# Daily Currency Interventions in Emerging Markets: Incorporating Reserve Accumulation to the Reaction Function*

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**Abstract**

This study considers emerging market central bank interventions motivated by international reserve management. Emerging market central banks use currency intervention as a policy tool against exchange rate movements and accumulate international reserves as an insurance against sudden stops or reversals in capital flows. To account for both of these motivations, the model of Ito and Yabu (2007), which is exclusively based on exchange rate targeting, is extended to include the international reserves-to-GDP ratio at a daily frequency. Daily values of the ratio are forecast using the Mixed Data Sampling (MIDAS) model and exchange rate returns. Compared with the benchmark model, we find that the MIDAS model performs better in forecasting the reserve-to-GDP ratio. The extended model is estimated by using the floating exchange rate regime period data of Turkey. We identify breaks in the Turkish intervention policy, and the reserve-to-GDP variable in the extended model is found to have a significant role in the intervention reaction function.

**Keywords:** currency intervention, international reserves, emerging markets, Turkey, mixed data sampling

**JEL classification:** F31, E58, G15, C22, C53

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# 1. Introduction

Currency intervention has been a policy tool regularly used by emerging market central banks in floating exchange rate regimes. The relevance of interventions has been evident during and after the global financial crisis during which emerging markets have experienced large capital flows because of the Quantitative Easing (QE) policies in developed countries. Considering the fact that central banks are not profit driven, theoretical motivations for currency interventions include exchange rate and international reserve management related purposes. Unlike the few advanced economies who still use currency interventions, such as Japan, both purposes are relevant for emerging markets. However, most of the studies in the literature focus on the exchange rate related purposes. The relation of interventions and international reserves is usually discussed in a context that is disconnected from the exchange rate related motivations. This study extends an intervention policy reaction function developed for advanced economies to include an international reserve component. In this way, the new reaction function is able to address concerns of emerging market economies. It is shown that the extended model captures interventions in Turkey better than the model solely based exchange rates.

Exchange rate interventions have kept their popularity in emerging markets and some advanced economies as a short-term remedy for fluctuations in currency markets. Advanced economies such the US, the UK, Germany, and France, sometimes individually and sometimes in coordination, intervened on currency markets after the Plaza Accord in order to avoid extreme depreciations or appreciations of their currencies.[1] Interventions in deep currency markets (i.e. advanced economies) are considered to have a non-significant impact, whereas in emerging markets the currency markets are thinner.[2]

A further motivation for emerging economies to employ interventions is to accumulate international reserves. Emerging market central banks try to optimize international reserves as an insurance against sudden stops in capital flows (Calvo et al., 2012; Jeanne and Ranciere, 2011) or as a mechanism that would make up for the underdeveloped financial markets (Dominguez, 2010) in exchange for the opportunity cost of the spread between public sector bonds over interest earned from international reserves held. Obstfeld et al. (2010) point out the possibility that capital flights might be financed by withdrawals of bank deposits. In this case, the monetary base will shrink rapidly and will lead to a crisis if the central bank does not have enough international reserves to sustain

1 Although this was not the first period of frequent central bank interventions in advanced economies, it is of particular importance since it occurred after the breakdown of the Bretton Woods system, when no consensus on exchange rate stability was reached. For a historical account to currency interventions, see Bordo et al. (2007).

2 For surveys on central bankers beliefs that currency interventions are efficient, see Neely (2008) and Mohanty and Berger (2013).

the demands as the lender of last resort. Similarly, Frankel and Saravelos (2012) present empirical evidence that countries with higher international reserves were more successful in weathering the global financial crisis compared to the countries with low levels of reserves.

A market participant interested in the probability and efficiency of a central bank intervention might get biased results if she exclusively focuses on one of these two motivations. For instance, as shown by Dominguez et al. (2013) for the case of Czech Koruna (CZK), interventions that are not primarily intended to affect the exchange rate but carried out by reserve management purposes might indeed influence the exchange rates depending on the frequency of interventions. They find that frequent interventions motivated for reserve accumulation affect the exchange rates. The results of the study imply that if all interventions are treated equally and reserve management related interventions are not distinguished, an efficiency analysis will give biased results during a period when there are frequent interventions for reserve management. Therefore, the significance of each motivation of central banks should be clarified and interventions for each motivation should be isolated for a more accurate efficiency analysis of currency interventions.

The contribution of our study to the literature is threefold. First, we extend the infrequent intervention model of Ito and Yabu (2007) by assuming that policymakers optimize a weighted loss function of deviations of exchange rate from a target level and of reserve-to-GDP ratio from a fixed optimal level of reserves. Second, we calculate daily forecasts for reserve-to-GDP ratios, which is a variable that is available only at the quarterly level since it requires GDP data.

Third, as an empirical contribution and illustration, we analyze currency interventions of the Central Bank of the Republic of Turkey (CBRT) during the floating exchange rate regime. Turkey is selected as an empirical case because it is an emerging market that has been intervening to the currency markets both for exchange rate and reserve accumulation purposes, it is one of the countries with the largest optimal reserves-actual reserve gap (Calvo et al., 2012), its intervention data are publicly available, and the CBRT announcements indicate possible changes in its motivations so that implications of the model estimates can be compared with the announcements.

There are four main findings of the study. First, at the daily level, it is possible to generate forecasts for the quarterly reserve-to-GDP ratio that perform better than the benchmark model. Improvements of the forecasts are shown to reach up to 45% of the benchmark model performance. Second, we identify structural breaks in the reaction function of the CBRT. Structural break tests imply there are fragmentations of the CBRT reaction data both for the extended model and the original Ito and Yabu (2007) model. Therefore, analyzing the full sample period might be misleading. Third, the daily reserve-to-GDP variable is found to be significant in the full sample and in the sub-samples, while a comparable pattern is not observed for the exchange rate variables. Fourth, with the extended model, market participants can distinguish false alarms of interventions more successfully. The noise-to-signal ratio analyses show that the extended model gives lower ratios in comparison to the model only with exchange rates. The improvement with the extended model goes up to 20% for US Dollar (USD) purchases.

The study is organized as follows: Section 2 gives an overview of interventions by the CBRT and their motivation. Section 3 derives the infrequent intervention model with reserve-to-GDP levels and notes its interpretation. Section 4 summarizes the dataset used and calculates daily reserve-to-GDP forecasts. Section 5 tests structural breaks in the policy function, while Section 6 reports the estimation results. The final section concludes.

# 2. Intervention Motivations

## 2.1. Intervention Motivations in Emerging Markets

Motivations of policymakers for interventions have been investigated by surveys carried out with central bankers and in the theoretical literature. According to the practices noted in the surveys, addressing developments in the exchange rates either in the level or the volatility have been the top priorities of policymakers (Neely, 2008; Mohanty and Berger, 2013). Furthermore, "discouraging short term capital flows" and foreign exchange reserve management have been noted as other important motivations of central banks (Mohanty and Berger, 2013).

The recent literature that relate currency interventions to capital flow shocks (Cavallino, 2015; Ghosh et al., 2016; Blanchard et al., 2015) and reserve accumulation behavior of emerging markets against sudden-stops (Calvo et al., 2012; Jeanne and Ranciere, 2011) imply that reserve ratios are crucial for intervention decisions. Therefore, for emerging market economies, a currency intervention reaction function that would include both exchange rate and foreign exchange reserve related purposes would be more relevant from a market participants' point of view, instead of deriving a reaction function for each purpose separately.

## 2.2. Intervention Policy of the CBRT

The CBRT has adopted a floating exchange rate regime in 2001. After the breakout of the 2001 financial crisis in Turkey, the floating exchange rate regime has been introduced on 22 February 2001 and as one of the many following financial reforms, the law regulating the CBRT has been amended to give the bank more independence. The CBRT has been intervening in the currency market sporadically with changing motivations under administrations of all three governors until 2015.[3] Description of the CBRT interventions and reasons for selection of the reaction function components used in the study are given in this section.

Currency interventions of the CBRT are either announced interventions with auctions or unannounced direct interventions. In the interventions with auctions, time and maximum amount of foreign exchange to be purchased (sold) are announced beforehand. Sometimes, the number of planned auctions in a certain month is announced as additional information, but the CBRT always reserves the right to stop the interventions or start them as it sees viable. Thus, announced interventions are not deterministic in practice. Unannounced interventions are communicated to the public on the day they are performed and the amounts of the interventions are announced after 15 days of the intervention day. The number of unannounced interventions is small compared to the number of announced interventions.

The amounts of unannounced interventions have been larger than those of the announced ones. Foreign exchange amounts purchased/sold vary between 9 million USD to 2.25 billion USD. There have been cases in which unannounced interventions are 3 or 9 million USD but they are usually more than 300 million USD and in one case reached 5.4 billion USD. Details of the intervention data of the CBRT are given in Section (4).

After 2011, the CBRT has devised other unconventional monetary policy tools in addition to currency interventions. The reserve option mechanism (ROM) has been introduced during late 2011 as a stabilizing policy tool (Değerli and Fendoğlu, 2015). At the beginning of 2014, after the sudden depreciation of the Turkish Lira (TRY) against the USD, the CBRT started directly financing the foreign exchange demands of the oil importing state owned enterprises. These policy changes should be addressed in studies on effectiveness of currency interventions or dropped from the sample (Onder and Villamizar, 2015).

The CBRT has been cautious in its communications with respect to the floating exchange rate regime and the aim of currency interventions. Most of the time, the aim is put as "increasing market volatility and calming disorderly markets". The wording of the exchange rate policy of the CBRT has been changed after 2012. The CBRT's "Monetary and Exchange Rate Policy for 2013", which is published in December 2012 (CBRT, 2012), repeats the central bank's message of "no target" but also includes the statement "...Nonetheless, with a view to limiting the risks to the financial stability, the CBRT does not remain unresponsive to the excessive appreciation or depreciation of the TL...". The

[3] The governors of the CBRT from 2001 till 2015 are Süreyya Serdengeçti (14/03/2001-14/03/2006), Durmuş Yılmaz (18/04/2006-13/04/2011) and Erdem Başçı (14/04/2011-19/04/2016).

statement implies that even though the CBRT does not have a strict target for the exchange rate as in the case of a fixed exchange rate or pegged regime, it does make its comparisons of "excessive appreciation or depreciation" with an interval in mind. In some of the press releases regarding interventions (CBRT, 2009) and exchange rate policy texts (CBRT, 2007a), the need for building foreign exchange reserve as an emerging market economy has been noted by pointing at the "right" periods to do so.

Despite the recent literature given above on the connection of interventions and capital flows; Figures (1) and (2), which include quarterly net capital flows to Turkey and quarterly net interventions by the CBRT respectively, show why an approach based on capital flows may not be the correct approach for the case of Turkey. Intuitively, net capital inflows (outflows) should decrease (increase) the USD/TRY exchange rate level and based on the movement in the exchange rate; the CBRT should increase (decrease) its foreign exchange reserves, which means it intervenes to the market by purchasing (selling) USD.[4] However; counter intuitively, the figures show that the CBRT intervened to the markets only by selling USD after 2011 even though there are persistent capital inflows to Turkey after this date. Besides, in the ad hoc classification of Blanchard et al. (2015) based on the reaction to capital flows, Turkey is classified as a non-intervener country. Therefore, an approach directly based on capital inflows is not taken here.

In addition to the referred literature on the reserve accumulation in emerging economies, a reaction function based on deviations from an exchange rate target and reserve optimization is selected for two reasons. The first reason is that intuitively the target in this reaction function does not mean a level of exchange rate that is to be protected as in a fixed exchange rate regime; but it rather refers to a smoothed path for the exchange rate based on the history. Indeed, such attempts by policymakers to smooth the impact of the shocks in the currency markets are found to be very effective (Fratzscher et al., 2015).

The same reasoning of an "implicit target for smoothness" can be applied to other periods unless the motivation for currency interventions is explicitly communicated differently. Such a period started after 2006 in which the CBRT's press releases about currency interventions motivated by exchange rate reserve management. During this period, the CBRT explicitly announced that the main motivation for some of the interventions is reserve accumulation referring to the need of strong international reserves for emerging markets.

The second reason is related to the traceability of the central bank behavior. From a market participant point of view, a target level of exchange rate based on short and long-term deviations is much easier to track than volatility of exchange rates, which might be subject to model specification errors. There is no consensus on how to model the

[4] The exchange rate of TRY at time $t$ is expressed in terms of 1 USD.

volatility. In the Turkish case for instance studies that include deviations from exchange rate volatility use different specifications of GARCH models (Guimarães-Filho and Karacadag, 2004; Herrera and Özbay, 2005). A better estimate of the volatility can be obtained using the intraday data; but genuine data for computing the so-called realized volatility may not be available at all for an outsider. Furthermore, market participants do not have information on the model of the CBRT for measuring volatility. On the other hand, historical exchange rate data is easily accessible, reliable and tractable.

Moreover; although the CBRT notes excessive volatility in the currency market as the main motivation, results of the limited studies on Turkey show that exchange rate volatility is not a significant motivation of interventions. For the first three years of the floating exchange rate (i.e. 2001-2003), Guimarães-Filho and Karacadag (2004) find that the CBRT's interventions are not motivated by the deviations in the exchange rate return and volatility from their previous month's values. For the period 1993-2003, Herrera and Özbay (2005) study the motivations of the CBRT with a Tobit model. By restricting their research only to short-term variables, they find that the CBRT interventions are not motivated by short-term deviations from the exchange rate return and volatility, which supports the findings of Guimarães-Filho and Karacadag (2004). Recently, Onder and Villamizar (2015) find that the effect of interventions on exchange rate volatility is small and short lived, while they have a larger significant effect on exchange rate returns.

# 3. A Model of Infrequent Intervention with Reserve Targeting

Based on the Almekinders and Eijffinger (1996) model of intervention, Ito and Yabu (2007) develop a model of infrequent interventions that aims to capture the motivation of the Bank of Japan's currency interventions between 1991 and 2002. Here, the model of Ito and Yabu (2007) is extended by adding a component of international reserves to the objective function.

Let $s_t$ represent the log of USD/TRY exchange rate at time $t$. The central bank is assumed to have the following objective function:

$$\min_{Int_t} \; E[(\alpha(s_t - s_t^T)^2 + \beta(Q_t(\Delta s_t, \Lambda_{t-1}) - G_t)^2)|\Omega_{t-1}] \tag{1}$$

where $s_t^T$ is the target level of the USD/TRY exchange rate at time $t$, $\Omega_{t-1}$ is the information available at time $t-1$, $G_t$ is the target level of foreign reserve-to-GDP ratio, and $Int_t$ is volume of currency intervention. $G_t$ is assumed to be exogenous and constant at level $G_t = a$. The coefficients $\alpha$ and $\beta$ are the weights of the exchange rate target gap and the reserve ratio target gap respectively with $\alpha, \beta \geq 0$. $Q_t(\Delta s_t, \Lambda_{t-1})$ gives the level of reserve-to-GDP ratio at time $t$ based on first difference of the exchange rate return, $\Delta s_t$, and a matrix of variables, $\Lambda_{t-1}$, that might play a role in determination of the ratio. As it is shown in Section 4.1, $\Lambda_{t-1}$ is assumed to consist of lags of $\Delta s_t$ and some quarterly variables. $Q_t(\Delta s_t, \Lambda_{t-1})$ is assumed to be linear in $\Delta s_t$ as follows:

$$Q_t(\Delta s_t, \Lambda_{t-1}) = \kappa \Delta s_t + R_{t-1}(\Lambda_{t-1}) + v_t, \tag{2}$$

where $\kappa$ denotes the effect of $\Delta s_t$ on the reserve-to-GDP ratio, $R_{t-1}(\Lambda_{t-1})$ denotes the component of the ratio that is not related to $\Delta s_t$, and $v_t$ is an i.i.d error.

A critical aspect of modeling currency interventions is the assumptions on the exchange rate movements. The literature suggests that a number of factors such as interest rates and money supplies differentials, commodity prices, and order flows might affect exchange rate levels. In a recent literature review, Rossi (2013) studies the exchange rate predictability with different forecast horizons, predictors, model specifications, and evaluation methods. According to the review, the predictability of the models depend on all of these factors and the Random Walk (RW) without a drift appears to be the strongest benchmark model. Particularly, at the daily level, the evidence against the RW model is limited to a number of studies and exchange rate pairs (Rime et al., 2010; Ferraro et al., 2015). Therefore, the policymakers are assumed to model the exchange rate movements as a RW and try to influence the exchange rates by interventions as follows[5]:

$$s_t = s_{t-1} + \rho Int_t + u_t. \tag{3}$$

It has to be noted that the RW assumption will be kept throughout the study and only interventions are assumed to effect exchange rates. USD purchases and sales are denoted by (+) and (-) respectively because the motivation in purchases is assumed to be increasing $s_t$ while in sales, the motivation is to decrease $s_t$.

Using (3), $Q_t(\Delta s_t, \Lambda_{t-1})$ can be written in terms of intervention as follows[6]:

$$Q_t(Int_t, \Lambda_{t-1}) = \eta Int_t + R_{t-1}(\Lambda_{t-1}) + v_t, \tag{4}$$

where $\eta = \kappa\rho$ and denotes the effect of interventions on reserve levels. As USD purchases (sales) increase (decrease) the value of $Q_t(Int_t, \Lambda_{t-1})$, $\eta$ has to be positive, which implies

5 For advanced economies, Yilmaz (2003) shows that during periods of coordinated currency interventions, the exchange rates deviate from the martingale property. Some deviations from the RW assumption are included as robustness checks in Section (7).

6 Note that $\Delta s_t = (s_t - s_{t-1}) = (s_{t-1} + \rho Int_t - s_{t-1}) = \rho Int_t$.

that coefficients $\kappa$ and $\rho$ should have the same sign.

The minimization problem in (1) can be solved by using (3) and (4). The optimal level of currency intervention, $Int_t^*$, can be written as:

$$Int_t^* = \frac{a\beta\eta}{\alpha\rho^2+\beta\eta^2} - \frac{\alpha\rho}{\alpha\rho^2+\beta\eta^2}(s_{t-1}-s_t^T) - \frac{\beta\eta}{\alpha\rho^2+\beta\eta^2}R_{t-1}(\Lambda_{t-1}),$$

which can be simplified to

$$Int_t^* = -\frac{\alpha\rho}{\alpha\rho^2+\beta\eta^2}(s_{t-1}-s_t^T) + \frac{\beta\eta}{\alpha\rho^2+\beta\eta^2}(a-R_{t-1}(\Lambda_{t-1})). \tag{5}$$

The first term in the equation denotes the effect of deviations of exchange rate from the target level. The sign of this coefficient depends on the sign of $\rho$. Holding other parameters constant, the interpretation of $\rho$ is similar to Ito and Yabu (2007). Assuming that USD is purchased (sold) when TRY appreciates (depreciates) against the USD, leaning–against–the–wind behavior of central banks implies that $\rho > 0$ (i.e. $s_t$ increases (decreases) after purchases (sales) of USD). Similarly, leaning-with-the-wind implies $\rho < 0$. In the extended model, the parameter is weighted by the relative importance of other variables. The second term in Equation (5) denotes the effect of the gap between the optimal and the current level of reserve-to-GDP levels. The coefficient of this term is positive. Thus, as the optimal level of reserve-to-GDP increases (decreases), the optimal level of currency intervention will increase (decrease), and as $R_{t-1}(\Lambda_{t-1})$ increases (decreases), the optimal intervention level will decrease (increase). The parameters $\alpha$ and $\beta$ weigh the deviations based on their importance in the objective function. The term $\alpha\rho^2+\beta\eta^2$ in the denominators of the coefficients normalizes the effects. Note that if $\beta = 0$ and $\alpha = 1$, the second term in the equation drops and the equation boils down to the optimal level of intervention given in Ito and Yabu (2007).

Jeanne and Ranciere (2011) show that most of the emerging market economies, except the Asian countries in their sample, have smaller reserve-to-GDP ratios than the optimal value. Therefore, for an emerging country in which $a > R_{t-1}(\Lambda_{t-1})$, the model is expected to explain the foreign currency purchases by the central banks better than sales.

For the sake of simplicity, in the rest of the study, $a$ is normalized to 0 and Equation (5) is expressed in a compact form as follows:

$$Int_t^* = A(s_{t-1}-s_t^T) + BR_{t-1}(\Lambda_{t-1}). \tag{6}$$

where

$$A = -\frac{\alpha\rho}{\alpha\rho^2+\beta\eta^2}, \text{ and} \tag{7}$$

$$B = -\frac{\beta\eta}{\alpha\rho^2+\beta\eta^2}. \tag{8}$$

The exchange rate target is assumed to be composed of five elements that capture the short-term and long-term movements in the exchange rate. Short-term elements are the previous day's and previous month's exchange rates, $s_{t-2}$ and $s_{t-21}$ respectively. Long-term elements are the 1, 3, and 5-year moving averages, which are defined as

$$s_t^{kMA} = \frac{1}{k260}\sum_{i=0}^{k260-1} s_{t-i}, \tag{9}$$

where $k = 1,3,5$ and a year is assumed to have 260 business years. Then the target exchange rate can be written as follows:

$$s_t^T = \delta_1 s_{t-2} + \delta_2 s_{t-21} + \delta_3 s_{t-1}^{long} \tag{10}$$

where

$$s_t^{long} = c_1 s_t^{1MA} + c_2 s_t^{3MA} + c_3 s_t^{5MA}. \tag{11}$$

The coefficients of the target exchange rate and long-term exchange rate are normalized to one which means that $\delta_1+\delta_2+\delta_3 = 1$, and $c_1+c_2+c_3 = 1$. Using the definitions of the target exchange rate level and the long term exchange rate, the optimum level of intervention in Equation (6) can be written as:

$$\begin{aligned} Int_t^* =& \gamma_1(s_{t-1}-s_{t-2}) + \gamma_2(s_{t-1}-s_{t-21}) + \gamma_3(s_{t-1}-s_{t-1}^{1MA}) \\ &+ \gamma_4(s_{t-1}-s_{t-1}^{3MA}) + \gamma_5(s_{t-1}-s_{t-1}^{5MA}) + \gamma_6 R_{t-1}(\Lambda_{t-1}) \end{aligned} \tag{12}$$

where $\gamma_1 = \delta_1 A$, $\gamma_2 = \delta_2 A$, $\gamma_3 = \delta_3 c_1 A$, $\gamma_4 = \delta_3 c_2 A$, $\gamma_5 = \delta_3 c_3 A$, and $\gamma_6 = B$.

In this form, the model implies that policymakers will react to exchange rate movements continuously. However, as it can be observed on Figures (3) and (4) that present Turkish intervention data, it is an empirical fact that there might spells of interventions or just a stand alone intervention. Ito and Yabu (2007) capture the possibility of non-frequent interventions by introducing political costs to the model. For the Japanese case, the intuition of political costs is based on the necessity of an approval by the Ministry of Finance for the Bank of Japan to start interventions. The approval of the initial intervention is assumed to decrease the costs of the following interventions. In Turkey, the

CBRT independently decides on interventions; so the preceding intuition is not valid for the Turkish case. On the other hand, as noted in the survey of Neely (2008); except one bank, central banks are in general very quick to make an intervention even there has not been an intervention in the previous day. Therefore, the motivation suggested by Ito and Yabu (2007) seems to apply to the very special case of the Bank of Japan rather that the general situation, and particularly not to the case of the CBRT.

Instead, public announcements on the auctions for currency interventions justify a similar cost effect for the case of Turkey. As noted in the previous section, the CBRT sometimes chooses to intervene to the markets with unannounced interventions; but usually use auctions whose rules are predetermined. However, the end date is left undetermined by the note that the CBRT has the right to end the auctions when they see the continuation unnecessary. The public announcement of these interventions is taken as the cost of interventions and it is assumed that subsequent interventions are more likely since the cost does not apply to them.

The cost function, $C_t$, is defined as

$$C_t = \begin{cases} C_1^P - C_2 I(Int_{t-1} > 0) & \text{if } \; Int_t > 0 \\ C_1^S - C_2 I(Int_{t-1} < 0) & \text{if } \; Int_t < 0 \end{cases} \tag{13}$$

where $C_1^P > 0$ is the cost of purchasing USD, $C_1^S > 0$ is the cost of selling USD, and $I(.)$ is the indicator function that is used to indicate if there is an intervention of the same kind in the previous period. The intuitively correct case for facilitation of interventions is $C_2 > 0$ which corresponds to the situation where an intervention in period $t-1$ decreases the cost of intervention at time $t$. The cost of intervention can also be modeled as a fixed amount for both USD sales and purchases as in Kearns and Rigobon (2005), but here costs are assumed to be different for both directions in order to account for asymmetric effects of interventions.

The central bank will make its intervention decisions by comparing the costs and benefits of interventions given in Equations (13) and (12) respectively. Different cases implied by these comparisons can be written as follows:

$$IInt_t = \begin{cases} -1 & \text{if } \; Int_t^* + \varepsilon_t < \mu_1 + \gamma_7 I(Int_{t-1} < 0) \\ 0 & \text{if } \; \mu_1 + \gamma_7 I(Int_{t-1} < 0) < Int_t^* + \varepsilon_t < \mu_2 - \gamma_7 I(Int_{t-1} > 0) \\ 1 & \text{if } \; \mu_2 - \gamma_7 I(Int_{t-1} > 0) < Int_t^* + \varepsilon_t \end{cases} \tag{14}$$

where $\mu_1$ and $\mu_2$ are the cut-off levels for USD sales and purchases respectively, and

$\varepsilon_t \sim N(0, \sigma^2)$.[7] Assuming the sign of the intervention at time $t$ is never different from the intervention sign at time $t-1$[8], intervention decisions can be re-written in the form of an ordered probit model as:

$$IInt_t = \begin{cases} -1 & \text{if} \quad y_t^* < \mu_1 \\ 0 & \text{if} \quad \mu_1 < y_t^* < \mu_2 \\ 1 & \text{if} \quad \mu_2 < y_t^* \end{cases} \tag{15}$$

where $y_t^* = X_t\gamma + \varepsilon_t$ and

$$\begin{aligned} X_t\gamma = &\gamma_1(s_{t-1} - s_{t-2}) + \gamma_2(s_{t-1} - s_{t-21}) + \gamma_3(s_{t-1} - s_{t-1}^{1MA}) \\ &+ \gamma_4(s_{t-1} - s_{t-1}^{3MA}) + \gamma_5(s_{t-1} - s_{t-1}^{5MA}) + \gamma_6 R_{t-1}(\Lambda_{t-1}) + \gamma_7 IInt_{t-1} \end{aligned} \tag{16}$$

It has to be noted that by using the ordered probit model in Equation (15), we can only estimate standardized values of the coefficients which are $\gamma_i^* = \gamma/\sigma$ and $\mu_i^* = \mu_i/\sigma$ which means that $\delta$ and $c$ values can be calculated as $\delta_1 = \gamma_1^*/(\sum_{i=1}^5 \gamma_i^*)$, $\delta_2 = \gamma_2^*/(\sum_{i=1}^5 \gamma_i^*)$, $\delta_3 = (\sum_{z=3}^5 \gamma_z^*)/(\sum_{i=1}^5 \gamma_i^*)$, $c_j = \gamma_{j+2}^*/(\sum_{i=3}^5 \gamma_i^*)$ for $j = 1,2,3$ but $A$ and $\rho$ cannot be identified. Similarly, a standardized value for $B$ is given by the estimations; but $\eta$, along with the parameters $\alpha$ and $\beta$, is not identified. This model is referred as the "extended model" and the version of the model without the reserve variable is referred as the "Ito & Yabu model".

Ito and Yabu (2007) note that the model they give can be seen as a "reaction function with neutral bands". Within the neutrality bands, the central bank will not react to exchange rate movements. With the new variable added to the model, it is now a reaction function that reacts also to the international reserves accumulated as a ratio to GDP until the time of intervention decision. Below the negative band, the central bank will react by selling USD and above the positive band, it will react by purchasing USD. $\gamma_1$ and $\gamma_2$ coefficients denote reactions based on the short-term deviations; $\gamma_1$, $\gamma_2$, and $\gamma_3$ are the long-term deviation coefficients; $\gamma_6$ is coefficient of existing reserves, and $\gamma_7$ is the momentum coefficient, which tells that an intervention is more likely today if there was an intervention on the previous day. A positive value of $\gamma_7$ means that the likelihood of an intervention today increases based on the existence of a previous day intervention .

7 For the model only with exchange rate targeting, Ito and Yabu (2007) put the sign conditions on the cut-off levels as $\mu_1 < 0$ and $\mu_2 > 0$. Intuitively, the value of the optimal intervention will be pushed downward by the negative effect of the new $\gamma_6 R_{t-1}(\Lambda_{t-1})$ term. Therefore, a sign restriction on the cut-off levels is not employed here.

8 This assumption is validated for the intervention data of CBRT. A purchase (sale) of USD is always followed by a purchase (sale) or no intervention period.

A reaction function without the neutrality bands can be given as the following:

$$\begin{aligned} IInt_t =& \phi_0 + \phi_1(s_{t-1} - s_{t-2}) + \phi_2(s_{t-1} - s_{t-21}) + \phi_3(s_{t-1} - s_{t-1}^{1MA}) \\ &+ \phi_4(s_{t-1} - s_{t-1}^{3MA}) + \phi_5(s_{t-1} - s_{t-1}^{5MA}) + \phi_6 R_{t-1}(\Lambda_{t-1}) + \upsilon_t \end{aligned} \tag{17}$$

which is the linearization of the preceding probit model with a constant (Ito and Yabu, 2007). This linear model is called as "conventional extended model" and the version of the model without the reserve variable is referred as "conventional model" throughout the study.

# 4. Data

The initial dataset includes New York closing spot rates for the USD/TRY exchange rate starting from 26 March 2001 to 16 October 2015. It starts just after the CBRT decided to implement a floating exchange rate regime on 22 February 2001. The first month of the floating exchange rate regime is not included in the data set because of the sharp devaluation of the TRY in the immediate period.[9] The USD/TRY exchange rate is plotted in Figure (5) with the 1, 3, and 5-year moving average values for the whole sample.

Intervention data are retrieved from the CBRT database. There are 2314 days with interventions. Unannounced interventions are less frequent and are announced on the day they are carried out but the amounts of interventions are given 15 days after the interventions. For this type of interventions, the CBRT is partially following the policy recommendations of Bhattacharya and Weller (1997) who argue that efficiency of interventions is at the maximum when an intervention is announced but the amount is not. The delay in the announcement of the amount is not relevant for the ordered probit regression analysis, which only works with the information whether an intervention is occurred or not.

There are 2305 auctions and 27 direct unannounced interventions in the dataset, which means that on some days the CBRT used both auctions and direct interventions. 1496 of the interventions are purchases and 818 are sales of the USD. The maximum amount of an intervention on a single day is 5441 million USD, which was a purchase, while the minimum amount is 5 million USD, which is again a purchase. For the sales, the maximum amount is 3351 million USD and the minimum amount is 10 million USD.

The OLS and ordered probit regressions do not use the whole dataset. As it is described below, the sample is split into an estimation and a forecast sample to generate forecasts for the reserve-to-GDP ratios. The estimation period ends on 31 December

9 Blanchard et al. (2015) take the period for Turkey starting from 2003-Q3. This might be another approach to start the daily dataset.

2005. The rest of the sample after this date until 30 September 2015 is used in the regressions. The end of the sample is chosen to be 30 September 2015 because this is the final date on which quarterly data, and therefore the reserve-to-GDP ratio, are available. The dataset used in ordered probit regressions consists of 2522 days. There are 1018 USD purchase and 679 USD sale days during the time period that sums up to 1697 intervention days. The maximum amounts of purchases and sales are 5.5 billion USD and 3.3 billion USD respectively.

## 4.1. Daily reserve-to-GDP ratio forecasts

Estimating the model in (15) requires the use of the daily $R_{t-1}(\Lambda_{t-1})$ series. However, such a series is not available at the daily level since the calculation of the series uses quarterly GDP data.[10] In order to carry out the regression analysis, a synthetic $R_{t-1}(\Lambda_{t-1})$ series is calculated by using the Mixed Data Sampling (MIDAS) model.[11] For each day in a quarter, forecasts for the end of quarter's reserve-to-GDP ratio are calculated and the values are brought together to generate the necessary series. Since the reserve-to-GDP ratio is treated as a quarterly variable from now on, for notational convenience the subscript $t$ of the reserve-to-GDP ratio is replaced with $d = 1, 2, \ldots, D$ where $D$ is the maximum number of quarters in the dataset.

There are other methods to work with mixed frequency date in the time series econometrics literature but the MIDAS model is selected as the method of forecasting for two reasons. First, it handles the mixed data with a single equation in a parsimonious fashion and allows us to write the daily reserve-to-GDP forecasts in a functional form that is given in Equation (4). Second, Andreou et al. (2011) and Bai et al. (2013) show that the MIDAS model is less prone to specification errors than its competitor, state-space models.

In its simplest form, a MIDAS model for a quarterly series of interest, $Q_d$, can be written as follows:

$$Q_d = \psi_0 + \psi_1 \sum_{j=0}^{(q_S-1)} \sum_{i=0}^{(m-1)} \omega(\theta, i + j * m) S_{(m-i,d-j)} + \nu_{(d)}, \tag{18}$$

where $q_x$ is the number of low frequency lags, $\psi_j$ is the corresponding coefficient for the aggregated high frequency variable at low frequency lags, $m$ is the fixed number of

10 Besides employing the approach we have here, the closest series to the real $R_{t-1}(\Lambda_{t-1})$ can be calculated using the quarter end values for the reserve-to-GDP-ratio and daily exchange rate returns. Such a series is used in the probit model estimations and we get similar results we present here. The advantage of the MIDAS approach is that it can give daily forecasts by including more data in a concise manner.

11 For the properties of the MIDAS models, please see Ghysels et al. (2004), Ghysels et al. (2007), and Foroni and Marcellino (2013).

high frequency periods in one single low frequency period, $(i,d)$ is the $i^{th}$ lagged high frequency period in the low frequency period $d$, $S_{(i,d)}$ is the high frequency variable (e.g. daily series), and $\omega(\theta, i+j*m)$ is the polynomial distributed lag function that depends on the hyper parameter $\theta$. There are various functional specifications for the polynomial function $\omega$, but the Almon distributed lag polynomial is used in this study.[12] The polynomial function can be written as:

$$\omega(\theta,i) = \sum_{p=0}^{n_p} \theta_p i^p, \tag{19}$$

and assumes that the weight of the $i^{th}$ lag can be calculated with underlying $(n_p+1)$ hyper parameters $\theta = (\theta_0,\ldots,\theta_p)$. $n_p$ is taken to be 2 in the calculations.

Forecasts for the reserve-to-GDP ratios are calculated by MIDAS with leads. The MIDAS with leads methodology allows us to calculate forecasts for the end of the quarter we are in as move through the quarter. "Lead" refers to the data used within the quarter that a forecast is made. For instance, if one wants to make a forecast at the 10th day of the quarter for the end of the quarter[13], these 10 days are called leads. Days that belong to the previous quarter/s are called lags.

The high frequency variable, $S$, is taken as daily exchange rate returns. Exchange rate return and daily lags are selected to be the high frequency variable to ensure the appearance of $\Delta s_t$ in Equation (4). An Autoregressive (AR) term and quarterly factor series are also added in the estimations. The performance of the forecasts are improved by using the first lag of one quarterly factor that is extracted from six quarterly macroeconomic series (Stock and Watson, 2002; Andreou et al., 2013).

The MIDAS with leads forecast equation can be given as follows:

$$Q_{d+h} = \psi_0^h + \sum_{r=0}^{(q_Q-1)} \zeta_r^h Q_{(d-r)} + \sum_{r=0}^{(q_F-1)} \tau_r^h F_{(d-r)} + \psi_1^h \Bigg[ \sum_{i=(3-J_{\Delta s})*m/3}^{(m-1)} \omega(\theta^h, i-m)\Delta s_{(m-i,d+1)} + \sum_{j=0}^{(q_{\Delta s}-1)} \sum_{i=0}^{(m-1)} \omega(\theta^h, i+j*m)\Delta s_{(m-i,d-j)} \Bigg] + \nu_{(d+h)}^h, \tag{20}$$

where $h$ is the forecast horizon; $\zeta_r$ is the coefficient of the AR term and $q_Q$ is the number of lags of the low frequency variable; $F_{d-r}$ is the quarterly factor at time $F_{d-r}$, $\tau_r$ and

[12] Calculations are made also with Beta polynomial and exponential Almon lag polynomial functions. The Almon lag polynomial gives the best results in terms of forecasting performance and speed. Results retrieved using other functions are available upon request.

[13] This forecasts might also be called a 55-day ahead forecast assuming that there are 65 days in a quarter.

and $q_F$ are the corresponding coefficient and lag number of the quarterly factors; $J_{\Delta s}$ and $q_{\Delta s}$ are the number of leads and lags of exchange rate returns respectively. Finally, the autoregressive lag is taken to be 1. The forecast horizon, $h$, is fixed to one quarter since we do not need further forecast horizons. However, a forecast calculated at the $n^{\text{th}}$ day of a quarter is called the $(65-n)$-day ahead forecast for ease of expression, where $n = 1, 2, \ldots, 65$.

After the estimation of the model parameters and decision on the weights of the lags, the weight of the $\Delta s_t$ on a specific date can be separated in order to write the equation in form of Equation (4). The constant, AR term, factors and lags of the exchange rate returns are stacked into the matrix $\hat{\Lambda}_{t-1}$ so that

$$\hat{Q}^t = \hat{\psi}_1 \omega(\hat{\theta}, t)\Delta s_t + \hat{R}^{t-1}(\hat{\Lambda}_{t-1})$$

which is the forecast of the end-of-quarter reserve-GDP-ratio at time $t$. The superscript $t$ identifies the series as a forecast series. From this equation, the variable that is used in the ordered probit regressions can be written as follows:

$$\hat{R}^{t-1}(\hat{\Lambda}_{t-1}) = \hat{Q}^t - \hat{\psi}_1 \omega(\hat{\theta}, t)\Delta s_t \tag{21}$$

The quarterly series we use for calculating the quarterly factor are imports and exports as a share of GDP, production (excluding construction), hourly earnings, monetary aggregate (M1), and passenger car registrations. The factors are extracted by using the Principal Component Analysis (PCA) with a window size of 40. Already the first one these factors explains 51% of the total variation in the quarterly series. Other factors explain 34%, 18%, 7%, and 2% respectively. We only report the forecasts results using the first factor, which delivered the best results.

Quarterly series and the daily exchange rate return are winsorized at the 1% level in order to prevent any outlier effects.

Quarterly changes in the international reserves of the CBRT are given in Figure (6) and the reserve-to-GDP series are plotted in Figure (7). Both the ratio series and the exchange rate return series are tested for a unit root before performing the regressions.

The number of leads and lags that are used to calculate the forecasts may vary. Here, the number of leads and lags are selected based on the root mean squared forecast error (RMSFE) of different specifications. The selection procedure of the leads and lags follows three steps. At the first step, we calculate 1 to 65-day ahead forecasts with a recursive window scheme and the RMSFE of the forecasts are gathered. Then, for each lag and within the quarter forecast horizon, the RMSFE performances are compared with the benchmark AR(1) model with a constant. At the final step, the lag value that gives the best average performance is selected. Table (1) reports RMSFE values of the forecasts for several forecast horizons and lags with respect to the benchmark model. The performance of the forecast is up to 45% better compared to the benchmark model. The estimated Almon polynomial lag functions are given in Figure (8).

The best average performance is received from lag 95 with an average performance of 0.6. The $\hat{R}^{t-1}(\hat{\Lambda}_{t-1})$ series is generated by using this lag.[14] Figure (9) plots the generated $\hat{R}^{t-1}(\hat{\Lambda}_{t-1})$ series against the real reserve-to-GDP series.

## 5. Identifying Structural Breaks

During the estimation periods for the probit regressions, there have been notable domestic and global events that may have change the intervention policy of the CBRT. First; since the beginning of 2006, the governor of the CBRT changed twice. Durmuş Yılmaz was appointed as the governor on 14 March 2006 and Erdem Başçı was appointed on 14 April 2011. The governors' policy objectives might play a role in the currency intervention policies (Ito and Yabu, 2007). Second, the global financial crisis started in 2008 after the collapse of the Lehman Brothers and the Federal Reserve started the first round their QE policy, which continued until 2014 with two renewed rounds. Turkey had negative quarter–on–quarter GDP growth rates in the last quarter 2008 and first quarter of 2009 with $-5.9\%$ and $-5.6\%$ respectively, which are the lowest growth rates since the banking crisis in 2001. The financial crisis and both the start and end of the QE policy has implications on the capital flows to Turkey, hence reserve management. Finally, at the start of 2014, the CBRT implemented new policies to cope with the deviations in the exchange rate and started to support the USD need of the state owned oil-importing firms directly.

The possibility of changes in the intervention policy of the CBRT is first analyzed by the methodology introduced by Andrews (1993) who shows that the existence, statistical significance, and location of one structural break point can be tested by using F or Wald statistics, and simulates asymptotic critical values. Accordingly, for the linear version of the probit model is used as given in Equation (17), we calculate recursive Chow test F-statistics for every point within the middle 80% of the data (i.e. the first and last 10% are trimmed following Andrews (1993)). Figure (10) gives the calculated F-statistics. The maximum value is received at on date 04 August 2011 which implies a structural break at this date. The conventional model gives the same break date, but with higher value of the statistics.

Considering the number of events that might have caused policy changes, the existence of multiple structural breaks is tested by the Bai and Perron (2003a) (BP) test

[14] 95 is the sum of the leads and lags used in the forecasts.

for an unknown number of structural breaks. For the BP test, the maximum number of structural breaks is taken as 5, the trimming ratio is 0.1, and the errors are assumed to be heteroskedastic. We start by applying the BP test to the linear model including both the exchange rate and reserves. Table (2) displays the test statistics for each number of breaks. The critical values for the test statistics are given in Bai and Perron (2003b). Bai and Perron (2003a) note that the sequential procedure gives better results for the number of structural breaks; so the break points suggest by this procedure is taken as a reference.[15] The dates of the breaks estimated by the sequential procedure are 24 September 2007, 03 August 2011, and 19 June 2013.

The first structural break point coincides to a period when the CBRT increased the maximum amount of auctions from 45 million USD to 90 million USD due to the capital inflows to Turkey due to the evaluation of the housing and credit markets abroad (CBRT, 2007b). In 2008, after the global financial crisis, buying auctions are suspended and selling auctions have continued for a while. Foreign reserve concerns mark the period before and after the global financial crisis. The second suggested structural break point is at a time when the CBRT announced that it would intervene to the markets when seen necessary. This announcement came in August 2011 after the announcement of suspension of interventions in July 2011. The second round of the US QE ended in the second quarter of 2011, and the interventions are directed to address uncertainty in the foreign exchange market. Finally, on the last structural break date, the conditional termination of the QE based on positive economic data was announced and it was noted that the programme could be wrapped in 2014. The announcement and subsequent termination of the QE programme created upward movements in the currency markets, and the CBRT has increased the amount of interventions. For the further analysis we proceed using these three break points and four sub-periods accordingly. In contract to the extended model the procedure suggests 4 break points for the benchmark model with only exchange rates, the original (Ito and Yabu, 2007) model, see Table (3).

# 6. Estimation Results

## 6.1. Linear regression results

The linear regressions results of Equation (17) with Newey and West (1987) heteroskedasticity and autocorrelation consistent (HAC) errors are given in Table (4). Results of the conventional model are given in Table (5) for comparison. According to the $R^2$ values, the

[15] The table also gives the estimates of the number of structural breaks from LWZ and BIC. These values are 4 and 5 respectively.

explanatory power of the conventional model with reserves is the smallest in the last period of the sample. The final sub-period in the sample has been marked with the political risk and introduction of new policy measures by the CBRT to deal with the movements in the currency markets; therefore, the low performance of the model in the last period is expected. A more complex model might be needed to capture the events of the last period.

The coefficient of momentum variable, $\phi_7$, is significant in the full sample and in all sub-sample regressions. The positive sign of the coefficient implies that the cost of interventions decreases if there is an intervention on the previous day. The size of the coefficient gets smaller in time and is the smallest in the last sub-period implying that the predictability of a future intervention based on the current day intervention decreases over time.

The reserve variable coefficient, $\phi_6$, is significant in the full sample and for the first three sub-sample regressions. The negative sign is in line with the implications of the model and implies that as the amount of reserve accumulated before the day of intervention, intervention will decrease. Our initial assumption on the reserve variable is that it would explain the USD purchases in a better way in Turkey. The size of the coefficient is the largest in the third subsample in which there has been no USD purchases carried out. This suggests that in the third sub-sample, there is indeed an over accumulation of reserves compared to the optimal level and it contradicts the assumption that Turkey, as an emerging country, has always a deficit in the reserve-to-GDP ratio and should be inclined to accumulate reserves continuously.

None of the exchange rate variable coefficients is significant at the full sample; while for the conventional model, 3-year and 5-year moving average variable coefficients are significant. Coefficient for the deviations from the previous day, $\phi_1$, is never significant in any regressions of neither of the conventional extended and conventional models. This result is in line with the CBRT announcements saying that the bank does not intervene based on short-term movements in the exchange rates. For the extended model, coefficients for the deviations from the 1-year and 3-year moving average are significant for the first three sub-samples while the 5-year term has a significant effect in the first two sub-samples. The signs of the exchange rate variable coefficients are not significant through regressions suggesting that relative importance and weight of the variables in the objective function change depending on the circumstances of certain periods.

## 6.2. Ordered probit estimations

The results of the ordered probit regressions of the extended model for the full sample and the four sub-samples are given in Table (6), whereas probit regression results for the Ito & Yabu model are reported in Table (7) for comparison. The tables contain coefficient estimates, cut-off point estimates (i.e. estimates of $\mu_1$ and $\mu_2$), and Pseudo-$R^2$ or *McFadden's* $R^2$ for each regression.

Fitted values of the probit regressions are given in Figures (11) and (12) with the estimated cut-off point estimates for the full sample and sub-samples respectively. Changes in the cut-off values within periods can be observed on the graphs. For the USD purchases, the estimated cut-off value for the first period is lower and for the second period is higher than the estimated cut-off point for the USD purchases in the full sample regression. For the USD sales, the estimated cut-off points are lower in the first and third periods, and higher in the second and fourth periods than the estimated cut-off point in the full sample regression. The lower (higher) cut-off point for the USD purchases (sales), the higher the probability that the CBRT is intervening to the markets. The band for intervention (i.e. the area between the cut-off points) is the narrowest for the second period (i.e. 25/09/2007–03/08/2011); so, only based the band width, the CBRT would be expected to be in the currency markets with the highest probability during this period.

The coefficient of the momentum variable, $\gamma_7^*$, is significant at the 1% level and has the expected positive sign in all of the regressions implying that an intervention today increases the possibility of an intervention tomorrow. Size comparison of the coefficient within periods suggest that after the introduction of new measures by the CBRT such as ROM in the third period and directly supplying oil importing state-owned firms in the fourth period has decreased the influence of the momentum variable.

The coefficient of the reserve variable, $\gamma_6^*$, is significant in the full sample and in the first three sub-sample period regression. The coefficient has the theoretically expected sign. It is the smallest and insignificant in the last sub-sample period regression. In the final sub-sample, the cut-off point estimator is not significant either indicating that the extended model performs poorly in explaining the intervention behavior of the CBRT in this sub-sample period. However, considering the developments in the last period of the sample, this results comes as no surprise to us and indicates the necessity of analyzing this period in more detailed fashion, which is out of the scope of this study. The size of the coefficient is the largest in the first and third sub-sample period regressions. Starting from the end of the first period and during the second period, the CBRT has explicitly announced the aim of some interventions as accumulating international reserves by point outing the need for strong reserves in emerging market economies; so, intuitively we expect the coefficient to be largest in size in these two periods. The coefficient is indeed the largest in the first sub-sample period regression; however, the coefficient in the second period is not one of the largest on the contrary to our expectations. The robustness checks show the coefficient is indeed robust to different model specifications only in the second sub-sample period; but during this sub-sample period, the strength of the variable might have been mitigated by the concerns on the international risk on currency markets during the global financial crisis.

Significance of the reserve variable is tested with a Wald test with the null hypothesis that the variable does not have an affect on the reaction of the CBRT, $H_0 : \gamma_6^* = 0$ (i.e. the CBRT reacts according to the Ito & Yabu model), with the respective samples. The null hypothesis can be rejected at the 1% significance level for the full sample while the significance level drops to 5% for the first three sub-sample periods. For the last period, the test statistic suggests that we do not have enough evidence to reject the null hypothesis at a significant level. Hence, even though we cannot compare the extended model with the Ito & Yabu model directly because of the different structural breaks, we see the statistically significant affect of the reserve-to-GDP ratio in the reaction function.

Similar to the linear regression results, we observe a significant effect of the reserve variable in the third sub-sample period in which no USD purchases take place, justifying the evidence for the possibility that the CBRT chose to reduce its international reserves depending on the certain conditions of the period.

We cannot derive direct conclusions based on the coefficient estimates of the exchange rate variables since they are weighted values rather than the real effects of the exchange rate variables on interventions. Nevertheless, values of target exchange rate variable coefficients (i.e. $\delta$ and $c$ ) can be calculated by using the standardization conditions and by fixing non-significant terms to 0. Calculated $\delta$ and $c$ values for the extended model are given in Table (8). $\delta_1$,$\delta_2$, and $\delta_3$ correspond to the comparative weights of the deviation from previous day, deviation from previous month, and deviation from the long-term target level in the estimation function respectively. As it can be seen in the table, in the second and third sub-sample periods, only the long-term exchange rate variables are significant (i.e. $\delta_3 = 1$). In the final period, only significant coefficient is $\delta_2$. However, the signs of and sizes of the coefficients change depending on the estimation period. The positive weight of the 5-year moving average term transforms to negative in the second and third periods. In these two periods, the 3-year moving average term has a positive effect with a larger size compared to the weight of the 5-year moving average term implying that the 3-year moving average term has a more decisive role in these periods while in the first period this role has been divide into all terms.

Comparisons based on the Pseudo-$R^2$ values indicate that the explanatory power of the model changes over time. It has to be noted that the pseudo-$R^2$ of ordered probit regressions is not directly comparable with the OLS $R^2$. Therefore, even though the pseudo-$R^2$ values reported in Table (6) are smaller than the $R^2$ values from the conventional regressions, it does not necessarily imply that their explanatory power is smaller. Veall and Zimmermann (1996) show that Pseudo-$R^2$ values of the probit models are smaller than the OLS $R^2$. The Pseudo-$R^2$ reported for the probit model regressions actually correspond to a very high explanatory power for the full sample and two of the sub-samples. According to the $R^2$ values, the extended model has the smallest explanatory power in the last period as expected and due to the developments in this period noted above. The explanatory power of the model in the second period comparatively weaker than it is in the first and third periods, probably based on the risks brought by the global financial crisis.

Therefore, the probit model regression results for the extended model provide evidence for the economically significant influence of the international reserve accumulation behavior of the CBRT until mid-2013 whereas the regression results for the 05/08/2011-19/06/2013 period raise questions on the presumption that an emerging market economy has a continuous tendency to accumulate reserves.

## 6.3. Noise-to-signal analysis

The implications of the sub-sample probit regressions can further be analyzed with a noise-to-signal analysis (Ito and Yabu, 2007) in order to see how well the model performs in predicting future interventions. Using the probability of an intervention that is calculated after each probit regression, one can calculate early warnings (i.e. intervention/no-intervention days correctly predicted by the model) or false alarms (i.e. intervention/no-intervention days incorrectly signaled by the model) with the noise-to-signal ratio methodology introduced by Kaminsky and Reinhart (1999). The smaller a noise-to-signal ratio, the better a model performs in signaling future interventions. A description of the noise-to-signal ratio calculation and a breakdown of the results are given in Appendix (8).

Noise-to-signal ratios of both model for all sub-sample periods and a comparison of the models are reported in Table (9). In the first two sub-sample periods in which there are both USD purchases and sales, the noise-to-signal ratios from the extended model are smaller for the interventions by sales. This is an unexpected result since our initial assumption is that the model would better explain/predict USD purchases. However, in the breakdown of the results in Table (18), we see that the performance in the USD sales is due to the prediction of days without interventions rather than days with interventions. The number of days with USD sales is 4 in the first period and 20 in the second period while the numbers are 289 and 515 for the USD purchases for the respective periods. Therefore, the model safely assumes that there will not be USD sales in the future and we have lower noise-to-signal ratios for these two periods. Nevertheless, it has to be noted that when the number of days with USD sales increases in the third period, the performance of the model is still good and in the last period, it deteriorates; but the changes in the performance should not be taken as a direct evidence against the extended model with USD sales because as we argued earlier, we do not expect a very significant performance in the last period.

Comparisons of the extended model to the model only with exchange rates give little intuition about the relative performances of the models. According to the full sample comparisons, the extended model performs 5% better than the model only with exchange rates for USD purchases and 18% better for the USD sales interventions. At the sub-sample level, a direct comparison of the model performances is not possible since the number of structural break points is different. As a short-cut for comparison, if the we take the second and third period of the FX model as one period and average the noise-to-signal ratios, we see that during this time period, the extended model performs 20% better than the model only with exchange rates for USD purchases and 51% better for the USD sales interventions. In the last two periods during which there have been only USD sale interventions, extended model performs comparatively worse. However, these comparisons are blurred by the different segmentation of the sample.

The noise-to-signal analysis justifies our conclusions from the previous section and provides new insights. Even though the model is assumed to give better results for USD purchases based on the empirical evidence on emerging markets reserve accumulation behavior, the performance of the model for USD sales indicate that the extended model can explain both sides of the interventions. The performance of the model in the USD sales is driven by the low values of noise in the calculations which might be due to the small number of interventions by USD sales.

# 7. Robustness Checks

The robustness of the probit model regressions are checked by changing the specification of the exchange rate target, adding the exchange rate volatility in the regressions as a possible factor that would motivate the CBRT for interventions, and including interest rate differentials and macroeconomic news as deviations from the RW assumption for the exchange rate models.

The probit regressions results for the extended model given in Section (6) uses a fixed specification of exchange rate target that is previously used by Ito and Yabu (2007). Even though this specification covers a wide range of possibilities, the actual target may not include some of the short or long-term target elements. In order to test the robustness of the results for the reserve-to-GDP ratio, probit regressions are carried out by dropping each exchange rate target variable, and short-term and long-term components of the target separately. The columns (1)-(7) of the Tables (10)-(14) report the regression results for the full sample and sub-sample periods. The reserve-to-GDP ratio coefficient has the expected sign in all exchange rate target and sample specifications. The coefficient is significant in all specifications for the full sample and the second sub-sample period. In the third period, the coefficient loses its significance only when the long-term target component is dropped. The significance of the coefficient is not robust to different specifications of the target exchange rate; however, as it is reported in Table (6), in this period, all exchange rate target coefficients expect the deviation from the previous day are significant. Finally, the coefficient is not significant in the fourth sub-sample period regressions as expected.

The volatility of exchange rate has been note as one of the important motivations for currency interventions. In order to test the robustness of the results, the daily realized volatility of the USD/TRY exchange rate has been calculated as the square of the exchange rate returns. The volatility variable is included in the regressions and in another set of regressions, the first lag of the variable is also added to see the impact of the previous day volatility in the intervention behavior. The coefficient of the volatility variable is denoted by $\gamma^*_{vol}$ in the regressions. The columns (8) and (9) of the Tables (10)-(14) report the regression results. The reserve-to-GDP ratio coefficient has the expected the sign and significant for both model specifications and in all sample specifications expect the fourth sub-sample period. In the last sub-sample period, the coefficient has the correct sign but insignificant as expected.

The fundamental models of exchange rates assume that inflation rate, money supply, and interest rate differentials decide the exchange rate levels. In order to test the robustness of the results based on the fundamental models at the daily level, only the interest rate differential is included in the regressions due to data availability and two different interest rate variables are calculated. The first variable is calculated by taking the difference of the overnight interest rates on deposits in Turkey and US. The second variable is calculated by taking the difference of the 3-month interest rate on deposits in Turkey and the US 3-month Treasury bill rate. The coefficients of the variable are denoted as $\gamma^*_{overnight}$ and $\gamma^*_{3M}$ respectively. The variables are included in the regressions separately. The columns (10) and (11) of the Tables (10)-(14) report the regression results with the interest rate variables. The reserve-to-GDP ratio coefficient loses its significant only in the third period and with inclusion of the overnight interest rate differential variable.

The macroeconomic data announcements in Turkey and the US are included in the regressions to see if the CBRT indeed reacts to some domestic or foreign macroeconomic developments that might be picked up by the reserve-to-GDP ratio variable. The new variables are two dummy variables that take a value of 1 if there is a macroeconomic data announcement on a specific date or 0 otherwise. Economic calendar data for the US GDP, consumer price index, and unemployment data are retrieved from the US Bureau of Economic Analysis and Bureau of Labor Statistics. For Turkey, the calendar data for the same macroeconomic indicators are retrieved from the Turkish Statistical Institute. In the US macroeconomic news variable, FED policy rate change dates are also included considering the impact of these decisions on small economics but the policy rate data are not included for Turkey based on the literature arguing that interventions might signal policy rate changes (Kaminsky and Lewis, 1996), and interventions and policy rate are complementary tools (Ghosh et al., 2016). The news variable coefficients for Turkey and the US are denoted as $\gamma^{*}_{TRYNews}$ and $\gamma^{*}_{USNews}$ respectively. The column (12) of the Tables (10)-(14) reports the regression results with the news variables. The sign and significance of the reserve variable is robust to the inclusion of the news variables in the full sample and the first three sub-sample specifications.

The final columns of the Tables (10)-(14) include regression results for a big model that includes all robustness check variables excepts the overnight interest rate differential that does not turn out to be significant in other specifications. The results are robust to this specification in the full sample and the first two sub-sample periods. In the third sub-sample period specification, the coefficient loses its significance.

To our best knowledge, there has not been an attempt in the literature to identify the reserve accumulation behavior of the central banks at the daily frequency. Therefore, the validity of the forecasts generated by the MIDAS with leads might be a concern. It can be argued that the policy makers assess the sufficiency of their foreign exchange reserves based on the end of period forecasts that rely on already available metrics. In order to isolate this concern, a forecast series that assume the end of period reserves-to-GDP ratio is calculated by using the already available GDP and foreign exchange reserves data. For Turkey, the reserves data is publicly available at the weekly frequency, so the forecast for the end of period ratio is updated every week and uses the GDP data from the previous period.

The weekly updated forecast series, the MIDAS forecasts, and the real values for the end of period reserve-to-GDP ratios are plotted in Figure (13). As it can be seen on the graph, there are differences between series over time and the relative performance is of the forecast series cannot be visually assessed for some periods. For the series plotted in the graph, the RMSFE of the MIDAS series is 0.0269 while the RMSFE of the weekly updated series is 0.0317; thereby, the MIDAS forecasts have a 15% better performance than the weekly updated series.

Similar to the series generated by the MIDAS with leads, the weekly updated forecasts are tested to see whether they prompt central banks to intervene in the currency markets. The structural break tests with the forecasts variable reports there are 5 structural breaks in the policy reaction function. The ordered probit regression results for the full sample and 6 sub-sample periods are reported in Table (15). The sign of the weekly updated variable coefficient is expected to have a negative sign since a low (high) level of expected end of period reserve-to-GDP ratio would prompt the CBRT to buy (sell) foreign exchange reserves. Even though the variable coefficient has the correct sign and significant in the full sample specification, the sign is positive in the sub-sample specifications and the coefficient loses its significance. We think the difference between the MIDAS series and the weekly updated series comes from first, because of the difference in the forecast performances, and second, because the variable specified with the MIDAS model is able to capture a component that is more intuitive for the current reserve accumulation behavior. Furthermore, the MIDAS specification that is employed in this study already uses the already available quarterly data.

Therefore, the robustness checks show that the results for the extended model are robust in the full sample and the second sub-sample period for all model specifications considered. The robustness in the second sub-sample period is an expected results based on the announcements of the CBRT on currency accumulations in this period. The first sub-sample period regression results are sensitive to the target exchange rate level specifications due to the significance of these variables in this period. The currency accumulation announcements in this period are close to the beginning of the second sub-sample period and we think this might be the reason why the model is not able to show the significance of the variable in a robust way. In the third sub-sample period, the significance of the variable is sensitive to the inclusion of the long-term exchange rate target that is shown to be significant in this period. Additionally, it is shown that a naive approach to the end of period reserve-to-GDP ratio fails to deliver a better forecast performance than the MIDAS forecasts and it is not significant in the sub-sample ordered probit regressions.

# 8. Conclusions

This study extends a model of infrequent interventions to include reserve accumulation motivation in emerging markets. The model implies that policymakers react to short and long-term movements in the currency markets while often at the same time aim at achieving an optimal level of reserve-to-GDP ratio that would insure themselves against sudden-stops in capital flows. Implications of the model are tested by the CBRT currency intervention data during the floating exchange rate regime period.

The model requires the use of the reserve-to-GDP ratio, which is not available at a daily frequency. A daily series of reserve-to-GDP ratio is generated using the MIDAS methodology with leads. Forecasts generated by this method are shown to perform better than the benchmark model.

The policy function is tested for structural breaks due to the events that might have potentially caused changes in the CBRT intervention policy during the sample period. There are three structural break points found that divide the dataset into four sub-sample periods. Ordered probit regression results show that the reserve variable is significant in the full sample and in the first three sub-sample periods covering the floating exchange rate regime period until 20 June 2013. After this date, only the momentum variable is found to be significant. In the noise-to-signal ratio analysis, the performance of the extended model in estimating the USD sales might be due to the low frequency of interventions by sales. A set of robustness checks show that the sign of the variable coefficient is robust to different model specifications and the significance of the coefficient is only in the full sample and the second sub-sample period in which the motivation of the CBRT for reserve accumulation is explicit.

Further research on the model might include application of the model to other emerging market economies that intervene on currency markets and are motivated to accumulate international reserves. Another research path might focus on improving the daily forecast performances that would potentially give better estimates for the reserve variable in the model. The model presented in the study assumes that currency interventions influence both the reserve levels and exchange rates on the contrary of the limited empirical evidence that show depending on the intervention strategy, interventions that aim to accumulate reserves may not influence exchange rates. The model can be modified to identify these strategies and check the reaction functions separately. It can also be extended to include other motivations such as exchange rate volatility. Finally, the normalization of the optimal reserve level can be dropped and a dynamic model can be studied in which optimal level of reserves can be modified quarterly based on new macroeconomic data. If one can see the movements in the optimal reserve-to-GDP level, this research would also be illuminating to see the reasons behind the high performance of the extended model in estimating the USD sales.

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# Tables

**Table 1:** MIDAS forecast performances

| Horizon | Lag | | | | |
|---|---|---|---|---|---|
| | 81 | ... | 95 | ... | 132 |
| 1 | 0.658 | ... | 0.576 | ... | 0.588 |
| 2 | 0.675 | ... | 0.571 | ... | 0.582 |
| 3 | 0.667 | ... | 0.557 | ... | 0.560 |
| 4 | 0.636 | ... | 0.536 | ... | 0.550 |
| 5 | 0.633 | ... | 0.534 | ... | 0.545 |
| . | . | . | . | . | . |
| . | . | . | . | . | . |
| . | . | . | . | . | . |
| 61 | 0.688 | ... | 0.684 | ... | 0.629 |
| 62 | 0.679 | ... | 0.699 | ... | 0.649 |
| 63 | 0.731 | ... | 0.747 | ... | 0.672 |
| 64 | 0.738 | ... | 0.777 | ... | 0.705 |
| 65 | 0.789 | ... | 0.822 | ... | 0.723 |
| Mean | 0.614 | ... | **0.600** | ... | 0.625 |

Root mean squared error (RMSFE) values of the MIDAS with leads forecasts of the quarterly reserve-to-GDP ratios. Horizon refers to the daily distance from the end of the quarter at the time when the forecast is made. Lag refers to the to the total number of daily data used in the current and previous quarters. There are either 64 or 65 working days in a given quarter in the dataset, thus a quarter is assumed to have 65 working days to account for the longest possible quarters. The values in the table are the ratios of the forecasts to the RMSFE of the benchmark model, AR(1) model with a constant. The value in bold refers to the minimum value averaged over all horizons and the corresponding lag value, 95, is used in the calculation of the daily reserve-to-GDP variable.

**Table 2:** Structural break test with unknown number of breaks, the conventional extended model

| | | | | |
|---|---|---|---|---|
| $SupF_t(1)$ | $SupF_t(2)$ | $SupF_t(3)$ | $SupF_t(4)$ | $SupF_t(5)$ |
| 518.08*** | 82899.02*** | 231921.04*** | 249005.76*** | 8605.78*** |
| $SupF_t(2\|1)$ | $SupF_t(3\|2)$ | $SupF_t(4\|3)$ | $SupF_t(5\|4)$ | |
| 11972.00*** | 2042.20*** | 71.50*** | 13.00** | |
| $UDMax$ | $WDMax(5\%)$ | $WDMax(10\%)$ | | |
| 249005.76*** | 249005.76 | 249005.76 | | |
| Number of Breaks Selected | | | | |
| Sequential procedure | 3 | | | |
| LWZ | 4 | | | |
| BIC | 5 | | | |

Bai and Perron (2003a) (BP) structural break test with an unknown number of breaks for the conventional reaction function with the reserve ratio variable, the conventional extended model. Results from the sequential procedure are used in the subsequent calculations. In case of this model, the sequential procedure gives 2 structural breaks at the 10, 5, and 2.5, and 1% significance levels. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 3:** Structural break test with unknown number of breaks, the conventional model

| | | | | |
|---|---|---|---|---|
| $SupF_t(1)$ | $SupF_t(2)$ | $SupF_t(3)$ | $SupF_t(4)$ | $SupF_t(5)$ |
| 6449.23*** | 5045896.84*** | -523503.06 | -3108675.99 | 2231104.06*** |
| $SupF_t(2\|1)$ | $SupF_t(3\|2)$ | $SupF_t(4\|3)$ | $SupF_t(5\|4)$ | |
| 5100.07*** | 1463.33*** | 95.72*** | 98.96*** | |
| $UDMax$ | $WDMax(5\%)$ | $WDMax(10\%)$ | | |
| 5045896.84*** | 5045896.84 | 5045896.84 | | |
| Number of Breaks Selected | | | | |
| Sequential procedure | 4 | | | |
| LWZ | 4 | | | |
| BIC | 5 | | | |

Bai and Perron (2003a) (BP) structural break test with unknown number of breaks for the conventional reaction function only with the exchange rate deviation variables, the conventional model. Results from the sequential procedure are used in the subsequent calculations. In case of this model, the sequential procedure gives 4 structural breaks at the 10, 5, 2.5% and 1% significance levels. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 4:** OLS regressions, the conventional extended model

| | Full Sample | 31/01/06-24/09/07 | 25/09/07-03/08/11 | 05/08/11-19/06/13 | 20/06/13-30/09/15 |
|---|---|---|---|---|---|
| $\phi_1$ | -0.58 | 0.52 | 0.14 | 0.22 | 0.55 |
| | (-0.78) | (0.36) | (0.15) | (0.08) | (0.50) |
| $\phi_2$ | -0.11 | 0.73*** | 0.38 | 1.25* | -0.59* |
| | (-0.60) | (3.44) | (1.33) | (1.84) | (-1.67) |
| $\phi_3$ | 0.22 | -1.26** | 0.63** | -3.16** | -0.55 |
| | (0.96) | (-2.41) | (2.19) | (-2.18) | (-0.84) |
| $\phi_4$ | -0.24 | 2.91*** | -6.13*** | -6.13*** | 1.10 |
| | (-0.79) | (2.84) | (-6.19) | (-2.75) | (1.33) |
| $\phi_5$ | -0.15 | -4.54*** | 4.30*** | 4.07 | -0.70 |
| | (-0.61) | (-3.94) | (5.18) | (1.49) | (-1.27) |
| $\phi_6$ | -2.00*** | -1.96** | -1.23** | -2.67*** | -0.12 |
| | (-8.78) | (-2.29) | (-2.36) | (-2.89) | (-0.26) |
| $\phi_7$ | 0.82*** | 0.62*** | 0.55*** | 0.43*** | 0.35*** |
| | (56.34) | (9.69) | (13.29) | (5.01) | (4.28) |
| $\phi_0$ | 0.93*** | 1.08*** | 0.83*** | 1.12*** | -0.51** |
| | (8.83) | (2.85) | (3.67) | (2.95) | (-2.08) |
| N | 2522 | 429 | 1009 | 489 | 595 |
| $R^2$ | 0.89 | 0.78 | 0.70 | 0.73 | 0.15 |

Classical OLS regression results for the conventional reaction function with the reserve variable, the conventional extended model, given in Equation (17):

$$\begin{aligned} IInt_t = &\phi_0 + \phi_1(s_{t-1} - s_{t-2}) + \phi_2(s_{t-1} - s_{t-21}) + \phi_3(s_{t-1} - s_{t-1}^{1MA}) \\ &+ \phi_4(s_{t-1} - s_{t-1}^{3MA}) + \phi_5(s_{t-1} - s_{t-1}^{5MA}) + \phi_6 R_{t-1}(\Lambda_{t-1}) + \phi_7 IInt_{t-1} + \upsilon_t. \end{aligned}$$

t statistics in parentheses $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

**Table 5:** OLS regressions, the conventional model

| | Full Sample | 31/01/06-29/08/07 | 30/09/08-03/08/09 | 04/08/09-22/07/11 | 25/07/11-19/06/13 | 20/06/13-30/09/15 |
|---|---|---|---|---|---|---|
| $\phi_1$ | -0.73 | -0.65 | 0.81 | -0.074 | -0.61 | 0.57 |
| | (-0.94) | (-0.48) | (0.74) | (-0.05) | (-0.22) | (0.52) |
| $\phi_2$ | -0.21 | 0.64$^{***}$ | -0.26 | -0.85$^{*}$ | 1.32$^{*}$ | -0.58$^{*}$ |
| | (-1.12) | (2.96) | (-0.84) | (-1.75) | (1.93) | (-1.67) |
| $\phi_3$ | -0.11 | -1.07$^{**}$ | 1.00$^{***}$ | 0.82$^{*}$ | -6.47$^{***}$ | -0.62 |
| | (-0.47) | (-1.97) | (3.01) | (1.67) | (-4.86) | (-1.18) |
| $\phi_4$ | 0.94$^{***}$ | 1.62$^{*}$ | 5.43$^{***}$ | 2.42$^{**}$ | -11.2$^{***}$ | 1.17 |
| | (3.46) | (1.95) | (2.78) | (2.02) | (-5.15) | (1.54) |
| $\phi_5$ | -1.24$^{***}$ | -3.11$^{***}$ | -7.88$^{***}$ | -1.99$^{**}$ | 11.3$^{***}$ | -0.76 |
| | (-5.24) | (-3.53) | (-4.05) | (-2.05) | (4.96) | (-1.53) |
| $\phi_6$ | | | | | | |
| $\phi_7$ | 0.90$^{***}$ | 0.68$^{***}$ | 0.45$^{***}$ | 0.20$^{***}$ | 0.47$^{***}$ | 0.35$^{***}$ |
| | (92.39) | (10.87) | (6.56) | (2.84) | (6.06) | (4.29) |
| $\phi_0$ | 0.019$^{***}$ | 0.23$^{***}$ | 0.069$^{*}$ | 0.76$^{***}$ | 0.025$^{**}$ | -0.58$^{***}$ |
| | (3.11) | (4.62) | (1.80) | (10.67) | (2.31) | (-7.05) |
| N | 2522 | 412 | 503 | 514 | 498 | 595 |
| $R^2$ | 0.89 | 0.80 | 0.81 | 0.060 | 0.71 | 0.15 |

Classical OLS regression results for the conventional reaction function only with the exchange rate deviation variables, the conventional model, given as follows:

$$\begin{aligned} IInt_t =& \phi_0 + \phi_1(s_{t-1} - s_{t-2}) + \phi_2(s_{t-1} - s_{t-21}) + \phi_3(s_{t-1} - s^{1MA}_{t-1}) \\ &+ \phi_4(s_{t-1} - s^{3MA}_{t-1}) + \phi_5(s_{t-1} - s^{5MA}_{t-1}) + \phi_7 IInt_{t-1} + \upsilon_t. \end{aligned}$$

t statistics in parentheses $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

**Table 6:** Probit regressions, the extended model

| | Full Sample | 31/01/06-24/09/07 | 25/09/07-03/08/11 | 05/08/11-19/06/13 | 20/06/13-30/09/15 |
|---|---|---|---|---|---|
| $\gamma_1^*$ | -2.63 | 12.4 | 0.21 | -0.73 | 7.73 |
| | (-0.61) | (1.13) | (0.04) | (-0.05) | (0.62) |
| $\gamma_2^*$ | -0.37 | 12.3*** | 1.36 | 5.95 | -6.27* |
| | (-0.33) | (2.85) | (0.86) | (1.27) | (-1.80) |
| $\gamma_3^*$ | 0.66 | -25.7*** | 2.70 | -11.7 | -2.85 |
| | (0.38) | (-3.21) | (1.42) | (-0.76) | (-0.50) |
| $\gamma_4^*$ | 0.50 | 41.0*** | -25.8*** | -151.8*** | 7.93 |
| | (0.22) | (3.36) | (-4.40) | (-3.37) | (1.15) |
| $\gamma_5^*$ | -2.96 | -53.3*** | 18.0*** | 131.4*** | -4.87 |
| | (-1.41) | (-3.96) | (3.34) | (3.07) | (-1.07) |
| $\gamma_6^*$ | -12.5*** | -15.5** | -6.55** | -11.3** | -3.11 |
| | (-9.73) | (-2.06) | (-2.04) | (-2.10) | (-0.66) |
| $\gamma_7^*$ | 2.67*** | 1.74*** | 1.82*** | 1.05*** | 1.45*** |
| | (34.21) | (7.21) | (13.69) | (3.63) | (5.98) |
| $\mu_1$ | -7.47*** | -12.8*** | -5.98*** | -8.94*** | -1.49 |
| | (-12.59) | (-3.90) | (-4.33) | (-3.95) | (-0.63) |
| $\mu_2$ | -3.94*** | -5.61* | -2.20 | | |
| | (-6.92) | (-1.76) | (-1.62) | | |
| N | 2522 | 430 | 1008 | 489 | 595 |
| Pseudo $R^2$ | 0.76 | 0.74 | 0.59 | 0.73 | 0.19 |

Regression results for the extended probit model with the reserve ratio variable, the extended model, which is given by the Equations (15) and (16):

$$IInt_t = \begin{cases} -1 & \text{if } \; y_t^* < \mu_1 \\ 0 & \text{if } \; \mu_1 < y_t^* < \mu_2 \\ 1 & \text{if } \; \mu_2 < y_t^* \end{cases}$$

where $y_t^* = X_t\gamma + \varepsilon_t$ and

$$\begin{aligned} X_t\gamma = & \gamma_1(s_{t-1} - s_{t-2}) + \gamma_2(s_{t-1} - s_{t-21}) + \gamma_3(s_{t-1} - s_{t-1}^{1MA}) \\ & + \gamma_4(s_{t-1} - s_{t-1}^{3MA}) + \gamma_5(s_{t-1} - s_{t-1}^{5MA}) + \gamma_6 R_{t-1}(\Lambda_{t-1}) + \gamma_7 IInt_{t-1}. \end{aligned}$$

t statistics in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 7:** Probit regressions, the Ito & Yabu model

| | Full Sample | 31/01/06-29/08/07 | 30/09/08-03/08/09 | 04/08/09-22/07/11 | 25/07/11-19/06/13 | 20/06/13-30/09/15 |
|---|---|---|---|---|---|---|
| $\gamma_1^*$ | -4.20 | -0.61 | 6.45 | 0.95 | -3.03 | 7.83 |
| | (-0.98) | (-0.07) | (0.93) | (0.08) | (-0.19) | (0.63) |
| $\gamma_2^*$ | -1.34 | 11.8** | -2.35 | -6.28* | 5.46 | -6.20* |
| | (-1.22) | (2.29) | (-1.01) | (-1.77) | (1.26) | (-1.78) |
| $\gamma_3^*$ | -0.20 | -21.9** | 5.16** | 7.23 | -27.5** | -4.14 |
| | (-0.12) | (-2.48) | (2.02) | (1.50) | (-2.34) | (-0.86) |
| $\gamma_4^*$ | 6.99*** | 28.7** | 57.6*** | 19.8** | -158.3*** | 9.47 |
| | (3.58) | (2.29) | (2.66) | (2.00) | (-5.31) | (1.52) |
| $\gamma_5^*$ | -9.15*** | -41.2*** | -71.5*** | -18.1* | 147.4*** | -6.31 |
| | (-5.07) | (-3.00) | (-3.27) | (-1.90) | (5.44) | (-1.63) |
| $\gamma_6^*$ | | | | | | |
| $\gamma_7^*$ | 2.94*** | 1.97*** | 1.57*** | 0.88*** | 1.13*** | 1.45*** |
| | (40.85) | (7.61) | (7.39) | (3.77) | (3.90) | (5.98) |
| $\mu_1$ | -1.72*** | -5.75*** | -2.25*** | | -4.00*** | 0.078 |
| | (-26.00) | (-4.66) | (-6.85) | | (-9.23) | (0.34) |
| $\mu_2$ | 1.54*** | 0.80*** | 2.91*** | -0.86*** | | |
| | (26.40) | (2.88) | (5.52) | (-3.45) | | |
| N | 2522 | 412 | 503 | 514 | 498 | 595 |
| Pseudo $R^2$ | 0.74 | 0.75 | 0.73 | 0.082 | 0.73 | 0.18 |

Regression results for the probit model only with the exchange rate deviation variables, the Ito & Yabu model, which is given as

$$IInt_t = \begin{cases} -1 & \text{if } y_t^* < \mu_1 \\ 0 & \text{if } \mu_1 < y_t^* < \mu_2 \\ 1 & \text{if } \mu_2 < y_t^* \end{cases}$$

where $y_t^* = X_t\gamma + \varepsilon_t$ and

$$X_t\gamma = \gamma_1(s_{t-1} - s_{t-2}) + \gamma_2(s_{t-1} - s_{t-21}) + \gamma_3(s_{t-1} - s_{t-1}^{1MA}) + \gamma_4(s_{t-1} - s_{t-1}^{3MA}) + \gamma_5(s_{t-1} - s_{t-1}^{5MA}) + \gamma_7 IInt_{t-1}.$$

t statistics in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 8:** Probit regressions, extended model coefficients

| | Full Sample | 31/01/06-24/09/07 | 25/09/07-03/08/11 | 05/08/11-19/06/13 | 20/06/13-30/09/15 |
|---|---|---|---|---|---|
| $\delta_1$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $\delta_2$ | 0.000 | -0.479 | 0.000 | 0.000 | 1.000 |
| $\delta_3$ | 0.000 | 1.479 | 1.000 | 1.000 | 0.000 |
| $c_1$ | 0.000 | 0.676 | 0.000 | 0.000 | 0.000 |
| $c_2$ | 0.000 | -1.079 | 3.308 | 7.441 | 0.000 |
| $c_3$ | 0.000 | 1.403 | -2.308 | -6.441 | 0.000 |

Results for the $\delta$ and $c$ coefficient calculations for the extended probit model with the reserve ratio variable, the extended model. The calculations are made by using the estimated results in Table (7) and formulas given in the text: $\delta_1 = \gamma_1^* / (\sum_{i=1}^{5} \gamma_i^*)$, $\delta_2 = \gamma_2^* / (\sum_{i=1}^{5} \gamma_i^*)$, $\delta_3 = (\sum_{z=3}^{5} \gamma_z^*) / (\sum_{i=1}^{5} \gamma_i^*)$, $c_j = \gamma_{j+2}^* / (\sum_{i=3}^{5} \gamma_i^*)$ for $j = 1, 2, 3$. In the calculations, the coefficients that are not significant are taken as 0. A value of 1 for the $\delta_i$ terms imply that all of the weight is on that specific variable $i$.

**Table 9:** Noise-to-signal ratios and relative performances

| | extended model | | | the Ito & Yabu model | |
|---|---|---|---|---|---|
| | Purchase | Sale | | Purchase | Sale |
| Full Sample | 0.038 | 0.009 | Full Sample | 0.039 | 0.011 |
| 31/01/06-24/09/07 | 0.043 | 0.003 | 31/01/06-29/08/07 | 0.050 | 0.005 |
| | | | 30/09/07-03/08/09 | 0.064 | 0.002 |
| 25/09/07-03/08/11 | 0.169 | 0.001 | 04/08/09-22/07/11 | 0.358 | |
| 05/08/11-19/06/13 | | 0.019 | 25/07/11-19/06/13 | | 0.016 |
| 20/06/13-30/09/15 | | 0.300 | 20/06/13-30/09/15 | | 0.252 |

Noise-to-signal ratios and comparative performances of the models with, extended model, and without, the Ito & Yabu, the reserve ratio variable for the full sample and the five sub-sample periods. The noise-to-signal ratios for the USD purchase and sales interventions are calculated as described in Appendix (8). Lower values of the noise-to-signal ratio indicate better performances.

**Table 10:** Robustness checks, the full sample period

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\gamma_1^*$ | | -2.92 | | -2.62 | -2.64 | -2.75 | -2.87 | -2.54 | -2.06 | -2.52 | -2.35 | -2.79 | -1.34 |
| | | (-0.70) | | (-0.61) | (-0.61) | (-0.63) | (-0.66) | (-0.59) | (-0.48) | (-0.58) | (-0.54) | (-0.65) | (-0.31) |
| $\gamma_2^*$ | -0.51 | | | -0.20 | -0.40 | -0.43 | -1.02 | -0.52 | -0.44 | -0.28 | -0.30 | -0.37 | -0.086 |
| | (-0.46) | | | (-0.20) | (-0.35) | (-0.38) | (-1.02) | (-0.46) | (-0.38) | (-0.24) | (-0.25) | (-0.32) | (-0.07) |
| $\gamma_3^*$ | 0.65 | 0.40 | 0.35 | | 0.84 | 1.21 | | 0.64 | 0.66 | 0.65 | 0.42 | 0.66 | 0.45 |
| | (0.38) | (0.26) | (0.23) | | (0.56) | (0.73) | | (0.37) | (0.38) | (0.37) | (0.23) | (0.38) | (0.25) |
| $\gamma_4^*$ | 0.52 | 0.85 | 0.70 | 0.89 | | -2.60*** | | 0.43 | 0.48 | -0.31 | -1.02 | 0.49 | -1.00 |
| | (0.23) | (0.39) | (0.32) | (0.45) | | (-3.01) | | (0.19) | (0.21) | (-0.13) | (-0.43) | (0.22) | (-0.43) |
| $\gamma_5^*$ | -2.99 | -3.26 | -3.12 | -3.12 | -2.56*** | | | -2.91 | -2.95 | -2.45 | -1.90 | -2.97 | -1.93 |
| | (-1.42) | (-1.58) | (-1.51) | (-1.53) | (-3.18) | | | (-1.39) | (-1.41) | (-1.18) | (-0.92) | (-1.41) | (-0.93) |
| $\gamma_6^*$ | -12.5*** | -12.3*** | -12.5*** | -12.5*** | -12.6*** | -13.3*** | -13.4*** | -12.5*** | -12.5*** | -12.5*** | -12.5*** | -12.5*** | -12.5*** |
| | (-9.73) | (-9.76) | (-9.87) | (-9.72) | (-10.12) | (-10.48) | (-10.48) | (-9.72) | (-9.72) | (-9.77) | (-9.74) | (-9.73) | (-9.76) |
| $\gamma_7^*$ | 2.66*** | 2.67*** | 2.66*** | 2.67*** | 2.67*** | 2.68*** | 2.75*** | 2.67*** | 2.67*** | 2.66*** | 2.65*** | 2.67*** | 2.65*** |
| | (34.23) | (34.41) | (34.47) | (34.22) | (34.28) | (34.75) | (36.16) | (34.19) | (34.16) | (34.06) | (33.92) | (34.22) | (33.93) |
| $\gamma_{vol}^*$ | | | | | | | | 74.8 | 84.5 | | | | 19.5 |
| | | | | | | | | (0.55) | (0.60) | | | | (0.14) |
| $\gamma_{vol}^*(Lag)$ | | | | | | | | | -49.7 | | | | -120.9 |
| | | | | | | | | | (-0.35) | | | | (-0.86) |
| $\gamma_{overnight}^*$ | | | | | | | | | | 0.021 | | | |
| | | | | | | | | | | (1.31) | | | |
| $\gamma_{3M}^*$ | | | | | | | | | | | 0.029** | | 0.031** |
| | | | | | | | | | | | (2.09) | | (2.17) |
| $\gamma_{TRYNews}^*$ | | | | | | | | | | | | 0.073 | 0.075 |
| | | | | | | | | | | | | (0.64) | (0.67) |
| $\gamma_{USNews}^*$ | | | | | | | | | | | | 0.092 | 0.097 |
| | | | | | | | | | | | | (0.89) | (0.96) |
| $\mu_1$ | -7.49*** | -7.40*** | -7.49*** | -7.46*** | -7.52*** | -7.86*** | -7.84*** | -7.46*** | -7.46*** | -7.30*** | -7.21*** | -7.46*** | -7.18*** |
| | (-12.59) | (-12.66) | (-12.74) | (-12.58) | (-13.11) | (-13.32) | (-13.27) | (-12.58) | (-12.58) | (-12.02) | (-11.83) | (-12.56) | (-11.79) |
| $\mu_2$ | -3.96*** | -3.87*** | -3.96*** | -3.93*** | -3.99*** | -4.32*** | -4.33*** | -3.93*** | -3.93*** | -3.76*** | -3.65*** | -3.92*** | -3.62*** |
| | (-6.93) | (-6.91) | (-7.05) | (-6.92) | (-7.30) | (-7.71) | (-7.73) | (-6.90) | (-6.91) | (-6.44) | (-6.23) | (-6.88) | (-6.18) |
| N | 2522 | 2541 | 2542 | 2522 | 2522 | 2522 | 2522 | 2522 | 2522 | 2522 | 2522 | 2522 | 2522 |
| Pseudo $R^2$ | 0.76 | 0.75 | 0.75 | 0.76 | 0.76 | 0.75 | 0.75 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |

Robustness checks for the extended probit model with the reserve ratio variable, the extended model, for the full sample period. Models (1)-(7) test the robustness of the reserve-to-GDP ratio variable to different exchange rate target specifications by dropping the exchange rate variables from the model one-by-one and and as short-term and long-term targets. Models (8) and (9) test the robustness of the variable against the inclusion of the exchange rate volatility, which is calculated as the square of the exchange rate returns, and the first lag of the volatility variable. Models (10) and (11) test the robustness of the variable against the inclusion of an interest rate variable that is first calculated as the difference between the overnight interest rates of Turkey and the US, and then the difference between the 3-month ahead interest rate on deposits in Turkey and the 3-month T-bill rate in the US. Model (12) tests the robustness of the variable against the inclusion of the macroeconomic data announcements for Turkey (GDP, inflation rate, unemployment rate) and the US (GDP, inflation rate, unemployment rate, and changes in policy rate). Finally, Model (13) checks the robustness against the inclusion of all the employed variables with a preference to the 3-month ahead interest rate difference.

t statistics in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 11:** Robustness checks, the first sub-sample period (31/01/06-24/09/07)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\gamma_1^*$ | | 14.8 | | 10.8 | 6.00 | 2.32 | -3.09 | 12.2 | 17.4 | 9.03 | 15.7 | 12.8 | 20.6* |
| | | (1.32) | | (0.93) | (0.57) | (0.22) | (-0.34) | (1.14) | (1.44) | (0.92) | (1.40) | (1.16) | (1.70) |
| $\gamma_2^*$ | 12.9*** | | | 0.047 | 1.78 | 0.74 | -3.96*** | 12.3*** | 12.3*** | 8.75* | 14.3*** | 12.4*** | 14.2*** |
| | (2.91) | | | (0.02) | (0.90) | (0.42) | (-2.77) | (2.86) | (2.92) | (1.85) | (2.80) | (2.79) | (2.75) |
| $\gamma_3^*$ | -25.2*** | -15.0*** | -12.8*** | | -8.74* | -9.20* | | -25.8*** | -23.5*** | -21.5*** | -29.0*** | -25.7*** | -26.2*** |
| | (-3.23) | (-2.74) | (-2.60) | | (-1.65) | (-1.72) | | (-3.14) | (-2.99) | (-2.79) | (-3.22) | (-3.17) | (-2.94) |
| $\gamma_4^*$ | 39.0*** | 27.7*** | 23.1*** | 13.4** | | -9.29*** | | 41.3*** | 38.1*** | 53.9*** | 37.2*** | 42.1*** | 35.6*** |
| | (3.39) | (3.13) | (3.01) | (2.56) | | (-2.77) | | (3.27) | (3.18) | (3.34) | (2.80) | (3.37) | (2.64) |
| $\gamma_5^*$ | -50.6*** | -38.9*** | -34.0*** | -28.5*** | -12.5*** | | | -53.6*** | -50.5*** | -65.5*** | -50.4*** | -54.5*** | -48.9*** |
| | (-4.05) | (-4.01) | (-4.14) | (-4.12) | (-3.65) | | | (-3.87) | (-3.83) | (-3.92) | (-3.52) | (-3.98) | (-3.40) |
| $\gamma_6^*$ | -13.9* | -10.7 | -10.2 | -16.6** | -3.61 | 1.42 | -4.22 | -15.7** | -14.5* | -18.1** | -15.1** | -16.2** | -15.1** |
| | (-1.89) | (-1.59) | (-1.55) | (-2.29) | (-0.42) | (0.16) | (-0.76) | (-2.10) | (-1.94) | (-2.19) | (-2.00) | (-2.14) | (-1.99) |
| $\gamma_7$ | 1.80*** | 1.99*** | 2.01*** | 1.98*** | 2.04*** | 2.28*** | 2.99*** | 1.74*** | 1.76*** | 1.65*** | 1.78*** | 1.74*** | 1.80*** |
| | (7.74) | (9.10) | (9.50) | (8.56) | (9.19) | (10.48) | (15.38) | (7.19) | (7.23) | (6.64) | (7.38) | (7.07) | (7.33) |
| $\gamma_{vol}^*$ | | | | | | | | 49.2 | 152.4 | | | | 212.7 |
| | | | | | | | | (0.23) | (0.66) | | | | (0.87) |
| $\gamma_{vol}^*(Lag)$ | | | | | | | | | -570.1* | | | | -627.5* |
| | | | | | | | | | (-1.91) | | | | (-1.95) |
| $\gamma_{overnight}^*$ | | | | | | | | | | -0.22 | | | |
| | | | | | | | | | | (-1.60) | | | |
| $\gamma_{3M}^*$ | | | | | | | | | | | 0.084 | | 0.077 |
| | | | | | | | | | | | (0.97) | | (0.83) |
| $\gamma_{TRYNews}^*$ | | | | | | | | | | | | -0.12 | -0.13 |
| | | | | | | | | | | | | (-0.39) | (-0.42) |
| $\gamma_{USNews}^*$ | | | | | | | | | | | | 0.50*** | 0.49** |
| | | | | | | | | | | | | (2.69) | (2.47) |
| $\mu_1$ | -11.9*** | -9.98*** | -9.49*** | -11.4*** | -6.22* | -3.70 | -4.33* | -12.8*** | -12.2*** | -15.9*** | -11.8*** | -13.1*** | -11.7*** |
| | (-3.84) | (-3.30) | (-3.29) | (-3.58) | (-1.65) | (-0.94) | (-1.89) | (-3.89) | (-3.83) | (-3.68) | (-3.34) | (-3.97) | (-3.29) |
| $\mu_2$ | -4.91 | -3.59 | -3.43 | -6.44** | -1.15 | 0.99 | -0.46 | -5.68* | -5.30* | -9.14** | -4.37 | -5.88* | -4.51 |
| | (-1.58) | (-1.29) | (-1.25) | (-2.10) | (-0.31) | (0.26) | (-0.20) | (-1.80) | (-1.67) | (-2.11) | (-1.21) | (-1.84) | (-1.22) |
| N | 430 | 449 | 450 | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 | 430 |
| Pseudo $R^2$ | 0.73 | 0.72 | 0.71 | 0.72 | 0.71 | 0.70 | 0.65 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 |

Robustness checks for the extended probit model with the reserve ratio variable, the extended model, for the first sub-sample period. Models (1)-(7) test the robustness of the reserve-to-GDP ratio variable to different exchange rate target specifications by dropping the exchange rate variables from the model one-by-one and and as short-term and long-term targets. Models (8) and (9) test the robustness of the variable against the inclusion of the exchange rate volatility, which is calculated as the square of the exchange rate returns, and the first lag of the volatility variable. Models (10) and (11) test the robustness of the variable against the inclusion of an interest rate variable that is first calculated as the difference between the overnight interest rates of Turkey and the US, and then the difference between the 3-month ahead interest rate on deposits in Turkey and the 3-month T-bill rate in the US. Model (12) tests the robustness of the variable against the inclusion of the macroeconomic data announcements for Turkey (GDP, inflation rate, unemployment rate) and the US (GDP, inflation rate, unemployment rate, and changes in policy rate). Finally, Model (13) checks the robustness against the inclusion of all the employed variables with a preference to the 3-month ahead interest rate difference.

**Table 12:** Robustness checks, the second sub-sample period (25/09/07-03/08/11)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\gamma_1^*$ | | 1.15 | | 0.26 | -0.51 | -0.35 | -0.71 | -0.024 | 0.40 | 0.55 | 0.36 | -0.63 | -0.74 |
| | | (0.23) | | (0.05) | (-0.10) | (-0.07) | (-0.14) | (-0.00) | (0.07) | (0.10) | (0.07) | (-0.12) | (-0.14) |
| $\gamma_2^*$ | 1.37 | | | 1.96 | 0.19 | 0.30 | 0.20 | 1.58 | 1.68 | 1.28 | 1.63 | 1.45 | 1.80 |
| | (0.91) | | | (1.33) | (0.12) | (0.19) | (0.14) | (0.95) | (0.98) | (0.82) | (1.03) | (0.92) | (1.05) |
| $\gamma_3^*$ | 2.70 | $3.28^{*}$ | $3.31^{*}$ | | 1.87 | 2.87 | | 2.71 | 2.74 | $3.69^{*}$ | $3.85^{**}$ | 2.69 | $3.87^{**}$ |
| | (1.42) | (1.89) | (1.91) | | (0.89) | (1.35) | | (1.43) | (1.44) | (1.96) | (2.01) | (1.41) | (2.01) |
| $\gamma_4^*$ | $-25.8^{***}$ | $-24.3^{***}$ | $-24.2^{***}$ | $-25.1^{***}$ | | $-5.85^{***}$ | | $-25.3^{***}$ | $-25.0^{***}$ | -6.47 | -8.95 | $-26.0^{***}$ | -8.71 |
| | (-4.42) | (-4.13) | (-4.18) | (-4.23) | | (-3.91) | | (-4.21) | (-4.16) | (-0.74) | (-1.01) | (-4.38) | (-0.98) |
| $\gamma_5^*$ | $17.9^{***}$ | $16.5^{***}$ | $16.4^{***}$ | $18.2^{***}$ | $-4.23^{***}$ | | | $17.4^{***}$ | $17.2^{***}$ | -1.21 | 1.12 | $18.0^{***}$ | 0.82 |
| | (3.35) | (3.09) | (3.12) | (3.33) | (-3.22) | | | (3.18) | (3.13) | (-0.15) | (0.13) | (3.32) | (0.10) |
| $\gamma_6^*$ | $-6.55^{**}$ | $-6.68^{**}$ | $-6.68^{**}$ | $-6.27^{*}$ | $-14.2^{***}$ | $-11.6^{***}$ | $-19.9^{***}$ | $-6.72^{**}$ | $-6.76^{**}$ | $-9.42^{***}$ | $-9.23^{***}$ | $-6.52^{**}$ | $-9.30^{***}$ |
| | (-2.04) | (-2.08) | (-2.08) | (-1.92) | (-4.70) | (-3.66) | (-7.45) | (-2.06) | (-2.07) | (-2.76) | (-2.71) | (-2.03) | (-2.71) |
| $\gamma_7^*$ | $1.82^{***}$ | $1.83^{***}$ | $1.84^{***}$ | $1.84^{***}$ | $1.97^{***}$ | $1.91^{***}$ | $2.12^{***}$ | $1.81^{***}$ | $1.81^{***}$ | $1.77^{***}$ | $1.78^{***}$ | $1.81^{***}$ | $1.77^{***}$ |
| | (13.74) | (13.89) | (14.02) | (13.92) | (15.49) | (14.76) | (17.39) | (13.64) | (13.62) | (13.08) | (13.12) | (13.61) | (13.02) |
| $\gamma_{vol}^*$ | | | | | | | | -89.9 | -88.2 | | | | -29.9 |
| | | | | | | | | (-0.67) | (-0.65) | | | | (-0.22) |
| $\gamma_{vol}^*(Lag)$ | | | | | | | | | -51.8 | | | | 7.97 |
| | | | | | | | | | (-0.35) | | | | (0.05) |
| $\gamma_{overnight}^*$ | | | | | | | | | | $-0.086^{***}$ | | | |
| | | | | | | | | | | (-2.80) | | | |
| $\gamma_{3M}^*$ | | | | | | | | | | | $-0.065^{***}$ | | $-0.066^{***}$ |
| | | | | | | | | | | | (-2.59) | | (-2.60) |
| $\gamma_{TRYNews}^*$ | | | | | | | | | | | | 0.19 | 0.19 |
| | | | | | | | | | | | | (1.01) | (0.97) |
| $\gamma_{USNews}^*$ | | | | | | | | | | | | 0.18 | 0.21 |
| | | | | | | | | | | | | (1.05) | (1.19) |
| $\mu_1$ | $-5.98^{***}$ | $-6.01^{***}$ | $-6.01^{***}$ | $-5.90^{***}$ | $-8.82^{***}$ | $-7.82^{***}$ | $-11.2^{***}$ | $-6.07^{***}$ | $-6.09^{***}$ | $-7.95^{***}$ | $-7.75^{***}$ | $-5.94^{***}$ | $-7.76^{***}$ |
| | (-4.33) | (-4.36) | (-4.36) | (-4.22) | (-6.56) | (-5.63) | (-9.01) | (-4.31) | (-4.32) | (-5.01) | (-4.94) | (-4.30) | (-4.93) |
| $\mu_2$ | -2.20 | $-2.24^{*}$ | $-2.24^{*}$ | -2.06 | $-5.19^{***}$ | $-4.16^{***}$ | $-7.62^{***}$ | -2.28 | $-2.30^{*}$ | $-4.06^{***}$ | $-3.87^{**}$ | -2.15 | $-3.88^{**}$ |
| | (-1.62) | (-1.65) | (-1.65) | (-1.50) | (-3.98) | (-3.06) | (-6.48) | (-1.64) | (-1.66) | (-2.62) | (-2.53) | (-1.58) | (-2.52) |
| N | 1008 | 1008 | 1008 | 1008 | 1008 | 1008 | 1008 | 1008 | 1008 | 1008 | 1008 | 1008 | 1008 |
| Pseudo $R^2$ | 0.59 | 0.59 | 0.59 | 0.59 | 0.58 | 0.59 | 0.57 | 0.59 | 0.59 | 0.60 | 0.60 | 0.60 | 0.60 |

Robustness checks for the extended probit model with the reserve ratio variable, the extended model, for the second sub-sample period. Models (1)-(7) test the robustness of the reserve-to-GDP ratio variable to different exchange rate target specifications by dropping the exchange rate variables from the model one-by-one and and as short-term and long-term targets. Models (8) and (9) test the robustness of the variable against the inclusion of the exchange rate volatility, which is calculated as the square of the exchange rate returns, and the first lag of the volatility variable. Models (10) and (11) test the robustness of the variable against the inclusion of an interest rate variable that is first calculated as the difference between the overnight interest rates of Turkey and the US, and then the difference between the 3-month ahead interest rate on deposits in Turkey and the 3-month T-bill rate in the US. Model (12) tests the robustness of the variable against the inclusion of the macroeconomic data announcements for Turkey (GDP, inflation rate, unemployment rate) and the US (GDP, inflation rate, unemployment rate, and changes in policy rate). Finally, Model (13) checks the robustness against the inclusion of all the employed variables with a preference to the 3-month ahead interest rate difference.

$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

**Table 13:** Robustness checks, the third sub-sample period (05/08/11-19/06/13)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\gamma_1^*$ | | -0.24 | | -1.44 | -1.53 | -1.27 | -14.8 | 0.37 | 10.8 | -1.31 | -1.42 | -0.38 | 10.3 |
| | | (-0.01) | | (-0.09) | (-0.09) | (-0.08) | (-0.81) | (0.02) | (0.66) | (-0.08) | (-0.09) | (-0.02) | (0.64) |
| $\gamma_2^*$ | 5.94 | | | 4.13 | 6.59 | 5.91 | -6.21 | 6.33 | 5.85 | 5.24 | 5.64 | 6.43 | 5.67 |
| | (1.27) | | | (1.12) | (1.53) | (1.40) | (-1.52) | (1.30) | (1.23) | (1.18) | (1.24) | (1.38) | (1.20) |
| $\gamma_3^*$ | -11.8 | 0.47 | 0.44 | | -11.4 | -8.33 | | -12.4 | -12.1 | -4.90 | -4.00 | -14.0 | -2.07 |
| | (-0.77) | (0.04) | (0.04) | | (-0.84) | (-0.72) | | (-0.80) | (-0.77) | (-0.32) | (-0.23) | (-0.93) | (-0.12) |
| $\gamma_4^*$ | -151.7*** | -168.6*** | -168.5*** | -181.3*** | | -21.5*** | | -148.6*** | -160.8*** | -183.7*** | -160.1*** | -154.7*** | -184.1*** |
| | (-3.40) | (-3.49) | (-3.54) | (-2.83) | | (-3.35) | | (-3.54) | (-3.24) | (-4.12) | (-3.57) | (-3.38) | (-3.21) |
| $\gamma_5^*$ | 131.4*** | 142.8*** | 142.7*** | 154.2** | -20.0** | | | 128.4*** | 140.8*** | 157.0*** | 132.8*** | 135.2*** | 154.3*** |
| | (3.09) | (3.11) | (3.15) | (2.50) | (-2.55) | | | (3.19) | (3.04) | (3.72) | (2.79) | (3.15) | (2.78) |
| $\gamma_6^*$ | -11.3** | -10.8** | -10.8** | -13.2*** | -16.5*** | -16.2*** | -4.44 | -11.9** | -10.0* | -8.14 | -9.93* | -10.8** | -8.03 |
| | (-2.11) | (-1.97) | (-1.98) | (-2.90) | (-3.75) | (-3.92) | (-1.58) | (-2.17) | (-1.77) | (-1.23) | (-1.72) | (-2.09) | (-1.33) |
| $\gamma_7^*$ | 1.05*** | 1.11*** | 1.11*** | 1.08*** | 1.23*** | 1.18*** | 2.70*** | 1.05*** | 1.09*** | 1.06*** | 1.04*** | 1.04*** | 1.06*** |
| | (3.66) | (3.68) | (3.72) | (3.70) | (4.32) | (4.11) | (12.93) | (3.62) | (3.65) | (3.65) | (3.61) | (3.59) | (3.58) |
| $\gamma_{vol}^*$ | | | | | | | | 578.1 | 488.7 | | | | 499.9 |
| | | | | | | | | (0.35) | (0.28) | | | | (0.28) |
| $\gamma_{vol}^*(Lag)$ | | | | | | | | | -2552.5* | | | | -2618.1* |
| | | | | | | | | | (-1.89) | | | | (-1.87) |
| $\gamma_{overnight}^*$ | | | | | | | | | | 0.100 | | | |
| | | | | | | | | | | (0.87) | | | |
| $\gamma_{3M}^*$ | | | | | | | | | | | 0.12 | | 0.16 |
| | | | | | | | | | | | (0.67) | | (0.89) |
| $\gamma_{TRYNews}^*$ | | | | | | | | | | | | 0.10 | 0.033 |
| | | | | | | | | | | | | (0.24) | (0.08) |
| $\gamma_{USNews}^*$ | | | | | | | | | | | | -0.34 | -0.28 |
| | | | | | | | | | | | | (-0.81) | (-0.64) |
| $\mu_1$ | -8.95*** | -8.96*** | -8.97*** | -10.3*** | -9.17*** | -9.28*** | -3.79*** | -9.11*** | -8.66*** | -7.26** | -7.48** | -8.80*** | -6.85* |
| | (-3.96) | (-3.78) | (-3.78) | (-5.46) | (-4.82) | (-5.12) | (-3.09) | (-3.96) | (-3.56) | (-2.10) | (-2.11) | (-3.99) | (-1.84) |
| N | 489 | 489 | 489 | 489 | 489 | 489 | 489 | 489 | 489 | 489 | 489 | 489 | 489 |
| Pseudo $R^2$ | 0.73 | 0.73 | 0.73 | 0.73 | 0.72 | 0.72 | 0.59 | 0.73 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 |

Robustness checks for the extended probit model with the reserve ratio variable, the extended model, for the third sub-sample period. Models (1)-(7) test the robustness of the reserve-to-GDP ratio variable to different exchange rate target specifications by dropping the exchange rate variables from the model one-by-one and and as short-term and long-term targets. Models (8) and (9) test the robustness of the variable against the inclusion of the exchange rate volatility, which is calculated as the square of the exchange rate returns, and the first lag of the volatility variable. Models (10) and (11) test the robustness of the variable against the inclusion of an interest rate variable that is first calculated as the difference between the overnight interest rates of Turkey and the US, and then the difference between the 3-month ahead interest rate on deposits in Turkey and the 3-month T-bill rate in the US. Model (12) tests the robustness of the variable against the inclusion of the macroeconomic data announcements for Turkey (GDP, inflation rate, unemployment rate) and the US (GDP, inflation rate, unemployment rate, and changes in policy rate). Finally, Model (13) checks the robustness against the inclusion of all the employed variables with a preference to the 3-month ahead interest rate difference.
t statistics in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

**Table 14:** Robustness checks, the fourth sub-sample period (20/06/13-30/09/15)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\gamma_1^*$ | | 4.66 | | 7.67 | 7.76 | 7.52 | 8.29 | 7.51 | 9.71 | 7.02 | 6.65 | 7.71 | 8.66 |
| | | (0.40) | | (0.62) | (0.64) | (0.61) | (0.67) | (0.59) | (0.64) | (0.56) | (0.52) | (0.63) | (0.58) |
| $\gamma_2^*$ | -5.99* | | | -6.88* | -6.64* | -6.58* | -5.15 | -5.80* | -5.70 | -8.12* | -7.61* | -6.24* | -6.92* |
| | (-1.78) | | | (-1.90) | (-1.93) | (-1.93) | (-1.57) | (-1.65) | (-1.64) | (-1.95) | (-1.82) | (-1.83) | (-1.71) |
| $\gamma_3^*$ | -2.83 | -7.17 | -7.02 | | 3.06 | 1.67 | | -2.34 | -1.93 | 1.25 | 0.44 | -2.81 | 1.17 |
| | (-0.49) | (-1.13) | (-1.12) | | (0.86) | (0.42) | | (-0.41) | (-0.34) | (0.18) | (0.06) | (-0.49) | (0.16) |
| $\gamma_4^*$ | 7.95 | 9.21 | 9.18 | 5.64 | | 1.04 | | 7.38 | 7.05 | 1.53 | 4.73 | 7.86 | 3.99 |
| | (1.16) | (1.29) | (1.29) | (1.30) | | (0.51) | | (1.10) | (1.05) | (0.18) | (0.60) | (1.14) | (0.51) |
| $\gamma_5^*$ | -4.85 | -5.57 | -5.53 | -3.61 | 0.035 | | | -4.53 | -4.34 | 0.51 | -1.96 | -4.84 | -1.57 |
| | (-1.07) | (-1.20) | (-1.20) | (-1.13) | (0.03) | | | (-1.02) | (-0.98) | (0.09) | (-0.35) | (-1.06) | (-0.28) |
| $\gamma_6^*$ | -3.14 | -3.00 | -3.02 | -3.91 | -5.56 | -6.45 | -4.27 | -2.94 | -3.02 | -4.17 | -3.38 | -3.11 | -3.28 |
| | (-0.66) | (-0.60) | (-0.61) | (-1.00) | (-1.34) | (-1.57) | (-1.21) | (-0.63) | (-0.65) | (-0.93) | (-0.71) | (-0.66) | (-0.70) |
| $\gamma_7^*$ | 1.45*** | 1.47*** | 1.47*** | 1.46*** | 1.49*** | 1.48*** | 1.49*** | 1.47*** | 1.46*** | 1.43*** | 1.44*** | 1.44*** | 1.45*** |
| | (6.02) | (6.11) | (6.13) | (6.05) | (6.24) | (6.22) | (6.25) | (6.05) | (5.95) | (5.91) | (5.95) | (5.93) | (5.90) |
| $\gamma_{vol}^*$ | | | | | | | | -2443.2 | -2448.2 | | | | -2415.4 |
| | | | | | | | | (-1.25) | (-1.25) | | | | (-1.24) |
| $\gamma_{vol}^*(Lag)$ | | | | | | | | | -646.1 | | | | -598.5 |
| | | | | | | | | | (-0.71) | | | | (-0.66) |
| $\gamma_{overnight}^*$ | | | | | | | | | | -0.10 | | | |
| | | | | | | | | | | (-1.03) | | | |
| $\gamma_{3M}^*$ | | | | | | | | | | | -0.080 | | -0.075 |
| | | | | | | | | | | | (-0.82) | | (-0.78) |
| $\gamma_{TRYNews}^*$ | | | | | | | | | | | | -0.12 | -0.083 |
| | | | | | | | | | | | | (-0.39) | (-0.27) |
| $\gamma_{USNews}^*$ | | | | | | | | | | | | 0.052 | 0.052 |
| | | | | | | | | | | | | (0.20) | (0.19) |
| $\mu_1$ | -1.51 | -1.41 | -1.42 | -1.90 | -2.68 | -3.12 | -2.00 | -1.50 | -1.56 | -2.75 | -2.23 | -1.49 | -2.25 |
| | (-0.63) | (-0.56) | (-0.57) | (-0.95) | (-1.26) | (-1.48) | (-1.09) | (-0.64) | (-0.66) | (-1.23) | (-0.89) | (-0.62) | (-0.92) |
| N | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 | 595 |
| Pseudo $R^2$ | 0.18 | 0.18 | 0.18 | 0.19 | 0.18 | 0.18 | 0.18 | 0.19 | 0.20 | 0.19 | 0.19 | 0.19 | 0.20 |

Robustness checks for the extended probit model with the reserve ratio variable, the extended model, for the fourth sub-sample period. Models (1)-(7) test the robustness of the reserve-to-GDP ratio variable to different exchange rate target specifications by dropping the exchange rate variables from the model one-by-one and and as short-term and long-term targets. Models (8) and (9) test the robustness of the variable against the inclusion of the exchange rate volatility, which is calculated as the square of the exchange rate returns, and the first lag of the volatility variable. Models (10) and (11) test the robustness of the variable against the inclusion of an interest rate variable that is first calculated as the difference between the overnight interest rates of Turkey and the US, and then the difference between the 3-month ahead interest rate on deposits in Turkey and the 3-month T-bill rate in the US. Model (12) tests the robustness of the variable against the inclusion of the macroeconomic data announcements for Turkey (GDP, inflation rate, unemployment rate) and the US (GDP, inflation rate, unemployment rate, and changes in policy rate). Finally, Model (13) checks the robustness against the inclusion of all the employed variables with a preference to the 3-month ahead interest rate difference.
t statistics in parentheses $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

**Table 15:** Probit regressions, the extended model with the forecasts using weekly data

| | Full Sample | First Sub-Sample | Second Sub-Sample | Third Sub-Sample | Fourth Sub-Sample | Fifth Sub-Sample | Sixth Sub-Sample |
|---|---|---|---|---|---|---|---|
| $\gamma_1^*$ | -2.88 | -14.6 | 12.1 | 4.79 | -0.50 | 4.09 | 0.53 |
| | (-0.67) | (-1.17) | (0.85) | (0.59) | (-0.05) | (0.21) | (0.05) |
| $\gamma_2^*$ | -1.41 | 18.8 | 0.99 | -2.42 | -2.93 | 14.7$^{***}$ | -1.50 |
| | (-1.24) | (1.60) | (0.22) | (-0.87) | (-0.78) | (3.19) | (-0.43) |
| $\gamma_3^*$ | -1.67 | 11.6 | 10.1 | 4.91 | 15.1$^{**}$ | -63.2$^{***}$ | -6.85 |
| | (-0.95) | (0.27) | (1.12) | (1.58) | (2.47) | (-4.04) | (-1.27) |
| $\gamma_4^*$ | 0.84 | 72.9$^{**}$ | 68.7$^{**}$ | 54.3 | -9.59 | -68.2$^{***}$ | 13.4$^{**}$ |
| | (0.39) | (2.26) | (2.10) | (0.94) | (-0.89) | (-3.71) | (2.20) |
| $\gamma_5^*$ | -3.58$^{*}$ | -133.5$^{**}$ | -76.8$^{**}$ | -67.8 | 0.10 | 80.7$^{***}$ | -10.2$^{***}$ |
| | (-1.89) | (-2.53) | (-2.15) | (-1.18) | (0.01) | (3.15) | (-2.66) |
| $\gamma_6^*$ | -7.22$^{***}$ | 2.48 | 3.82 | 1.85 | 6.20 | 4.18 | 1.09 |
| | (-7.64) | (0.26) | (0.45) | (0.35) | (1.08) | (0.68) | (0.22) |
| $\gamma_7^*$ | 2.79$^{***}$ | 2.23$^{***}$ | 0.56$^{*}$ | 1.99$^{***}$ | 1.42$^{***}$ | 1.93$^{***}$ | 1.80$^{***}$ |
| | (36.99) | (5.70) | (1.72) | (7.62) | (7.42) | (8.04) | (8.86) |
| $\mu_1$ | -5.16$^{***}$ | -8.80$^{*}$ | 2.90 | -1.54 | 2.62 | -1.12 | 0.18 |
| | (-11.20) | (-1.93) | (0.76) | (-0.47) | (1.07) | (-0.43) | (0.07) |
| $\mu_2$ | -1.74$^{***}$ | 0.25 | | 3.78 | | 4.12 | |
| | (-3.96) | (0.07) | | (1.13) | | (1.54) | |
| N | 2521 | 233 | 281 | 380 | 514 | 498 | 615 |
| Pseudo $R^2$ | 0.75 | 0.85 | 0.097 | 0.80 | 0.25 | 0.73 | 0.33 |

Regression results for the extended probit model with the reserve ratio variable that has been created with weekly updated forecasts instead of the MIDAS methodology. The estimated model is as follows:

$$IInt_t = \begin{cases} -1 & \text{if } \; y_t^* < \mu_1 \\ 0 & \text{if } \; \mu_1 < y_t^* < \mu_2 \\ 1 & \text{if } \; \mu_2 < y_t^* \end{cases}$$

where $y_t^* = X_t\gamma + \varepsilon_t$ and

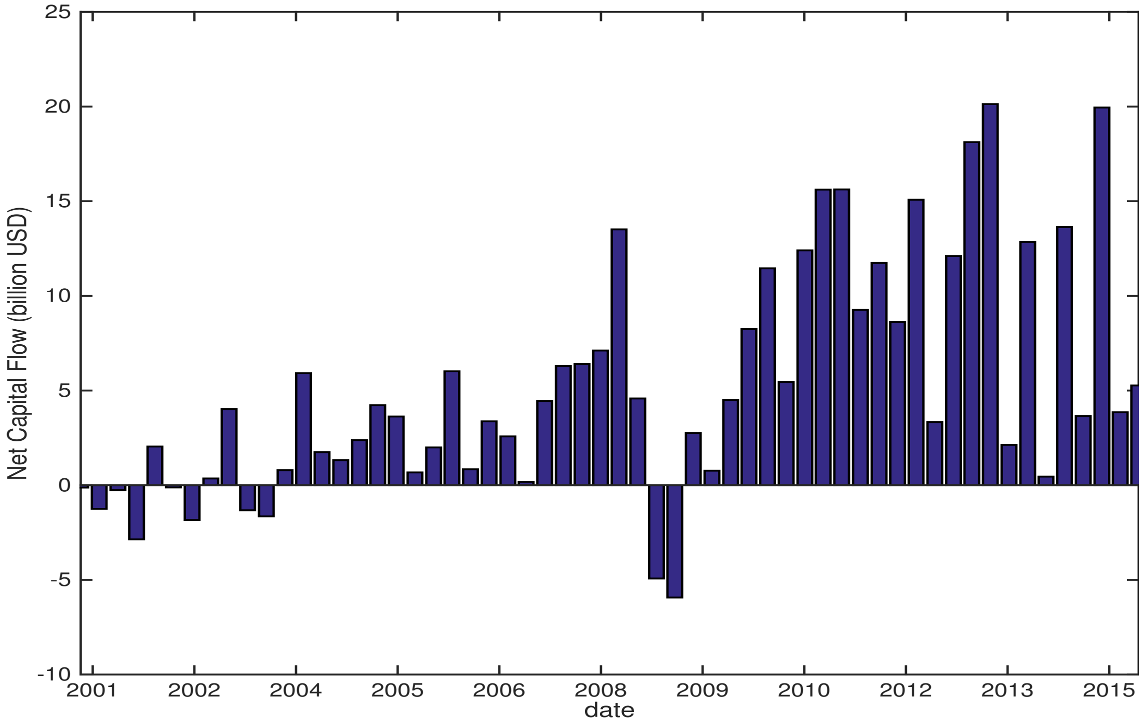
$$\begin{aligned} X_t\gamma =& \gamma_1(s_{t-1} - s_{t-2}) + \gamma_2(s_{t-1} - s_{t-21}) + \gamma_3(s_{t-1} - s_{t-1}^{1MA}) \\ &+ \gamma_4(s_{t-1} - s_{t-1}^{3MA}) + \gamma_5(s_{t-1} - s_{t-1}^{5MA}) + \gamma_6 R_t^{week} + \gamma_7 IInt_{t-1}. \end{aligned}$$

where $R_t^{week}$ denotes the weekly updated forecasts variable for the end of quarter reserve-to GDP ratios.

t statistics in parentheses $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

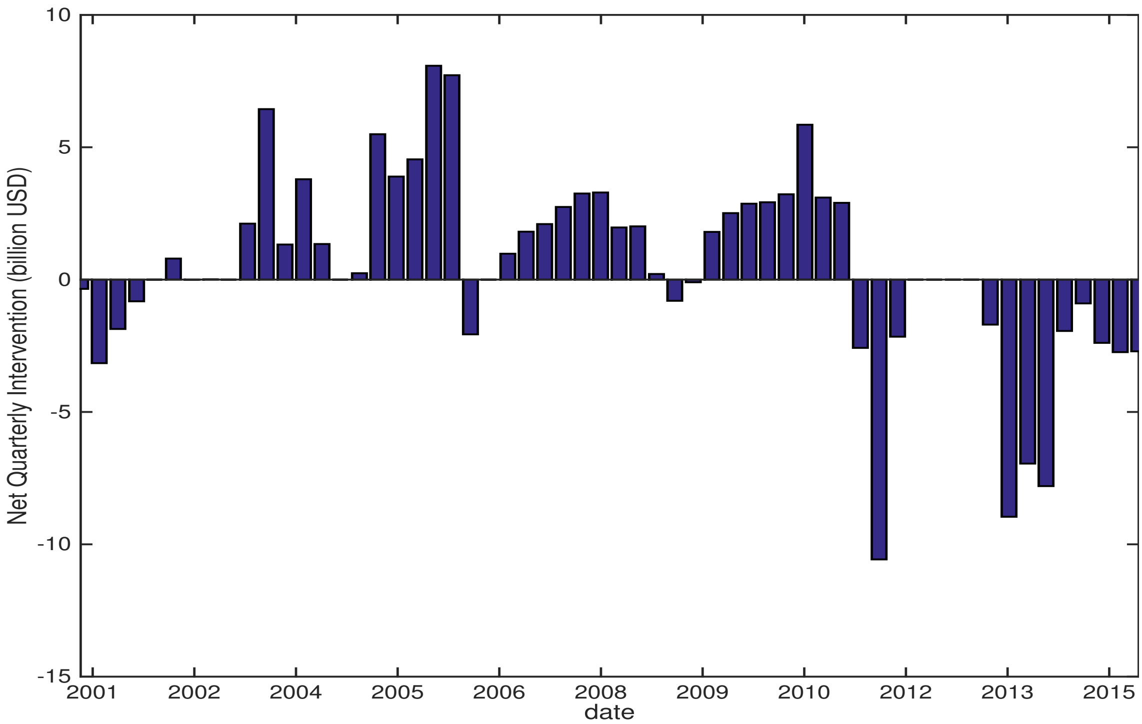
# Figures

**Figure 1:** Capital flows



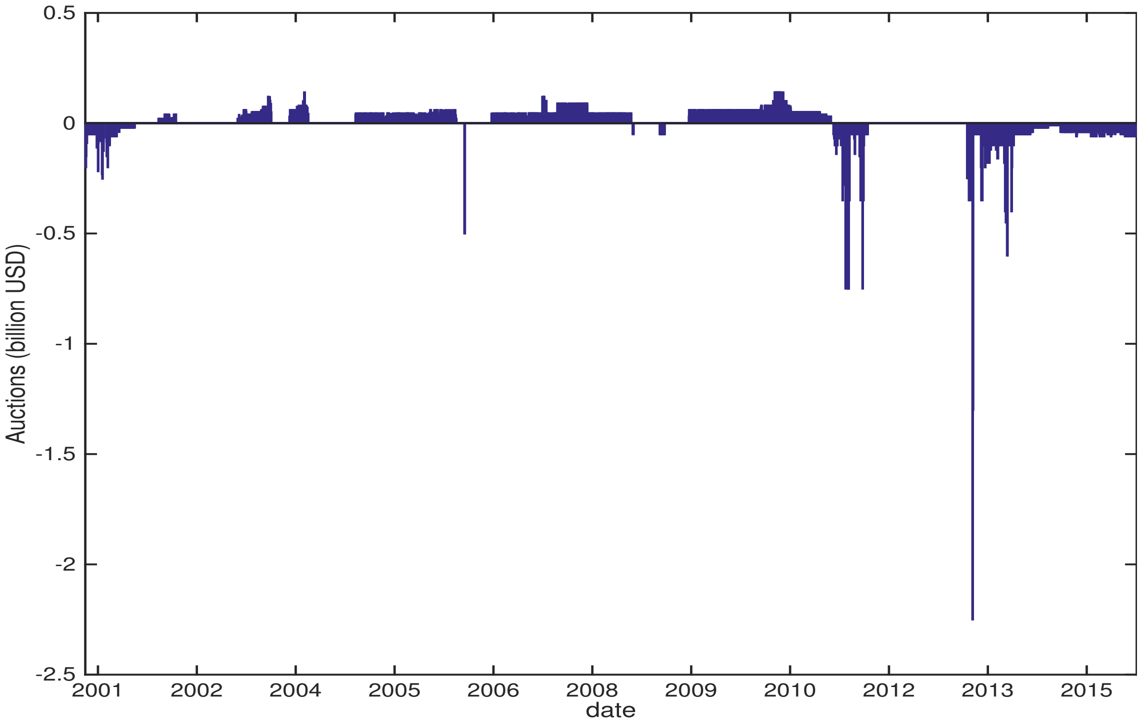

Quarterly capital flow data for the time period from 26 March 2001 to 16 October 2015. Positive values indicate capital inflows to Turkey while negative values are capital outflows from the country. *Source: The CBRT database*

**Figure 2:** Quarterly interventions



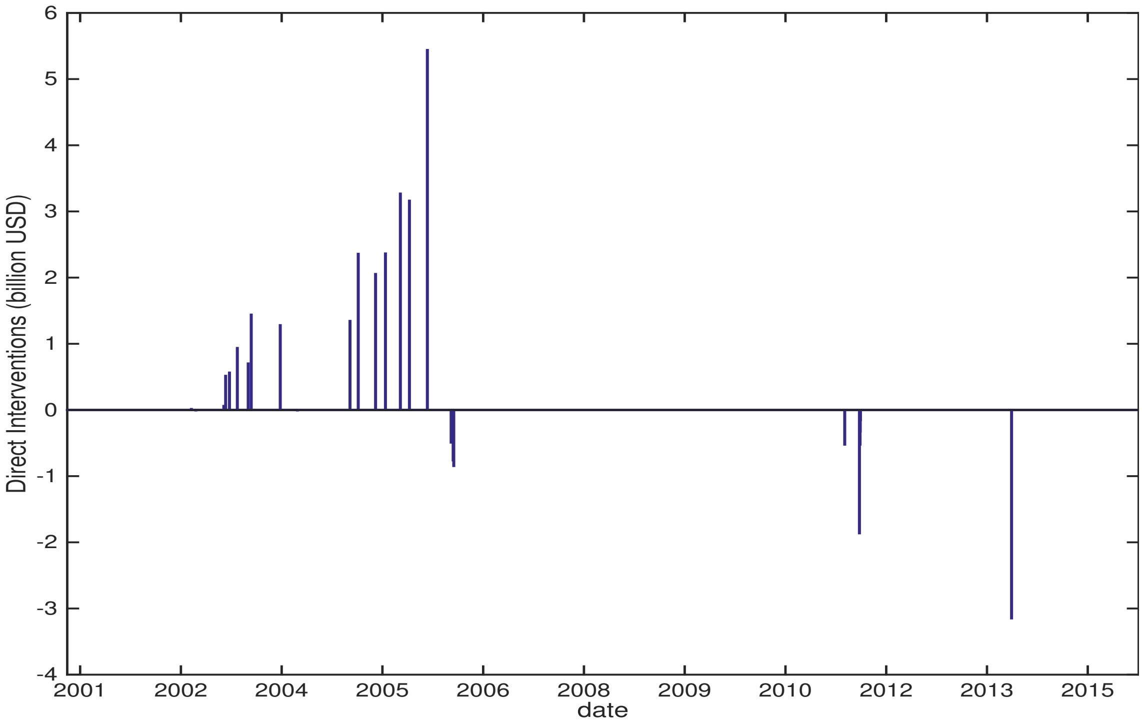

Total quarterly intervention data for the time period from 26 March 2001 to 16 October 2015. Positive values indicate USD purchases while the negative values are USD sales. *Source: The CBRT database*

**Figure 3:** Intervention data, auctions



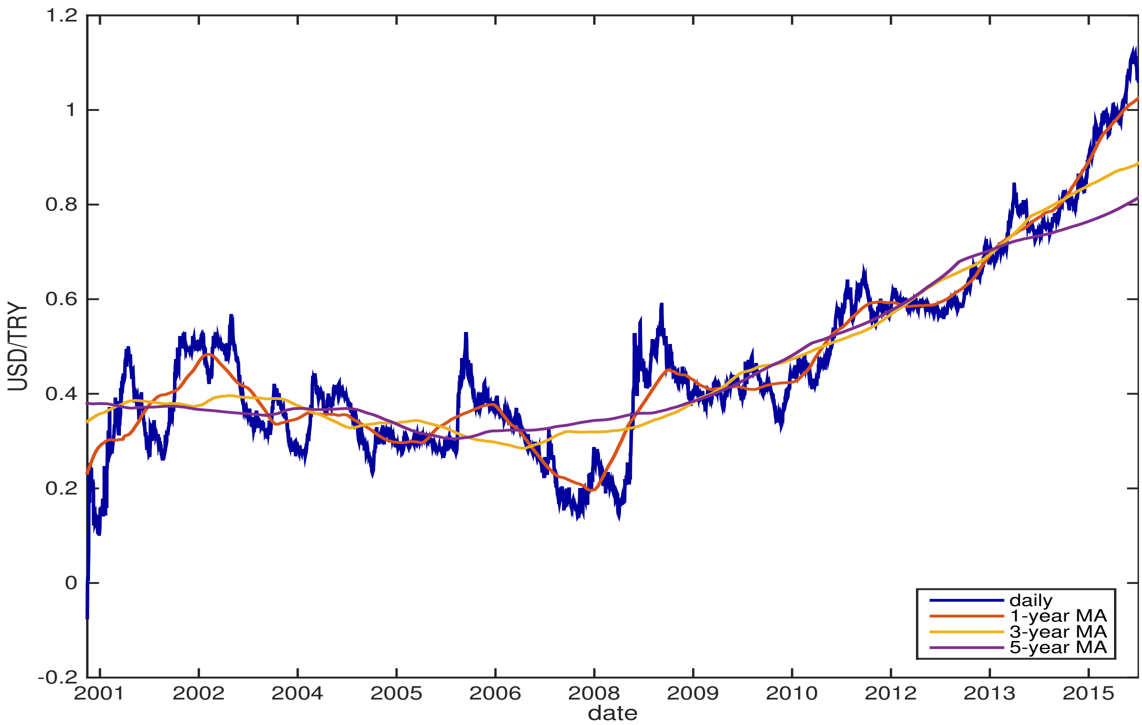

Interventions carried out by the CBRT with auctions. The data covers the time period from 26 March 2001 to 16 October 2015. Positive values indicate USD purchases while the negative values are USD sales. *Source: The CBRT database*

**Figure 4:** Intervention data, direct interventions



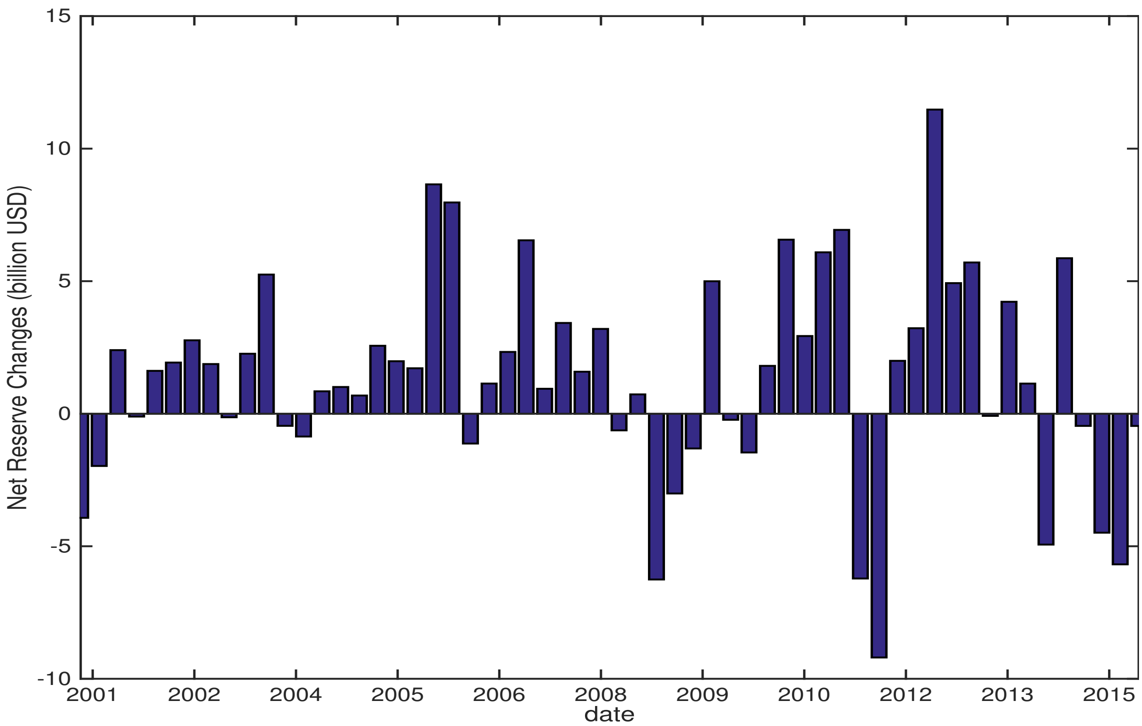

Direct interventions carried out by the CBRT. The data covers the time period from 26 March 2001 to 16 October 2015. Positive values indicate USD purchases while the negative values are USD sales. *Source: The CBRT database*

**Figure 5:** USD/TRY exchange rate



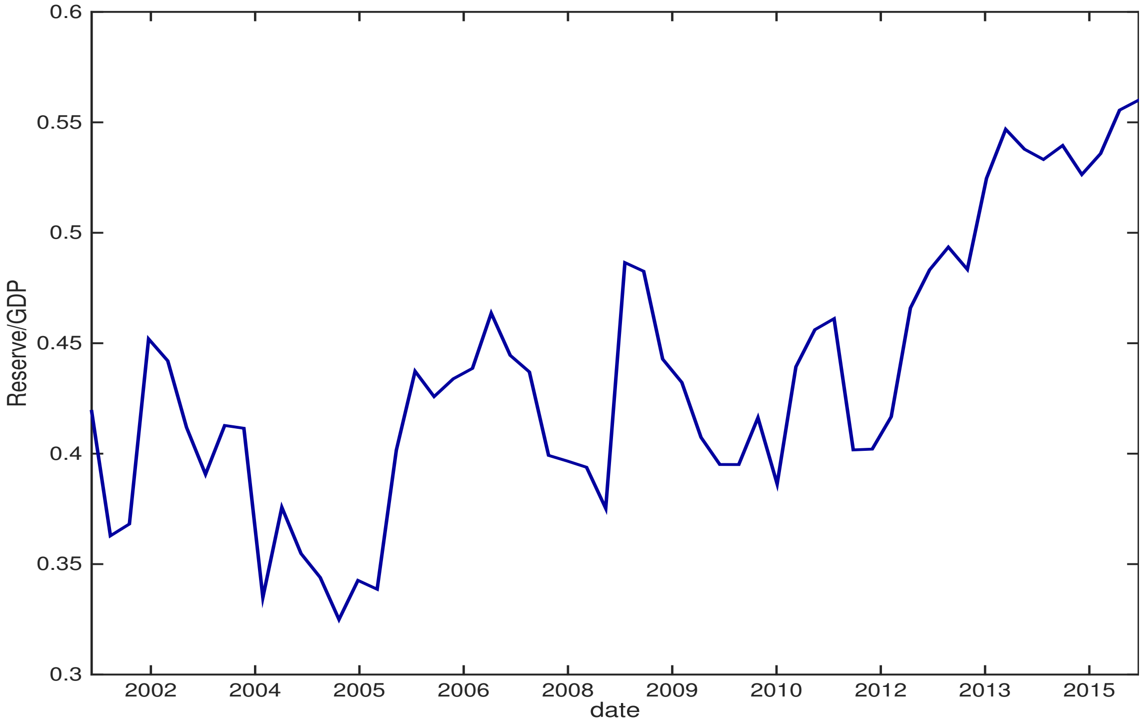

USD/TRY exchange rate values with 1-year, 3-year, and 5-year moving average values. *Source: The CBRT database and calculations of the authors.*

**Figure 6:** Foreign exchange reserves



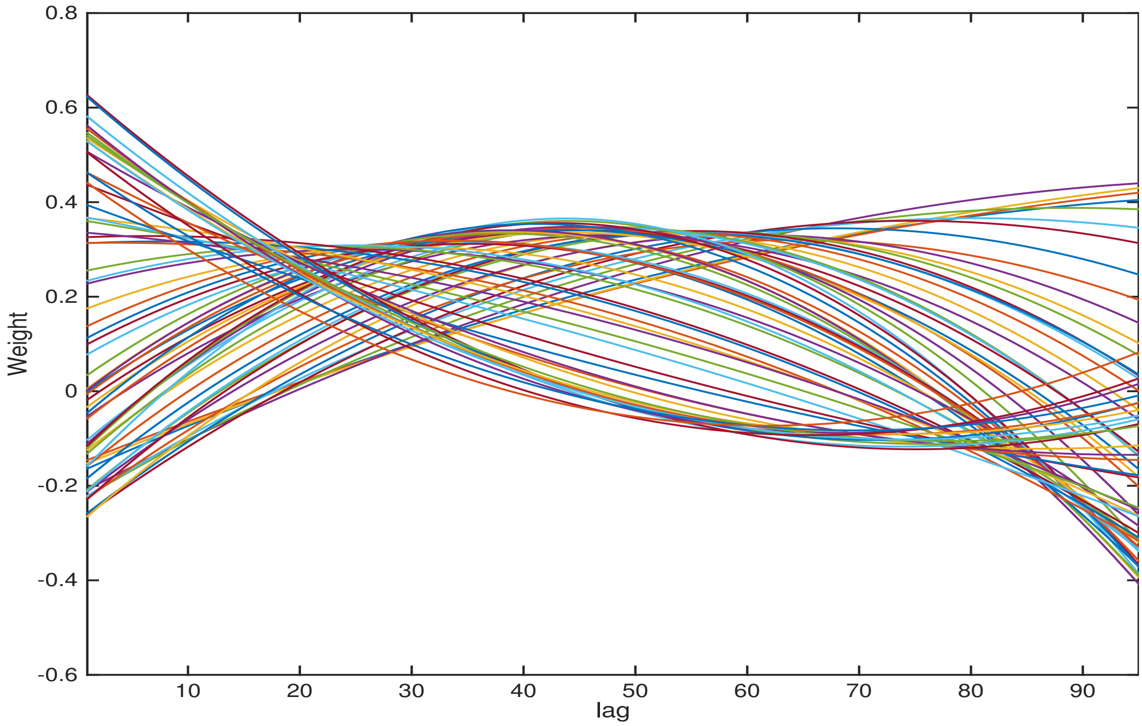

Quarterly change in international reserves of the CBRT for the time period from 26 March 2001 to 16 October 2015. *Source: The CBRT database*

**Figure 7:** International reserve-to-GDP ratio



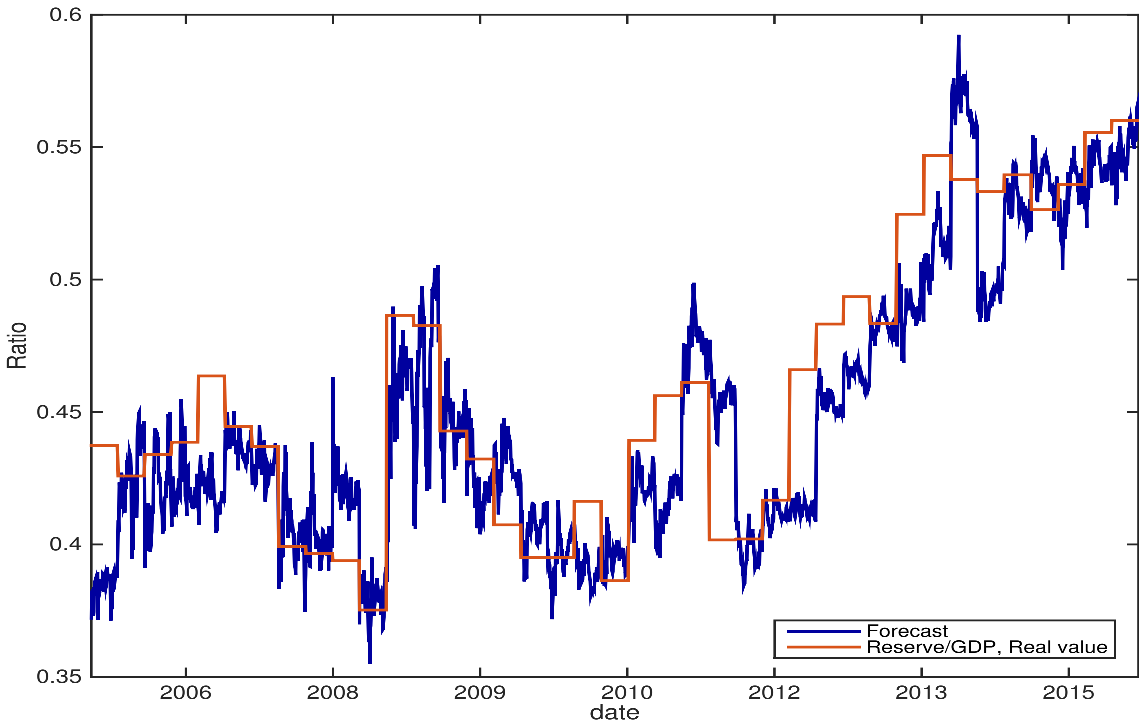

Quarterly ratio of the international reserves to GDP for the time period from 26 March 2001 to 16 October 2015. *Source: The CBRT database and calculations of the authors.*

**Figure 8:** MIDAS estimation, estimated weights



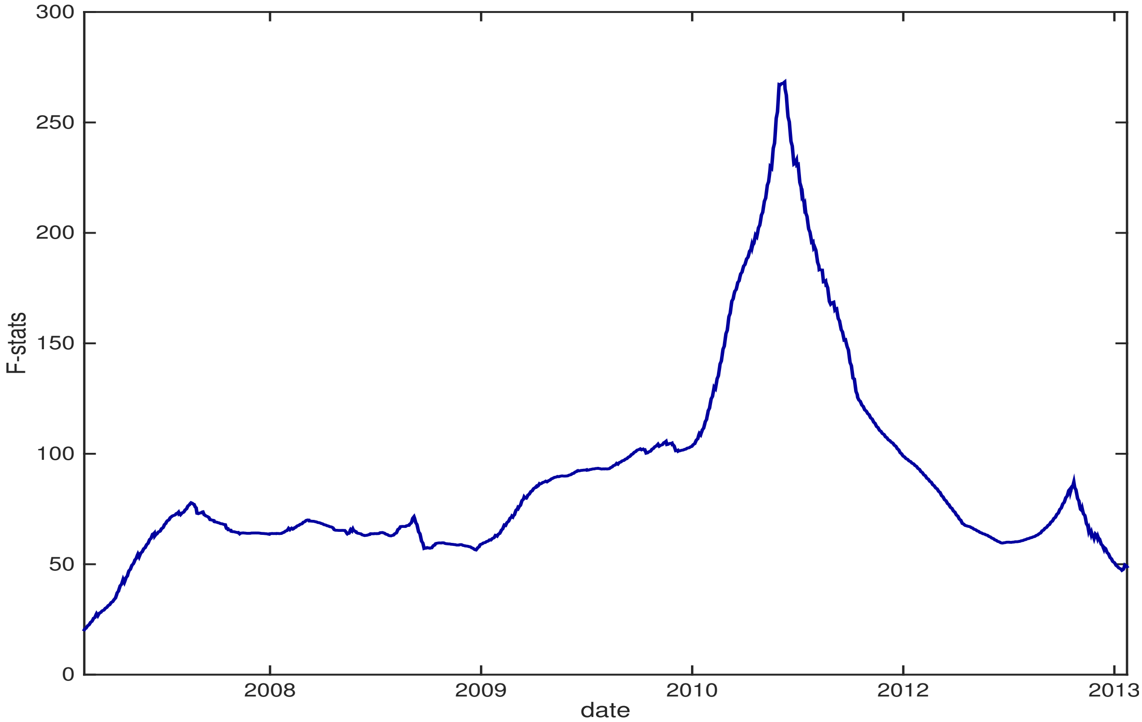

Estimated weights with the MIDAS with lead model for all forecast horizons. Almon distributed lag polynomial function with two hyper parameters is used in the estimations.

**Figure 9:** Daily $\hat{R}^{t-1}(\hat{\Lambda}_{t-1})$ values



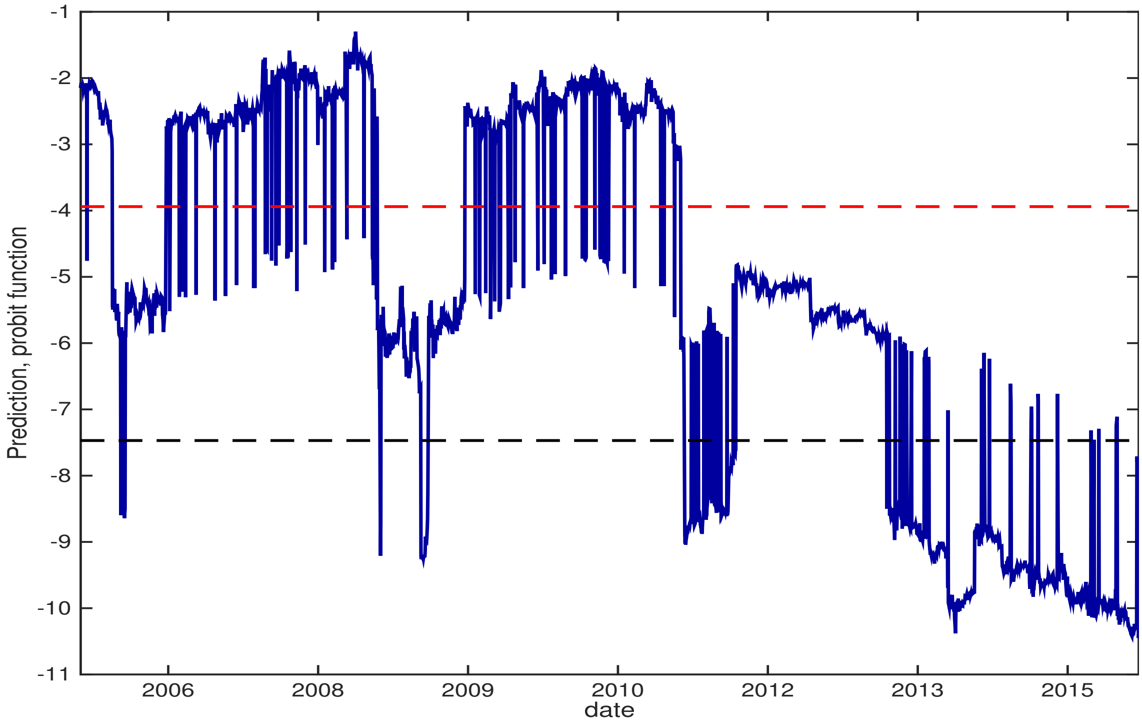

Plot of the calculated $\hat{R}^{t-1}(\hat{\Lambda}_{t-1})$ values with the quarterly reserve-to-GDP ratios for the forecast period, 02 January 2006 to 30 September 2015. $\hat{R}^{t-1}(\hat{\Lambda}_{t-1})$ values are plotted in blue and quarterly values are plotted in red.

**Figure 10:** Chow test statistics



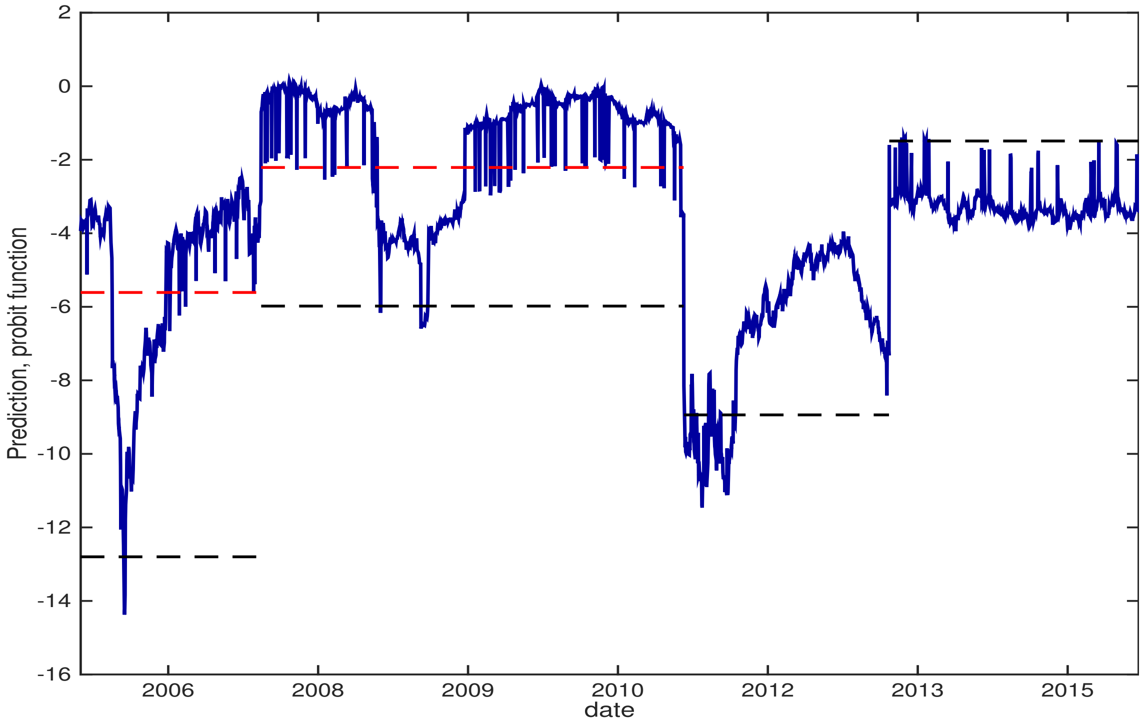

F-statistics of the Chow tests for the extended model estimation period, 02 January 2006 to 30 September 2015. The sample is trimmed at the 10% level.

**Figure 11:** Ordered probit regressions, fitted values, full sample



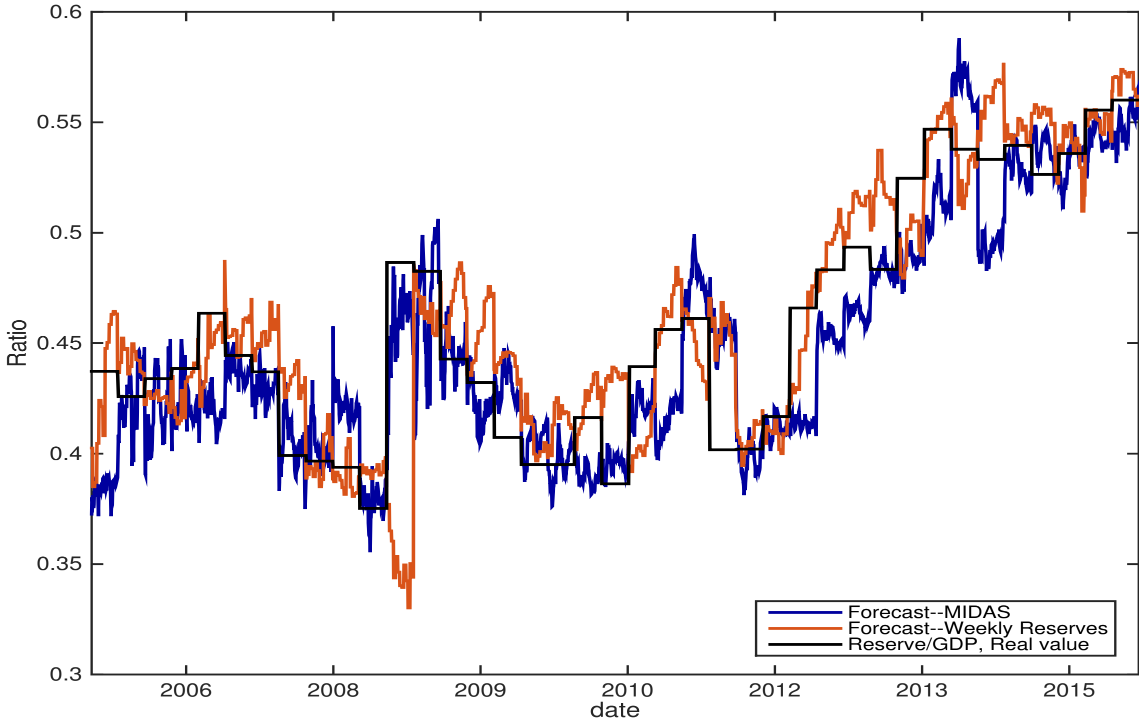

Predicted values and cut-off points for the full sample probit analysis. Dashed horizontal black line represents the estimated the cut-off point for the USD sales, $\hat{\mu}_1$, and Dashed horizontal red line represents the estimated the cut-off point for the USD purchases, $\hat{\mu}_2$. If the predicted value is smaller than the black line, the CBRT is likely to sale USD while it is higher than the red line, the central bank is likely to purchase USD.

**Figure 12:** Ordered probit regressions, fitted values, subsamples




Predicted values and cut-off points for the sub-sample probit analysis. Dashed horizontal black line represents the estimated the cut-off point for the USD sales, $\hat{\mu}_1$, and Dashed horizontal red line represents the estimated the cut-off point for the USD purchases, $\hat{\mu}_2$. If the predicted value is lower than the black line, the CBRT is likely to sale USD while it is higher than the red line, the central bank is likely to purchase USD. Notice that, there are no USD purchases in the third and fourth periods.

**Figure 13:** Daily reserve-to-GDP forecasts




Plot of the MIDAS forecasts, the forecasts generated using the weekly foreign exchange reserve levels, and the quarterly reserve-to-GDP ratios for the forecast period, 02 January 2006 to 30 September 2015. MIDAS values are plotted in blue, the forecasts using weekly data are plotted in red, and quarterly values are plotted in black.

# Appendix: Noise-to-Signal Analysis Breakdown

Let $Z_1$ be the number of days an intervention signal is issued by the model and an intervention is carried by the policy makers, $Z_2$ be the number of days an intervention signal is issued but an intervention is not carried, $Z_3$ be the number of days an intervention signal is not issued but an intervention is carried, and $Z_4$ be the number of days neither an intervention signal is issued nor an intervention is carried. Then the signal ratio will be $(Z_1/Z_1+Z_3)$ and the noise ratio or the false alarms will be $(Z_2/Z_2+Z_4)$. A "cutoff" level of probability refers to the probability level that is taken to be the threshold for probit model probabilities to be taken as a signal of interventions. Small values of the cutoff level will increase the signal ratio but will also increase the noise ratio, which implies an intervention alarm every day as a theoretical possibility. Thus, a level of cutoff probability that will signal enough but not introduce much noise has to be chosen. In order to do that, Kaminsky and Reinhart (1999) propose to minimise $((Z_2/Z_2+Z_4))/((Z_1/Z_1+Z_3))$ while Ito and Yabu (2007) minimize just the $Z_2/Z_1$ level. These two are the same problem because the numbers of intervention and no-intervention days are constant in the dataset.

**Table 16:** Noise-to-signal analysis, calculation

| | Intervention | No intervention |
|---|---|---|
| Signal issued | $Z_1$ | $Z_2$ |
| No signal issued | $Z_3$ | $Z_4$ |
| Total | $Z_1+Z_3$ | $Z_2+Z_4$ |

$$\text{signal} = \frac{Z_1}{Z_1+Z_3}, \quad \text{noise} = \frac{Z_2}{Z_2+Z_4}, \quad \text{noise-to-signal} = \text{noise}/\text{signal}$$

**Table 17:** Noise-to-signal analysis, optimal cut-off points in %

| | extended model | | | the Ito & Yabu | |
|---|---|---|---|---|---|
| | Purchase | Sale | | Purchase | Sale |
| Full Sample | 90 | 94 | Full Sample | 92 | 95 |
| 31/01/06-24/09/07 | 99 | 26 | 31/01/06-29/08/07 | 94 | 35 |
| 25/09/07-03/08/11 | 73 | 47 | 30/09/07-03/08/09 | 97 | 38 |
| | | | 04/08/09-22/07/11 | 96 | |
| 05/08/11-19/06/13 | | 94 | 25/07/11-19/06/13 | | 97 |
| 20/06/13-30/09/15 | | 97 | 20/06/13-30/09/15 | | 97 |

**Table 18:** Noise-to-signal ratio, breakdown.

| | extended model | | | | | the Ito & Yabu | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Purchase | | Sale | | | Purchase | | Sale | |
| Full sample | | | | | Full sample | | | | |
| | Intervention | No intervention | Intervention | No intervention | | Intervention | No intervention | Intervention | No intervention |
| Signal issued | 811 | 45 | 423 | 10 | Signal issued | 708 | 41 | 314 | 9 |
| No signal issued | 207 | 1459 | 256 | 1833 | No signal issued | 310 | 1463 | 365 | 1834 |
| Total | 1018 | 1504 | 679 | 1843 | Total | 1018 | 1504 | 679 | 1843 |
| 31/01/06-24/09/07 | | | | | 31/01/06-29/08/07 | | | | |
| | Intervention | No intervention | Intervention | No intervention | | Intervention | No intervention | Intervention | No intervention |
| Signal issued | 48 | 1 | 3 | 1 | Signal issued | 197 | 5 | 2 | 1 |
| No signal issued | 241 | 140 | 1 | 425 | No signal issued | 76 | 134 | 2 | 407 |
| Total | 289 | 141 | 4 | 426 | Total | 273 | 139 | 4 | 408 |
| | | | | | 30/09/07-03/08/09 | | | | |
| | | | | | | Intervention | No intervention | Intervention | No intervention |
| | | | | | Signal issued | 91 | 5 | 18 | 1 |
| | | | | | No signal issued | 179 | 228 | 2 | 482 |
| | | | | | Total | 270 | 233 | 20 | 483 |
| 25/09/07-03/08/11 | | | | | 04/08/09-22/07/11 | | | | |
| | Intervention | No intervention | Intervention | No intervention | | Intervention | No intervention | Intervention | No intervention |
| Signal issued | 468 | 44 | 18 | 1 | Signal issued | 102 | 3 | | |
| No signal issued | 47 | 235 | 2 | 987 | No signal issued | 373 | 36 | | |
| Total | 515 | 279 | 20 | 988 | Total | 475 | 39 | | |
| 05/08/11-19/06/13 | | | | | 25/07/11-19/06/13 | | | | |
| | Intervention | No intervention | Intervention | No intervention | | Intervention | No intervention | Intervention | No intervention |
| Signal issued | | | 26 | 2 | Signal issued | | | 15 | 1 |
| No signal issued | | | 70 | 391 | No signal issued | | | 81 | 401 |
| Total | | | 96 | 393 | Total | | | 96 | 402 |
| 20/06/13-30/09/15 | | | | | 20/06/13-30/09/15 | | | | |
| | Intervention | No intervention | Intervention | No intervention | | Intervention | No intervention | Intervention | No intervention |
| Signal issued | | | 259 | 5 | Signal issued | | | 246 | 4 |
| No signal issued | | | 300 | 31 | No signal issued | | | 313 | 32 |
| Total | | | 559 | 36 | Total | | | 559 | 36 |

Calculated values according to Table (16). These values are used to calculate noise-to-signal ratios reported in Table (9).