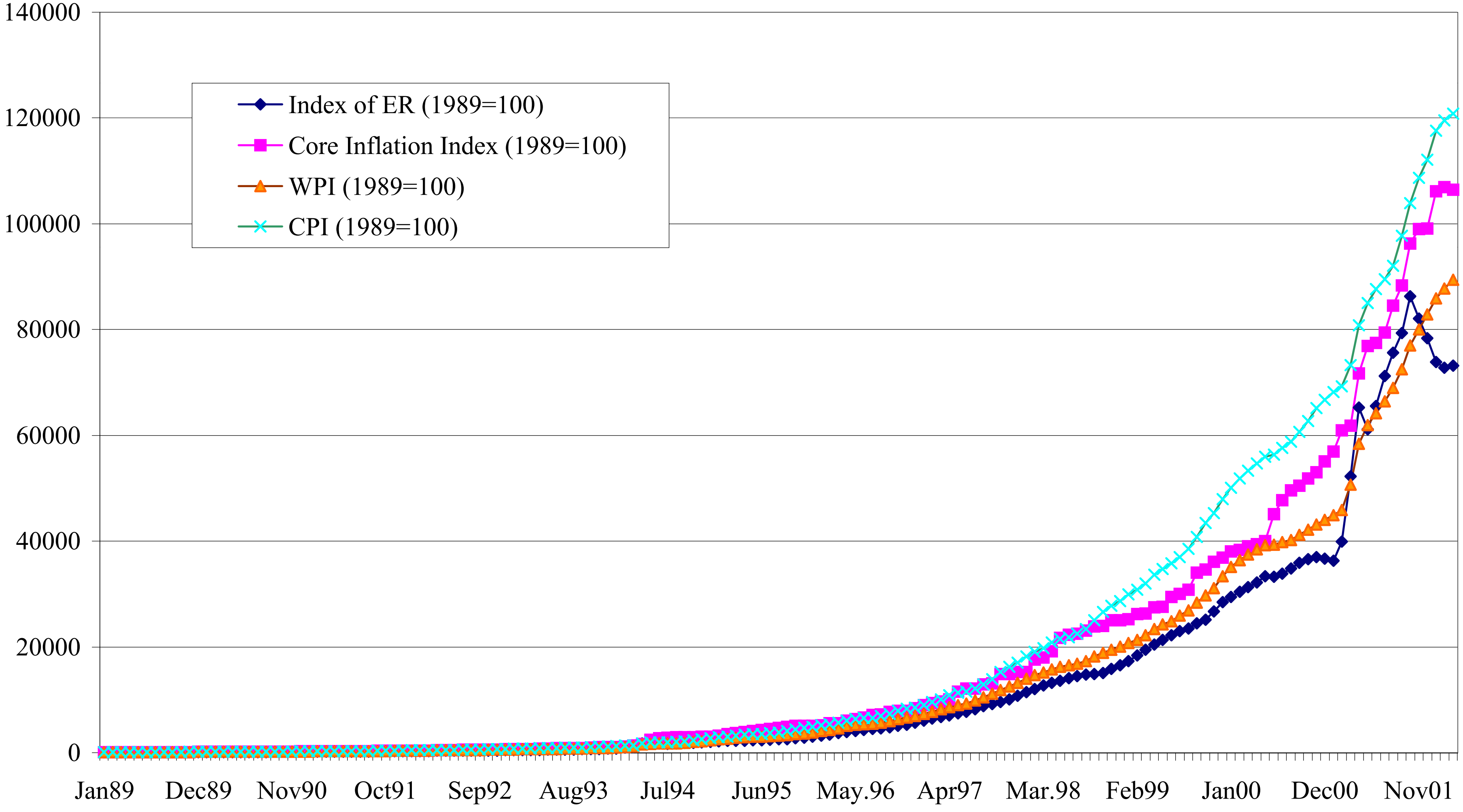

Figure 2
Indexes of the Exchange Rate (TL/$) and Prices (2001 Feb = 100)

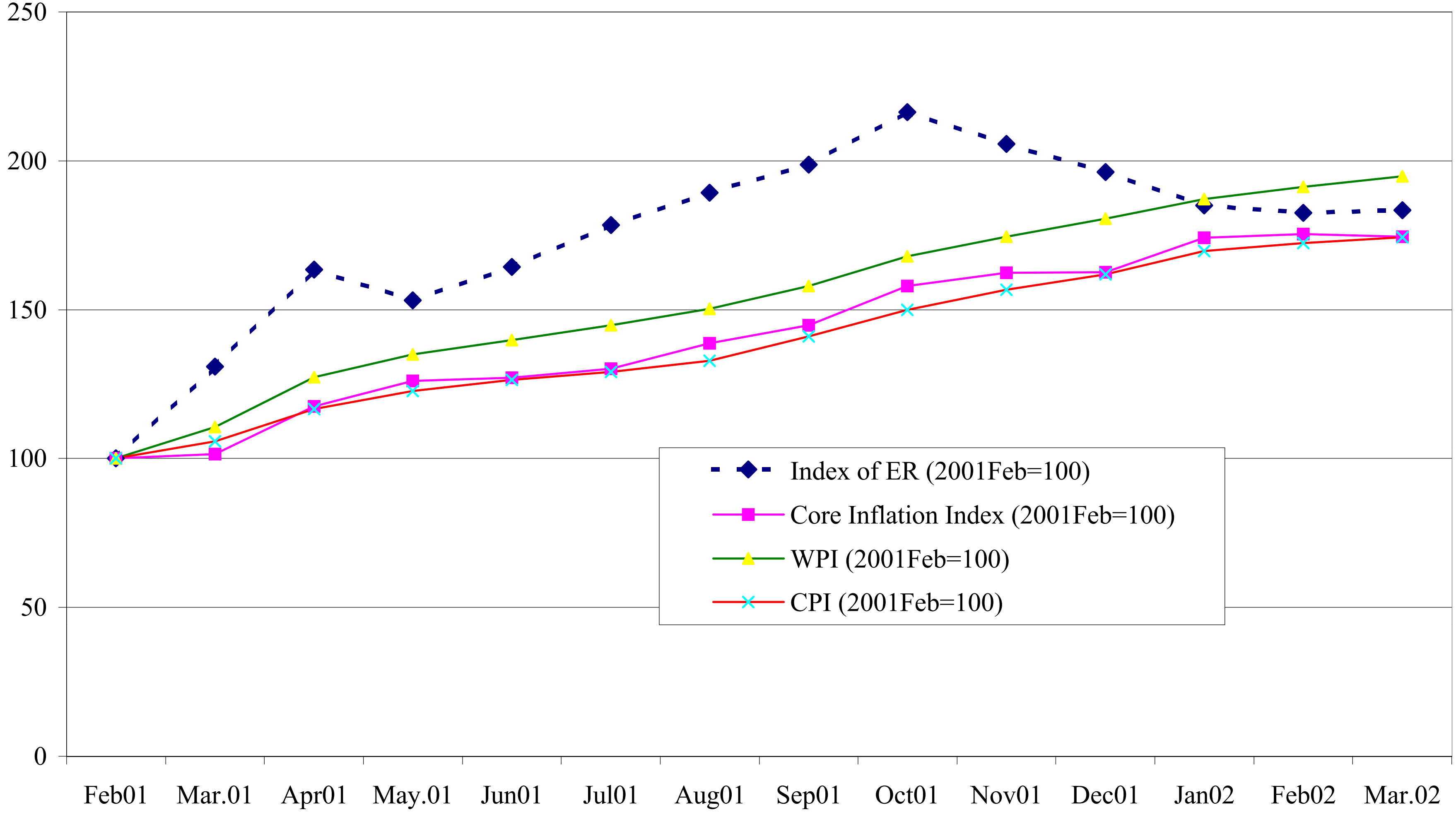

Figure 3. Indexes of the Exchange Rate (TL/US$) and Prices
(October 2001 = 100)

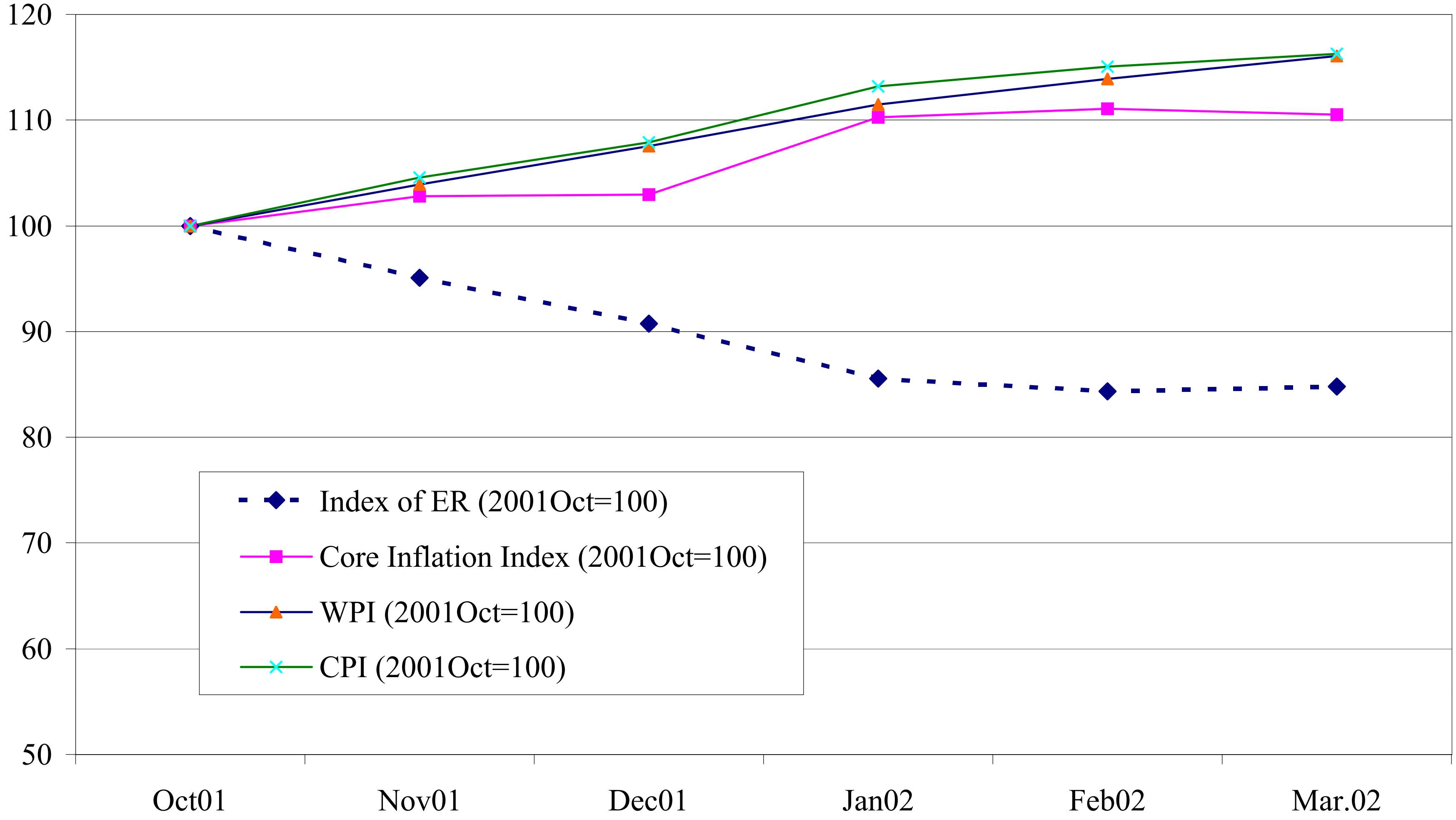

Figure 4: EXCHANGE RATE MISALIGNMENT in Turkey