The Effects of Monetary and Exchange Rate Policy Shocks: Evidence from an Emerging Market Economy*

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Many central banks that have opted for monetary autonomy have also been reluctant to relinquish control over the value of their currencies. As a result, they have operated through both interest rate and foreign exchange interventions. Using daily data from the Central Bank of Turkey during the period of 2002–10, we study the effects of simultaneous policies by first purging the intended monetary decisions from responses to real-time macroeconomic variables and then determining their impact on economic activity. We find that the Central Bank of Turkey adjusted its policy rate mostly in response to inflation levels relative to both the yearly target and agents' expectations, and conducted purchases and sales of foreign currency in response to exchange rate behavior. These responses varied depending on whether interventions were preannounced. In terms of effectiveness, we find that unannounced purchases of foreign currency had a significant effect in reducing exchange rate volatility but appeared to have no effect on exchange rate changes. Announced interventions, on the other hand, did have a significant impact on exchange rate changes and volatility. Finally, we find that changes in the policy rate affected inflation and output growth, with a lag delay of four and two quarters, respectively.

JEL Codes: E43, E52, E58, F31.

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1. Introduction

The *corner* (or *bipolar*) *hypothesis* and the *fix-or-float proposition* postulate that countries tend to move away from intermediate exchange rate regimes towards either hard pegs or fully flexible rates.[1] These concepts, which became conventional wisdom throughout the beginning of the 1990s, began to lose popularity after the East Asia crises of 1997–98 and the failure of Argentina's currency board in 2001. Since then, central banks have allegedly opted for monetary policy autonomy but have been reluctant to relinquish control over the value of their currencies. In fact, countries under an inflation-targeting regime have led concerted initiatives to affect the value of major currencies, some of which include the Smithsonian Agreement (1971), the Plaza and Louvre Accords (1985, 1987), the Chiang Mai Initiative (2000), and the Pittsburg Agreement (2009).

The Turkish case is no exception. Following the 2001 crisis, the Turkish economy underwent a structural transformation. The Central Bank of the Republic of Turkey (CBRT henceforth) was vested with independence and endowed with the primary objective of achieving and maintaining price stability. In 2002, the CBRT officially adopted an inflation-targeting regime and managed to bring high and chronic inflation down to single digits. Concurrently, in order to lower exchange rate volatility, the CBRT conducted foreign exchange interventions in one of two ways: (i) through *unannounced* interventions, often infrequent but large, and (ii) through *announced* interventions which consisted of predetermined dates and amounts, although with a discretionary (*optional*) amount of trading that took place during the day of the auction provided that monetary authorities decided to exceed the established amount.

In this paper we study the impact of simultaneous central bank policies in a unified framework. Namely, we analyze the effects of both interest rate and foreign exchange intervention on several macroeconomic variables that include inflation, output growth, and exchange rate behavior. Hence, our main objective is to evaluate the effectiveness of various types of central bank intervention. To this end, we extend the framework presented in Romer and Romer (2004) to allow for a bivariate policy model in which policy decisions are

[1] See Eichengreen (1994) and Obstfeld and Rogoff (1995).

governed by dependent decision processes. Specifically, we model the undertakings of monetary authorities (tailored to the various foreign exchange mechanisms of the CBRT) using a parametric approach, and purge the intended monetary decisions from responses to high-frequency and real-time macroeconomic data. Hence, an advantage of our estimation is that it allows for non-linearities when extracting the unexpected component of policy.

A key feature of our identification strategy consists of matching the actions of monetary authorities with stated targets and observable covariates—in other words, to closely observe what monetary authorities observed, and to capture their direct undertakings, especially with a clear timing profile. To this end, we employ proprietary data from the CBRT, comprising all direct sales and purchases of foreign currency as well as changes in the policy rate. We note that our measure of the policy rate differs from any market-based rate (such as the interbank rate) in the sense that it more accurately captures the intended decisions of the CBRT.[2]

To date, empirical studies have yet to converge on the effects of foreign exchange intervention. For instance, studies by Menkhoff (2013) or Villamizar-Villegas and Perez-Reyna (2017) show that nearly half of the surveyed literature find non-significant or inconclusive results. And studies that do find a significant impact mostly conclude that exchange rate effects are small and short-lived (see, for example, Fatum and Hutchison 1999 and Neil and Fillion 1999).

Furthermore, studies that center on the Turkish economy are rather limited, and some even face the challenge of covering restricted periods in which interest rate cuts always preceded purchases of foreign currency, making it harder to disentangle policy-specific effects. Akinci et al. (2006), for example, study eleven direct intervention episodes during 2001–03 using a time-varying parameter model to analyze the effects on curbing exchange rate volatility. Guimaraes and Karacadag (2004) also study the effects on exchange rate levels and volatility during the same time frame, using a GARCH model. In turn, Kilinc and Tunc (2014) use a structural

[2]In several countries, including the United States, a researcher has to sometimes infer the intended policy rate with the use of narrative records (see Romer and Romer 2004). In other cases, studies simply use overnight market rates (see Kilinc and Tunc 2014).

VAR to study the effects of policy on the Turkish economy during 2006–13.

The study that most closely relates to ours is Herrera and Ozbay (2005), which studies central bank interventions using a dynamic censored regression model during 1993–2003. In contrast, our paper mainly focuses on the effects of simultaneous policies. Hence, the unified policy framework provided in this study makes our work more amenable for empirical analyses and enables us to control for various policy interactions. Additionally, we differ in our definition of censored interventions and we only focus on the time period in which the CBRT adopted an inflation-targeting regime.[3]

Our investigation confirms some of the previous findings from the literature, but also yields some new results. Similar to Villamizar-Villegas (2016), we find that the price puzzle (i.e., positive relationship between prices and the policy rate) disappears once monetary shocks are purged from systematic responses of policy. Also, in line with Romer and Romer (2004), we find that a monetary contraction lowers industrial output with a one-quarter lag delay. On the other hand, we find that unannounced purchases of foreign currency had a significant effect in reducing exchange rate volatility, but appeared to have no effect on exchange rate changes. This result is similar to those found in Dominguez (1993), Bonser-Neal and Tanner (1996), Baillie and Osterberg (1997), Chang and Taylor (1998), Fatum and Hutchison (2003), Domac and Mendoza (2004), and Humala and Rodriguez (2010). However, in contrast with this strand of the literature, we find that announced interventions can affect both exchange rate changes and volatility.[4]

To the best of our knowledge, only a handful of studies exist that directly address the issue of having multiple policy instruments, few of which estimate their dependence. In this sense, we believe that our investigation will shed some light on pressing monetary policy questions such as the following: Under what conditions do

[3]While Herrera and Ozbay (2005) treat all episodes of no intervention as censored, we consider a variety of different censoring scenarios, all of which are presented in section 2.4. As a result, we find that announced and unannounced interventions have different policy implications.

[4]A few authors, such as Neil and Fillion (1999), Kearns and Rigobon (2002), Fatum and Hutchison (2003), and Rincón and Toro (2010), also find a significant (albeit short-lived) effect on the exchange rate.

central banks intervene in the foreign exchange market? What are the effects of having multiple instruments? How long do these effects last? And, finally, are decisions about various policies conducted in an independent manner?

This paper proceeds as follows: Section 2 describes the data and emphasizes the various policy instruments undertaken by the CBRT. It also comments on the potential types of interventions that could have been censored by external factors. Section 3 presents the methodology, tailored to the different foreign exchange intervention mechanisms. Section 4 presents the results and section 5 concludes.

2. Data and Context

Our data cover the period of January 2002 through May 2010. This time frame was particularly chosen since, prior to 2002, a fixed exchange rate regime was established. Following the 2001 crisis, the Turkish economy underwent a structural transformation. The CBRT was vested with independence and endowed with the primary objective of achieving and maintaining price stability. In 2002, the CBRT officially adopted an inflation-targeting regime and managed to bring high and chronic inflation down to single digits.

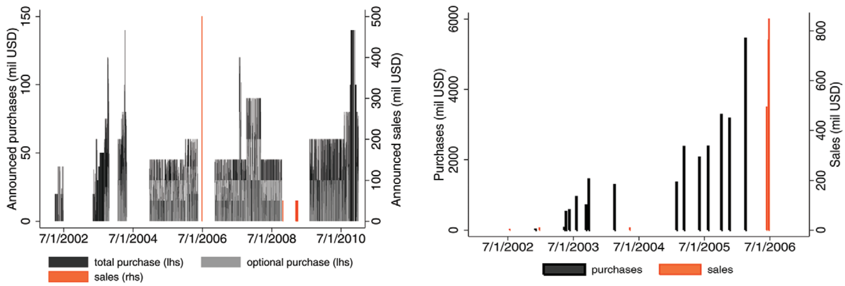
Following the quantitative easing (QE) program, and in order to address challenges posed by excess capital volatility, the CBRT adopted a set of additional monetary instruments in the second half of 2010, including a reserve option mechanism (ROM) and an interest rate corridor.[5] Consequently, we feel that further assumptions are needed after May 2010 in order to disentangle the effects of the newly established tools on both the interest rate and the Turkish lira.

2.1 Foreign Exchange Interventions

In order to lower exchange rate volatility, the CBRT conducted foreign exchange interventions in one of two ways: (i) through unannounced interventions, exercised through direct sales and purchases of USD, and (ii) through announced interventions, consisting of

[5]See Kara (2013) for a review of unconventional monetary measures undertaken by the CBRT.

Figure 1. Different Types of Foreign Exchange Interventions Conducted by the CBRT



A. Announced Interventions B. Unannounced Interventions

Notes: The left panel corresponds to sales and purchases of USD (in millions) through announced auctions along with optional purchases. The right panel corresponds to direct interventions. During the time of the study, it is clear that total purchases exceeded total sales.

predetermined dates and amounts, although with a discretionary (optional) amount of trading that took place during the day of the auction provided that monetary authorities decided to exceed the established amount.[6] Announcements for this last type of interventions ranged from one day to two weeks prior to the currency auction. Also, the CBRT did not use a deterministic rule to decide over which date to intervene or the amount of currency to be traded.

The left panel of figure 1 depicts the total number of sales and purchases (in millions of USD) through announced auctions along with optional purchases of foreign currency (the CBRT never conducted optional sales). As shown, the CBRT purchased foreign currency throughout most of the sample, with optional purchases starting in September 2003, and occasional sales during 2006, 2008, and 2009. Alternatively, the right panel of figure 1 depicts the total number of sales and purchases (in millions of USD) through unannounced interventions. Under this type of trading, purchases and sales were infrequent but large, averaging \$1.7 and \$0.3 billion USD, respectively.

[6] There were limits on how much the CBRT could exceed the pre-established amount.

Similarly, table 1 shows the amount of foreign currency traded for every type of foreign exchange intervention. As seen, all purchases were larger than sales, by more than tenfold. As will be discussed in greater depth in the next section, this asymmetry reveals a systematic bias towards trying to depreciate domestic currency. As such, we address the *fear of floating* or rather, the *fear of appreciation*, by allowing some of these interventions to follow a censored Tobit type I model. Table 1 also shows that sales were largely concentrated in the year 2006. Purchases, on the other hand, were most abundant in 2003 and 2005.

2.2 Policy Rate

Our measure of the policy rate corresponds to the CBRT's overnight borrowing rate between February 20, 2002 and May 16, 2008 (due to the abundant liquidity in the Turkish market); to the overnight lending rate between May 17, 2008 and May 20, 2010 (due to the liquidity shortage); and to the one-week repo lending rate after May 21, 2010. As such, our investigation differs from studies that use market-based rates such as the interbank rate. We argue that the latter can be more likely influenced by monetary factors driven by liquidity demand, as they comprise equilibrium conditions which reflect transactions within the financial system, including those between commercial banks and other non-banking entities. However, we conduct robustness exercises (reported in figure 10 in appendix 3) in order to assess the differences obtained if we had instead used the interbank rate.

Figure 2 depicts our measure of the policy rate and the interbank rate (left panel), as well as the observed, targeted, and expected yearly inflation (right panel). The figure shows that at the onset of 2002, inflation (or hyperinflation) levels reached 73.2 percent, while the target for inflation was set at 35 percent and the policy rate (depicted in the left panel) was set at 59 percent. With a sharp disinflation in 2001, the policy rate began to steadily decline until mid-2006. Starting in mid-2006, interest rates slightly rebounded but started falling again in 2008.

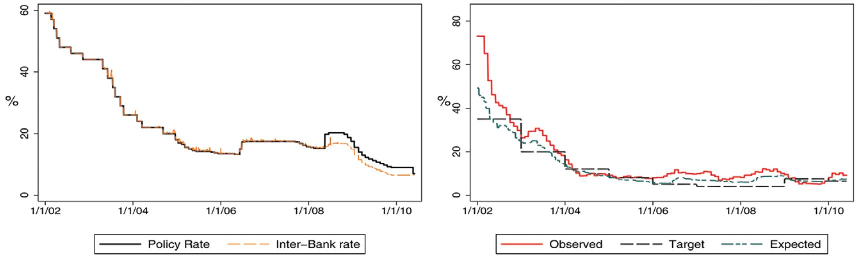
The positive relationship between inflation and interest rates can be misconstrued as evidence of the price puzzle. Nonetheless, a more reasonable explanation was that the CBRT kept interest rates high

Table 1. Foreign Exchange Interventions January 2002–May 2010 (billion USD purchases)

USD	**Total**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**
Unannounced Purchases	25.53	0.02	4.23	1.28	14.57	5.44	0.00	0.00	0.00	0.00
Unannounced Sales	2.12	0.01	0.00	0.01	0.00	2.11	0.00	0.00	0.00	0.00
Announced Purchases	28.52	0.79	4.99	2.60	3.63	2.24	4.75	3.60	2.91	3.00
Announced Sales	2.00	0.00	0.00	0.00	0.00	1.00	0.00	0.1	0.90	0.00
Optional Purchases	20.41	0.00	0.66	1.50	3.81	2.11	5.15	3.98	1.40	1.78

Sources: Central bank data and author's calculations.

Figure 2. Policy Rate and Yearly Inflation (observed, target, and expected)



Notes: The left panel corresponds to the CBRT policy rate. The right panel corresponds to the observed inflation, to the surveyed one-year-ahead expected inflation forecast, and to the yearly target.

to bring inflation down to single digits, and only conducted expansionary monetary policy once inflation decreased. In section 4.4 we show that the price puzzle is eliminated by purging the policy rate from systematic responses of policy.

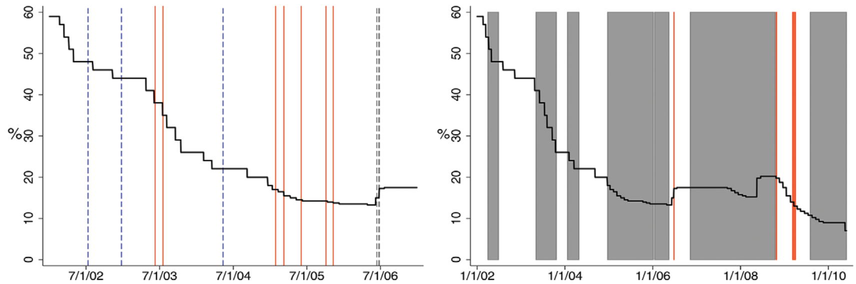
2.3 Simultaneous Policies: Leaning with or against the Wind?

Figure 3 depicts episodes in which the CBRT conducted announced and unannounced purchases and sales of foreign currency, along with changes in the policy rate. In the left panel, the solid (dashed) lines denote unannounced purchases (sales) of foreign currency. Hence, it shows that purchases were used in tandem with the policy rate, as they were conducted during episodes of interest rate cuts. However, as shown by the blue dashed lines,[7] there were some episodes in 2002 and 2004 in which the CBRT conducted *leaning-against-the-wind* policies (i.e., interest rate cuts along with sales of foreign currency).

Similarly, the right panel of figure 3 shows that in 2008 and 2009, announced sales (orange lines) coincided with interest rate

[7]Colors appear in the online version, available at http://www.ijcb.org.

Figure 3. Simultaneous Monetary Policies



A. Unannounced Interventions

B. Announced Interventions

Notes: The left panel corresponds to unannounced interventions, where solid (dashed) lines denote purchases (sales) of foreign currency. Some purchases were not included given that they did not occur within one week of a policy rate change. The right panel corresponds to announced interventions, where shaded regions (solid lines) denote purchases (sales) of foreign currency.

cuts, exerting potentially opposing forces on the exchange rate.[8] Lastly, given the high number of announced purchases throughout the sample, they coincided with both interest rate hikes (*leaning against the wind*) and interest rate cuts (*leaning with the wind*).

2.4 Censored Interventions

Earlier we highlighted the asymmetry between purchases and sales of foreign currency conducted by the CBRT. That is, while purchases totaled 74.5 billion USD, sales totaled only 4.12 billion USD (see table 1). When modeling the various policy functions for foreign exchange intervention, the general absence of USD sales can take on two different interpretations: (i) either economic conditions were such that it was optimal for the CBRT to conduct only purchases of USD, or (ii) economic conditions were such that it was optimal for the CBRT to conduct sales of USD, but it did not carry them out given some external factor or constraint. The latter describes a

[8] Leaning-against-the-wind policies of both announced and unannounced foreign exchange interventions generally took place during heightened global financial market volatility, as can be seen in figure 9 of appendix 2.

Table 2. Foreign Exchange Interventions Considered as Censored

Type	Censored	Not Censored
Unannounced Total (Purchases – Sales)		X
Unannounced Purchases	X	
Unannounced Sales	X	
Optional Purchases	X	
Announced Purchases		X
Announced Sales		X
Changes in Policy Rate		X

censored process that, if estimated with a linear model, would yield inconsistent estimates.[9]

As such, table 2 describes the different specifications considered in this study when modeling policy. In essence, announced interventions and changes in the policy rate were not considered as being censored, while optional purchases were considered as censored given the complete lack of optional sales. Finally, unannounced interventions were considered as both censored (when taking sales and purchases individually) and uncensored (when taking the total). The main reasons for allowing unannounced interventions to have both specifications were to establish a benchmark comparison with other studies that also assume censored policy processes,[10] as well as to analyze the importance of the conditional probability of observing a positive intervention, by comparing both types of estimations.

3. Methodology

3.1 Policy Effects in a Potential Outcomes Framework

The main challenge of estimating the effects of policy is that monetary decisions are rarely isolated from economic developments. In a potential outcomes framework, this corresponds to not being able

[9]See Cohen (1949), Rosenbaum (1961), or Barr and Sherrill (1999).
[10]See, for example, Herrera and Ozbay (2005) and Villamizar-Villegas (2016).

to properly account for the systematic differences between treatment and control groups (i.e., intervention versus non-intervention episodes). For instance, assume that we are interested in the causal effect of purchasing "s" units of foreign currency. A counterfactual of interest can be stated as the effects of purchasing "s" given that the central bank actually purchased "$s - j$."[11] However, conditions could have significantly differed for when the CBRT purchased "s" or "$s - j$" (which most likely explains the difference in intervention values).

To see this point more formally, let Y_t be a vector of outcome variables, D_t a vector of policy instruments, and X_t a matrix of covariates needed to characterize the various policy functions. Histories of policy, outcomes, and exogenous variables are characterized as

$$\begin{bmatrix} \bar{D}_t \\ \bar{X}_t \\ \bar{Y}_t \end{bmatrix} = \begin{bmatrix} D_t & D_{t-1} & \cdots & D_{t-k} \\ X_t & X_{t-1} & \cdots & X_{t-k} \\ Y_t & Y_{t-1} & \cdots & Y_{t-k} \end{bmatrix}, \tag{1}$$

and the "relevant" statistic that policymakers use to determine policy at time "t" can be described by $z_t = \Phi_t(\bar{Y}_t, \bar{X}_t, \bar{D}_{t-1})$, for a given mapping Φ_t.

In principle, differences in outcome variables, whenever the CBRT purchased "s" units of foreign currency compared with when it purchased "$s - j$," can be formulated as follows:

$$E\left[Y_{t,s} \mid D_t = s\right] - E\left[Y_{t,s-j} \mid D_t = s - j\right] = \tag{2}$$

$$E[Y_{t,s} - Y_{t,s-j} \mid D_t = s] + E\left[Y_{t,s-j} \mid D_t = s\right] - E\left[Y_{t,s-j} \mid D_t = s - j\right], \tag{3}$$

where $Y_{t,s}$ corresponds to the vector of potential outcomes had the bank purchased "s" units of foreign currency, regardless of the actual amount purchased. Alternatively, observed purchases are dictated by the realization of D_t. The step between equations (2) and (3) simply corresponds to the addition and subtraction of the term $E\left[Y_{t,s-j} \mid D_t = s\right]$, that is, the conditional mean of Y_t had the CBRT purchased "$s - j$" units of foreign currency when it in fact purchased "s."

[11]Note that "j" can be set equal to "s" for the case of no interventions.

Equation (3) is hence comprised of three terms. The first term is our variable of interest and captures the average treatment effect (ATE) of purchasing "j" additional units of foreign currency (from "$s - j$" to "s"), given a purchase of "s." The second and third terms constitute the resulting bias that arises due to the non-randomization of treatment assignment.[12]

Fortunately, the conditional independence assumption (CIA henceforth) allows us to eliminate this bias. Namely, the CIA states that conditional on the relevant history, policy decisions are independent of potential outcomes, or as good as randomly assigned. This assumption, sometimes known as the selection-on-observables assumption, establishes the foundation based on which "regressions can also be used to approximate experiments in the absence of random assignment."[13] Formally, the CIA can be stated as equation (4):

$$Y_{t,s}(d_t) \perp D_t \mid z_t \qquad \forall d \in D, \forall s. \tag{4}$$

Consequently, the bias that corresponds to the second and third terms of equation (3) cancels out as shown:

$$\begin{aligned} BIAS &= E\left[Y_{t,s-j} \mid z_t, D_t = s\right] - E\left[Y_{t,s-j} \mid z_t, D_t = s-j\right] \\ &= E\left[Y_{t,s-j} \mid z_t, D_t = s\right] - E\left[Y_{t,s-j} \mid z_t, D_t = s\right] \\ &= 0. \end{aligned} \tag{5}$$

Equation (5) follows from the fact that policy instruments are independent of potential outcomes. As such, it is essential to extract the random component of policy from anything that may systematically react to informative variables. In the empirical application, it justifies the two-step procedure of first identifying exogenous monetary shocks and then estimating their effects on the economy. Accordingly, the first step of our methodology consisted of modeling the various policy rules in order to remove systematic responses to informative variables.

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[12]For example, when evaluating the effects of policy on inflation, it is reasonable to argue that the bias in equation (3) will most likely be positive, $E\left[Y_{t,s-j} \mid D_t = s\right] > E\left[Y_{t,s-j} \mid D_t = s-j\right]$, falsely attributing a greater effect on policy.

[13]Angrist and Pischke (2009, p. 18).

3.2 Computation of Monetary Shocks

3.2.1 Uncensored Policies

When computing monetary shocks, there is no reason to believe that policy decisions were independent. After all, the CBRT conducted monetary policy through both foreign exchange interventions (FXI henceforth) and interest rate interventions (IRI henceforth), and it is entirely plausible that decisions about one instrument altered the probability distribution of the other.[14] We thus proceed by parameterizing this dependence as follows:

$$
\begin{aligned}
FXI_t^* &= x_{1t}^{'}\beta_1 + \epsilon_{1t} \\
IRI_t &= x_{2t}^{'}\beta_2 + \epsilon_{2t} \\
\begin{pmatrix}\epsilon_{1t} \\ \epsilon_{2t}\end{pmatrix} &\sim N\left(0, \Sigma\right),
\end{aligned}
\tag{6}
$$

where the residuals of both policy functions (i.e., policy shocks) are assumed to be jointly normal with zero mean and variance-covariance matrix $\Sigma = \begin{bmatrix}\sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2\end{bmatrix}$.

The construction of a maximum-likelihood function for the bivariate process described in equation (6) is hence warranted in order to obtain estimates of all individual regressors as well as the estimated covariance between policy shocks. The corresponding bivariate normal likelihood is presented as

$$
L_n(\theta) = \prod_{t=1}^{T} \frac{1}{(2\pi)\left|\Sigma\right|^{1/2}} e^{-\frac{1}{2}(D_t-\mu)'\Sigma^{-1}(D_t-\mu)}, \tag{7}
$$

where $D_t = \begin{bmatrix}FXI_t \\ IRI_t\end{bmatrix}$ and $\mu = E_t\begin{bmatrix}x_{1t}^{'}\beta_1 \\ x_{2t}^{'}\beta_2\end{bmatrix}$. If the estimation of the maximum likelihood yields a significant covariance between policy residuals (σ_{12}), shocks can then be computed in vector form in order to account for the conditional dependence of policy. Otherwise, they can be computed by estimating linear fitted residuals of independent processes characterized by equation (6).

[14] In fact, the left panel of figure 3 suggests that both interest rate and foreign exchange interventions were sometimes orchestrated.

3.2.2 Censored Policies

Table 2 denotes which types of FXI were considered as censored and thus modeled with a Tobit type I model. We proceed to parameterize the maximum-likelihood function for the bivariate policy process in which FXI exhibit some degree of censoring.

Formally, let $A \equiv \left(\sigma_1^2 - \frac{\sigma_{12}^2}{\sigma_2^2}\right)$ and $b \equiv \left(x_{1t}^{'}\beta_1 + \frac{\sigma_{12}}{\sigma_2^2}(IRI_t - x_{2t}^{'}\beta_2)\right)$. It follows that

$$
\begin{aligned}
L_n(\theta) = & \prod_{FXI_t^* \leq 0} f\left(FXI_t, IRI_t \mid x_{1t}, x_{2t}\right) \\
& \times \prod_{FXI_t^* > 0} f\left(FXI_t, IRI_t \mid x_{1t}, x_{2t}\right) \\
& = \prod_{FXI_t^* \leq 0} \left(1 - \Phi\left(\frac{b}{A^{1/2}}\right)\right) \frac{1}{\sigma_2}\phi\left(\frac{IRI_t - x_{2t}^{'}\beta_2}{\sigma_2}\right) \\
& \times \prod_{FXI_t^* > 0} \frac{1}{A^{1/2}}\phi\left(\frac{FXI_t^* - b}{A^{1/2}}\right) \frac{1}{\sigma_2}\phi\left(\frac{IRI_t - x_{2t}^{'}\beta_2}{\sigma_2}\right), \quad (8)
\end{aligned}
$$

where $\phi(\cdot)$ and $\Phi(\cdot)$ correspond to the probability distribution function and the cumulative distribution function of a standard normal distribution, respectively. Similar to the case of uncensored policies, if the estimation of the maximum likelihood yields a significant covariance between policy residuals (σ_{12}), they can be computed in vector form as presented in Villamizar-Villegas (2016). However, if the covariance is not significant, policy shocks can be obtained by subtracting the conditional mean of policy from its observed value, as follows:

$$
\begin{aligned}
\epsilon_{1t} &= FXI_t - E\left[FXI_t \mid x_{1t}\right] \\
&= FXI_t - \Phi\left(\frac{x_{1t}^{'}\beta_1}{\sigma_1}\right)\left[x_{1t}^{'}\beta_1 + \sigma_1\lambda\left(\frac{x_{1t}^{'}\beta_1}{\sigma_1}\right)\right] \quad (9) \\
\epsilon_{2t} &= IRI_t - E\left[IRI_t \mid x_{2t}\right] \\
&= IRI_t - x_{2t}^{'}\beta_2, \quad (10)
\end{aligned}
$$

where the term $\lambda(\cdot) = \phi(\cdot)/\Phi(\cdot)$ corresponds to the inverse Mills ratio. The term $\Phi\left(\frac{x'_{1t}\beta_1}{\sigma_1}\right)$ of equation (9) represents the probability of observing a positive intervention (i.e., $Pr(FXI^*_t > 0 \mid x_{1t})$), whereas the last term in brackets is the expected value of the latent variable FXI^*_t.[15]

3.3 Impulse Response Functions

The second step of the methodology consisted of estimating the effects of the estimated residuals, ϵ_{1t} and ϵ_{2t}, on the different outcome variables in Y_t. To this end, we estimated impulse response functions (IRFs) for variables with a monthly frequency according to Jordà's (2005) methodology of local projections:

$$Y_{it+s} = \eta^s_0 + \eta^s_1\epsilon_{1t} + \eta^s_2\epsilon_{2t} + \vartheta_{it+s} \quad \text{for} \quad s = 0, 1, \ldots, h. \tag{11}$$

In this case, the correlation between policy lags disappears since shocks are summed up into monthly observations. Conversely, we estimated IRFs for variables with a daily frequency according to the methodology of Romer and Romer (2004):

$$Y_{it} = \gamma_0 + \sum_{j=0}^{h} \gamma_j \epsilon_{1t-j} + \sum_{k=0}^{h} \gamma_k \epsilon_{2t-k} + \varsigma_{it}. \tag{12}$$

Coefficients and standard errors (bootstrapped) were summed up every period in order to obtain the cumulative effect across time.[16]

4. Estimation and Results

4.1 Parametric Dependence of Monetary Shocks

Estimation results for the maximum-likelihood function of equations (7) and (8) are reported in table 3. Values correspond to the

[15]Residuals ϵ_{1t} and ϵ_{2t} correspond to the policy shocks for FXI_t and IRI_t, respectively.

[16]The number of lags varied depending on the frequency of the outcome variable ($h = 12$ if monthly, $h = 40$ if daily). IRFs were smoothened using a moving average of ± two lags, for readability purposes only.

Table 3. Covariances of Bivariate Process

Bivariate Model	Uncensored	Censored
FX Unannounced Total – Policy Rate	−0.05 (0.034)	
FX Announced Purchases – Policy Rate	−0.02 (0.034)	−0.06 (0.041)
FX Announced Sales – Policy Rate	0.08** (0.034)	0.65*** (0.208)
FX Unannounced Purchases – Policy Rate		0.40 (0.289)
FX Unannounced Sales – Policy Rate		0.10 (0.205)
FX Optional Puchases – Policy Rate		−0.08 (0.064)

Notes: All models consisted of 2,190 observations. Log-likelihoods for each model correspond to 1492.2, 8498.65, and 8592.0 for the uncensored specification, respectively, and to 875.1, 889.4, 5234.1, and 3185.1 for the censored specification, respectively. *, **, and *** indicate significance at the 10 percent, 5 percent, and 1 percent level, respectively. Standard errors are reported in parentheses.

covariance between v_t and ϵ_{2t}. As can be observed, none of the covariances are statistically significant except for the covariance between announced sales and the policy rate. For computational purposes, policy shocks were estimated according to equation (9) (for censored observations of announced purchases, unannounced purchases and sales, and optional purchases); equation (10) (for uncensored observations of policy rate changes); fitted residuals equivalent to when $\Phi\left(\frac{x_{1t}^{'}\beta_1}{\sigma_1}\right) = 1$ in equation (10) (for uncensored observations of unannounced totals, and announced purchases and sales); and equation (7) (for announced sales) when computing shocks in vector form.

Interestingly, most of these covariances turn significant when excluding inflation values relative to the yearly target from X_t (all except unannounced trades whose covariance is not significant across the different specifications of X_t). These findings indicate that, under the assumptions of the model, the CBRT's decisions of one instrument (conditional on X_t) did not alter the probability distribution of the other. However, this result does not mean that different policies did not react to the same target. In fact, many covariates that were included in x_{1t} were also included in x_{2t}.[17] Independence, in this case, is conditional on the set of control variables.

4.2 Policy Functions

Small open economies, such as Turkey, are known to be vulnerable to global financial conditions. As such, it is important to control for variables that affect both the financial and macroeconomic cycle. As Rey (2015, p. 21) states, "Fluctuating exchange rates cannot insulate economies from the global financial cycle, when capital is mobile. The 'trilemma' morphs into a 'dilemma'—independent monetary policies are possible if and only if the capital account is managed, directly or indirectly, regardless of the exchange-rate regime." We thus proceed by including variables such as the VIX index and the SPG Commodity Channel Index (SPGCCI) in the estimations that follow. All other variables included in our estimations are described in appendix 1, and their stationarity properties are reported in table 10 of appendix 4.[18]

Tables 4–7 show results for all the various types of foreign exchange policy functions. Table 4 shows that unannounced total interventions mostly reacted to the exchange rate behavior (measured in Turkish lira per U.S. dollar (TRY/USD)). That is, the CBRT tried to depreciate domestic currency by purchasing USD whenever the exchange rate appreciated (relative to the daily, weekly, and monthly exchange rate) and whenever exchange rate volatility increased. In specifications 3 and 4, interventions positively responded to lagged announced purchases of USD (exhibiting some momentum effect) as well as to changes in the policy rate (specification 3), indicating a leaning-against-the-wind policy.[19]

[17] An example is lagged interest rate interventions (ΔIRI_{t-1}), which were included in all specifications.

[18] We are grateful to an anonymous referee for suggesting these variables as proxies of global financial conditions. We also conducted additional exercises (not reported) using changes in the oil price (BRENT) instead of the SPGCCI index, yielding similar results.

[19] The CBRT purchased foreign currency while simultaneously conducting contractionary monetary policy.

Table 4. OLS Estimation: $FXI_t^{total} = x'_{1t}\beta_1 + \upsilon_t$

FX Unannounced Total (Uncensored)	**(1)**	**(2)**	**(3)**	**(4)**
FXI_{t-1}^{total}	0.00	0.00	0.00	0.00
	(0.010)	(0.010)	(0.009)	(0.009)
Inflation(π_{t-1}) – Target(π^*_{t-1})	−8.01	−8.53	−11.10	−11.09
	(9.582)	(9.670)	(10.131)	(10.064)
Industrial Production ΔInd_{t-1}	0.68*	0.73*	0.54	0.31
	(0.368)	(0.376)	(0.383)	(0.421)
Daily Depreciation Δe_{t-1}	−4.09*	−4.66**	−4.68***	−6.07**
	(2.102)	(2.202)	(2.195)	(2.824)
Weekly Depreciation Δe_{t-5}	−2.07*	−2.37**	−2.70**	−2.95**
	(1.126)	(1.192)	(1.225)	(1.264)
Monthly Depreciation Δe_{t-20}	−0.85*	−1.08***	−0.90**	−0.55
	(0.491)	(0.668)	(0.466)	(0.546)
Exchange Rate Vol_{t-1}		1.41**	1.60**	1.69**
		(0.669)	(0.694)	(0.669)
Announced Purchases$_{t-1}$			0.51***	0.51***
			(0.185)	(0.186)
Inflation Surprises ($\pi_{t-1} - \pi^e_{t-1}$)			0.00	0.05
			(0.326)	(0.300)
Policy Rate ΔIRI_{t-1}			3.70*	3.18
			(2.207)	(2.108)
VIX$_{t-1}$				−0.42
				(0.396)
Commodity Index $\Delta SPGCCI_{t-1}$				−0.87*
				(0.523)

Notes: Specifications x_{1t}(1–4) correspond to the different combinations of covariates. FX intervention is measured in millions of USD. All specifications consisted of 2,190 observations. R^2 = 0.005, 0.005, 0.007, and 0.007 for OLS specifications 1–4. *, **, and *** indicate significance at the 10 percent, 5 percent, and 1 percent level, respectively. Standard errors are reported in parentheses. Constant and year dummies not reported.

Additionally, specifications 1 and 2 show a positive effect of industrial output growth on USD purchases.[20] Finally, specification 4 shows that the CBRT purchased USD whenever commodity prices

[20]The effect of industrial output is not significant in specifications 3 and 4, possibly due to the high correlation between lagged output growth and the policy rate.

Table 5. Tobit Estimation: $FXI_t = max[0, x'_{1t}\beta_1 + v_t]$

Unannounced FXI (Censored)	**Purchases**	**Sales**
Inflation(π_{t-1}) – Target(π^*_{t-1})	−1.87	0.27
	(1.233)	(0.359)
Industrial Production ΔInd_{t-1}	0.13	0.04
	(0.095)	(0.036)
Weekly Depreciation Δe_{t-5}	−3.23*	0.69*
	(1.654)	(0.417)
Monthly Depreciation Δe_{t-20}	−0.80***	0.08*
	(0.303)	(0.040)
Exchange Rate Vol_{t-1}	−0.39	−0.22
	(0.761)	(0.143)
Policy Rate ΔIRI_{t-1}	0.50	−0.08
	(1.614)	(0.499)
VIX$_{t-1}$	−0.36**	0.00
	(0.174)	(0.018)
Commodity Index $\Delta SPGCCI_{t-1}$	−0.10	0.00
	(0.099)	(0.032)

Notes: Specifications x_{1t}(1–2) correspond to the different combinations of covariates. FX intervention is measured in millions of USD. All specifications consisted of 2,190 observations. Pseudo $R^2 = 0.12$ and 0.23 for Tobit specifications 1–2. *, **, and *** indicate significance at the 10 percent, 5 percent, and 1 percent level, respectively. Standard errors are reported in parentheses. Constant and year dummies not reported.

($SPGCCI$) decreased. Similarly, table 5 shows results for censored unannounced sales and purchases, when considered individually. Results are similar to those of table 4: purchases (sales) followed appreciating (depreciating) exchange rate episodes. One difference, nonetheless, is the significant effect of the VIX index on unannounced purchases.[21]

Table 6 presents the estimation results for optional purchases (recall that this type of FXI was considered as censored, given the complete lack of optional sales). Surprisingly, results show that many

[21] Tables 4–7 show that responses of the CBRT to global financial conditions (proxied by the VIX index) were addressed through either unannounced and optional purchases or through announced sales.

Table 6. Tobit Estimation: $FXI_t^{optional} = max[0, x'_{1t}\beta_1 + v_t]$

FX Optional Purchases (Censored)	**(1)**	**(2)**	**(3)**	**(4)**
$FXI_{t-1}^{optional}$	0.93***	0.93***	0.65***	0.62***
	(0.048)	(0.048)	(0.048)	(0.048)
Inflation(π_{t-1}) – Target(π^*_{t-1})	−0.52***	−0.51***	−0.43***	0.67***
	(0.143)	(0.143)	(0.144)	(0.164)
Industrial Production ΔInd_{t-1}	0.53***	0.51***	0.28***	0.03
	(0.082)	(0.083)	(0.083)	(0.097)
Monthly Depreciation Δe_{t-20}	−0.60***	−0.48**	−0.44**	−0.02
	(0.190)	(0.203)	(0.202)	(0.213)
Exchange Rate Vol_{t-1}		−0.64	−0.53	−0.36
		(0.399)	(0.391)	(0.399)
Announced Purchases_{t-1}			0.70***	0.72***
			(0.054)	(0.055)
Unannounced Purchases_{t-1}			0.00	0.00
			(0.003)	(0.003)
Policy Rate ΔIRI_{t-1}			3.76	2.92
			(3.000)	(2.918)
VIX_{t-1}				−0.72***
				(0.111)
Commodity Index $\Delta SPGCCI_{t-1}$				0.03
				(0.095)

Notes: Specifications $x_{1t}(1–4)$ correspond to the different combinations of covariates. FX intervention is measured in millions of USD. All specifications consisted of 2,190 observations. Pseudo R^2 = 0.06, 0.06, 0.07, and 0.11 for Tobit specifications 1–4. *, **, and *** indicate significance at the 10 percent, 5 percent, and 1 percent level, respectively. Standard errors are reported in parentheses. Constant and year dummies not reported.

variables affected the decision to optionally intervene in the foreign exchange market, as if expected by market participants.[22] In this case, the CBRT tried to depreciate domestic currency by purchasing USD whenever inflation was low (relative to the yearly target), whenever industrial output increased, and whenever the monthly

[22]This can be explained by the numerous times that the CBRT conducted optional purchases. In fact, after September 2003, the CBRT almost always exceeded the pre-established amount.

Table 7. OLS Estimation: $FXI_t = x'_{1t}\beta_1 + \upsilon_t$

Announced FXI (Censored)	Purchases	Sales
FXI_{t-1}	0.82***	0.16
	(0.021)	(0.139)
Inflation(π_{t-1}) – Target(π^*_{t-1})	1.34***	0.39**
	(0.354)	(0.167)
Industrial Production ΔInd_{t-1}	0.06***	−0.08***
	(0.017)	(0.019)
Monthly Depreciation Δe_{t-20}	−0.11**	0.03
	(0.048)	(0.059)
Exchange Rate Vol_{t-1}	−0.05	−0.05
	(0.065)	(0.058)
Unannounced $Purchases_{t-1}$	0.002*	0.00
	(0.001)	(0.001)
Unannounced $Sales_{t-1}$	−0.002	0.47***
	(0.002)	(0.132)
Inflation Surprises $(\pi_{t-1} - \pi^e_{t-1})$	−.11***	−0.04***
	(0.036)	(0.012)
Policy Rate ΔIRI_{t-1}	−1.12**	0.06
	(0.571)	(0.998)
VIX_{t-1}	−0.01	0.04**
	(0.014)	(0.016)
Commodity Index $\Delta SPGCCI_{t-1}$	0.02	0.02
	(0.016)	(0.023)

Notes: Specifications x_{1t}(1–2) correspond to the different combinations of covariates. FX intervention is measured in millions of USD. All specifications consisted of 2,190 observations. $R^2 = 0.74$ and 0.79 for OLS specifications 1–2. *, **, and *** indicate significance at the 10 percent, 5 percent, and 1 percent level, respectively. Standard errors are reported in parentheses. Constant and year dummies not reported.

exchange rate appreciated.[23] Specifications 3 and 4 also show that interventions positively responded to past purchases of announced interventions. Finally, specification 4 shows a significant and negative impact of the VIX index.

[23]The CBRT could have reacted to inflation levels, as some authors argue that even sterilized interventions can have an effect on prices via liquidity premiums (see Canzoneri and Cumby 2013).

Table 7 shows results for announced sales and purchases. While purchases were conducted after positive changes in industrial output growth, sales followed negative changes in output. Also, purchases were conducted whenever the monthly exchange rate appreciated, but sales seemed not to respond to exchange rate changes. We believe, however, that this is due to the scant number of sales within our sample. Additionally, sales and purchases reacted to inflation changes (relative to both the target and expected inflation).

In sum, these results are similar to those found in Kamil (2008) and Echavarria et al. (2013) in that central banks are inclined to purchase (sell) foreign currency whenever the exchange rate appreciates (depreciates). However, a novel feature in our investigation is that responses mostly varied depending on whether interventions were pre-announced.

Similar to Romer and Romer (2004), the IRI_t policy function of equation (6) was estimated using OLS around meeting date "m" of the open market committee of the CBRT. This setting (like in Romer and Romer 2004) assumes that unemployment acts through the measure of GDP gap (i.e., Okun's Law). Results are reported in table 8. Coefficients of the lagged policy rate ΔIRI_{t-1} are small and for the most part not statistically significant. Estimates also show that the main explanatory variable was inflation relative to the yearly target (i.e., the CBRT conducted contractionary policy in order to lower inflation). Other variables that prompted policy adjustments were lagged values of announced purchases and unannounced sales, weekly and monthly exchange rate changes, and the VIX index (i.e., the CBRT conducted monetary easing when market turmoil increased). We note that the negative impact of inflation surprises on policy adjustments is conditional to the inclusion of inflation changes with respect to the target rate. In many specifications, the effect of inflation surprises is reversed when excluding all other measures of inflation. The decision to include both measures of inflation was justified by their medium-to-low correlation of 0.32. In all specifications, the CBRT did not seem to respond to changes in the U.S. federal funds rate nor industrial output.

4.3 Policy Shocks

Figure 4 depicts the resulting monetary shocks $(\epsilon_{1t}, \epsilon_{2t})$ compared with the observed policy instruments (FXI_t, IRI_t). To improve

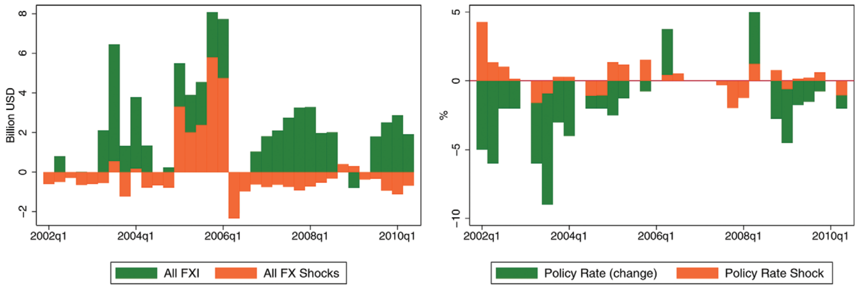
Table 8. OLS Estimation: $\Delta IRI_m = x'_{2t}\beta_2 + \epsilon_{2t}$

Policy Rate Changes (Uncensored)	**(1)**	**(2)**	**(3)**	**(4)**
ΔIRI_{m-1}	0.35*	0.24	0.20	0.12
	(0.202)	(0.171)	(0.176)	(0.152)
Inflation(π_{t-1}) – Target(π^*_{t-1})	0.19*	0.22**	0.23**	0.28***
	(0.099)	(0.099)	(0.103)	(0.066)
Weekly Depreciation Δe_{t-5}	−0.13*	−0.19***	−0.19***	−0.12
	(0.075)	(0.064)	(0.061)	(0.078)
Monthly Depreciation Δe_{t-20}	0.06*	0.06*	0.06**	0.07*
	(0.028)	(0.033)	(0.025)	(0.031)
Industrial Production ΔInd_{t-1}	0.01	0.00	0.01	0.05
	(0.015)	(0.014)	(0.017)	(0.034)
Inflation Surprises ($\pi_{t-1} - \pi^e_{t-1}$)	−0.15**	−0.18***	−0.19***	−0.14
	(0.063)	(0.058)	(0.059)	(0.072)
U.S. Federal Funds Rate Δi^*_{t-1}	−1.99	−0.71	−0.51	−1.63
	(3.244)	(3.136)	(2.831)	(2.865)
Unannounced Sales$_{t-1}$		0.003***	0.003***	0.002
		(0.001)	(0.001)	(0.001)
Announced Purchases$_{t-1}$			−0.01	−0.02***
			(0.006)	(0.008)
VIX$_{t-1}$				−0.05**
				(0.021)
Commodity Index $\Delta SPGCCI_{t-1}$				0.01
				(0.021)

Notes: Specifications x_{1t}(1–4) correspond to the different combinations of covariates. All models consisted of fifty-two observations given that estimations were conducted around meeting dates of the board of directors. R^2 = 0.59, 0.59, 0.60, and 0.67 for OLS specifications 1–4. *, **, and *** indicate significance at the 10 percent, 5 percent, and 1 percent level, respectively. Standard errors are reported in parentheses. Constant and year dummies not reported.

readability, all foreign exchange shocks and observed values were summed into quarterly observations. The deterministic component of policy can be interpreted as the difference between the dark shaded and light shaded bars (green and orange bars, respectively, in the online version). As shown, policy shocks greatly differed from observed values, especially during certain time periods. For instance, the left panel of figure 4 shows that the CBRT would have intervened less in the foreign exchange market had it not been for past

Figure 4. Observed Intervention versus New Measures of Policy Shocks: 2002–10



A. *FXI* versus Policy Shock ϵ_{1t} B. ΔIRI versus Policy Shock ϵ_{2t}

exchange rate movements. Specifically, during 2002–05 and 2007–10, most foreign exchange interventions were explained by the deterministic component of policy. In contrast, interventions in 2005 were highly unpredictable.

In turn, the right panel of figure 4 shows that most policy changes were explained by inflation levels. In this case, changes in inflation explained the variation in the policy rate by almost 65 percent, on average.

One important characteristic of correctly specified policy shocks is their unpredictability. In other words, information prior to the policy change should be uncorrelated with the estimated residuals. A heuristic exercise to test for this orthogonality condition is presented in table 9. Each column denotes a different estimated policy shock, whereas each row contains the different lagged policy intervention. Hence, policy shocks are individually regressed against all of the different types of intervention variables. Values with an "X" correspond to the variable (row) that was included under that specification (column), so the policy shock is, by construction, orthogonal to that variable. As it turns out, all residuals are correctly specified across the various intervention variables.

4.4 Impact on Outcome Variables

We considered four outcome variables in order to evaluate the effects of policy: (i) exchange rate changes, (ii) exchange rate volatility, (iii)

Table 9. Policy Shocks' Orthogonality Condition ($\epsilon_{it} = x'_{it}\beta + \eta_{it}$)

Policy Shock versus Lagged Policies	Unannounced Totals ϵ_{1t}	Unannounced Purchases ϵ_{1t}	Unannounced Sales ϵ_{1t}	Optional Purchases ϵ_{1t}	Announced Purchases ϵ_{1t}	Announced Sales ϵ_{1t}	Policy Rate Changes ϵ_{2t}
Unannounced Totals$_{t-1}$	X	X	X	0.00	0.00	0.00	0.00
				(0.002)	(0.001)	(0.001)	(0.001)
Unannounced Purchases$_{t-1}$	X	X	0.00	X	X	X	0.00
			(0.532)				(0.001)
Unannounced Sales$_{t-1}$	X	0.00	X	0.00	X	X	X
		(0.005)		(0.001)			
Optional Purchases$_{t-1}$	0.24	0.29	−0.02	X	0.01	0.00	0.06
	(0.269)	(0.271)	(0.222)		(0.011)	(0.007)	(0.178)
Announced Purchases$_{t-1}$	X	−0.23	−0.02	X	X	0.00	X
		(0.267)	(0.031)		(0.009)		
Announced Sales$_{t-1}$	−0.01	−0.01	−0.03	0.00	0.00	X	−0.00
	(0.020)	(0.017)	(0.025)	(0.001)	(0.002)		(0.013)
Policy Rate Changes$_{t-1}$	X	X	X	X	X	X	X

Notes: All models consisted of 2,190 observations. *, **, and *** indicate significance at the 10 percent, 5 percent, and 1 percent level, respectively. Standard errors (robust for OLS) are reported in parentheses.

changes in inflation, and (iv) industrial production growth. In all cases, the effects of both the estimated residuals (ϵ_{1t}, ϵ_{2t}) and the observed policy instruments (FXI_t, IRI_t) were computed.[24] While the former consist of correctly specified monetary surprises, the latter are most likely biased by anticipatory movements in the economy. The comparison of both measures is thus useful in order to get a better sense of the direction and magnitude of the bias driven by observed interventions (see equation (3)). Hence, the left panels of figures 5–8 depict responses in outcome variables due to policy shocks. Conversely, the right panels of figures 5–8 depict responses in outcome variables due to observed values of intervention.[25]

4.4.1 Exchange Rate Changes (Daily Frequency)

Panels C and E of figure 5 show significant effects of FX policy shocks on exchange rate changes. Namely, announced purchases of 1 billion USD depreciated domestic currency by up to 5 percent during days 10–40 after the intervention took place. On the other hand, announced sales of 1 billion USD appreciated domestic currency by up to 2.5 percent, but only during the first ten days following the intervention shock. These results are in contrast with most of the recent literature that find non-significant effects of FXI on the exchange rate (see Fischer 2001a, 2001b and Blanchard 2013). However, similar to Rey (2015), we argue that exchange rate effects are possible when breaking free from the monetary trilemma.[26]

Other FX policy shocks such as unannounced sales and purchases of foreign currency appeared to have a null effect on exchange rate changes.[27] Finally, consistent with the theory on interest rate parities, panel G shows that a 1 percent increase in the policy rate shock (IRI shock) appreciates domestic currency by 1 percent during the first month (days 5–25).

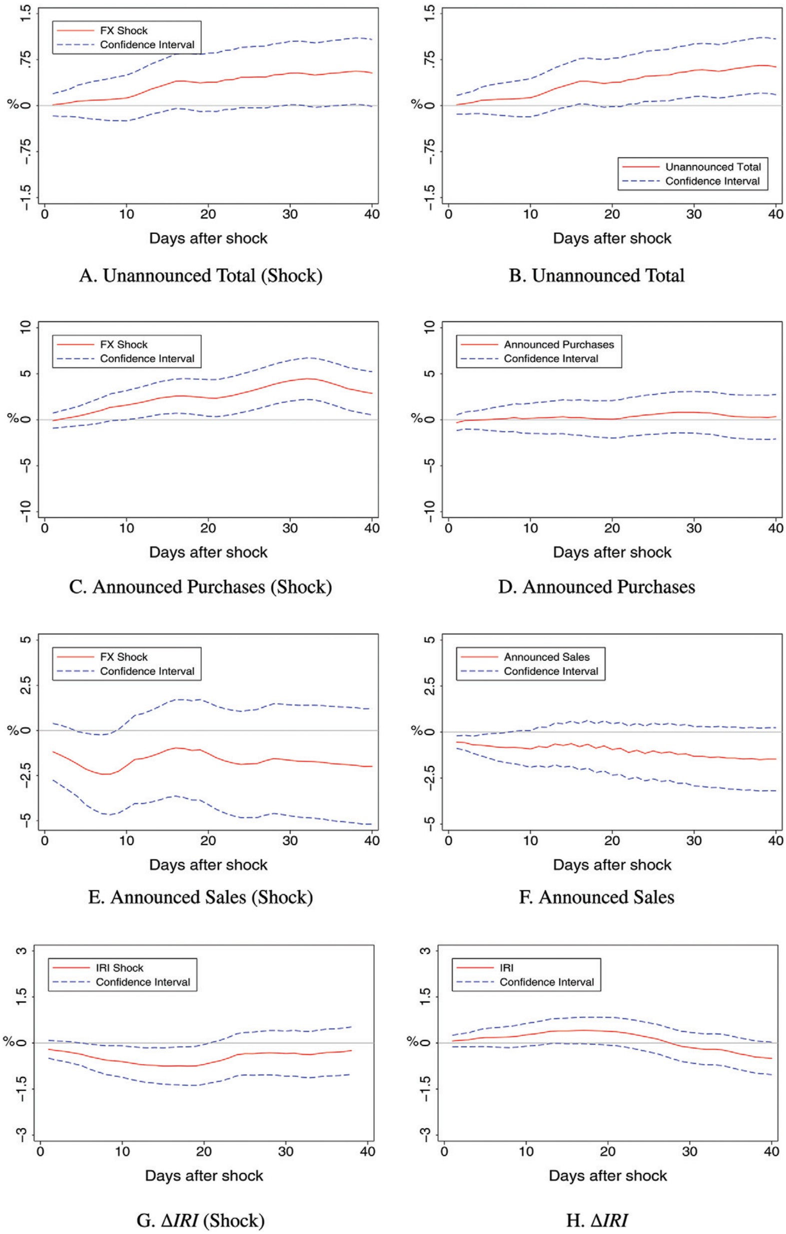
[24] Policy residuals were computed according to specification 4 of tables 4, 6, and 8, and according to the only specification presented in tables 5 and 7.

[25] IRFs not reported in figures 5–8 were not statistically significant.

[26] See Villamizar-Villegas and Perez-Reyna (2017).

[27] These results are in line with those found in Dominguez (1993), Dominguez and Frankel (1993), Humpage (1999), Kim, Kortian, and Sheen (2000), and Taylor (2004), but are contrary to those found in Disyatat and Galati (2007) and Adler and Tovar (2011).

Figure 5. Implied IRFs of Exchange Rate Changes (Δe_t)



Notes: IRFs A–F correspond to a response in exchange rate changes (%) to a 1 billion USD purchase (or sale). IRFs G–H correspond to a response in exchange rate changes (%) to a 1 percent increase in the policy rate.

4.4.2 Exchange Rate Volatility (Daily Frequency)

Figure 6 depicts the implied IRFs of exchange rate volatility. Panels A and C show the effects of an unannounced 1 billion USD purchase and sale, respectively. In both cases, the CBRT was able to stem volatility, although more so for purchases (5.0 percent) than for sales (0.05 percent). But, even though the effect of unannounced sales is small and short-lived, it is at least contrary to the effect found if using observed levels of intervention, as shown in panel D, where volatility increases by almost 15 percent.

Foreign exchange intervention through announced purchases of 1 billion USD also reduces exchange rate volatility by up to 7 percent, as shown in panel E, but effects subside after fifteen days. Finally, panel G shows that changes in the policy rate have no significant impact on exchange rate volatility.

4.4.3 Changes in Inflation (Monthly Frequency)

Figure 7 depicts the implied IRFs of changes in inflation. Panel H shows that an increase of 1 percent in the *observed* policy rate change (ΔIRI_t) has a strong and positive effect on inflation (of 1.0 percent) that lasts for more than fifteen months before the effect subsides. Taken at face value, this result is straightforward evidence of the "price puzzle" in which prices and interest rates are positively correlated. However, panel G shows that, just like in Romer and Romer (2004), this bias is completely eliminated: an increase of 1 percent in the policy rate shock lowers inflation by almost 1 percent, and effects are significant only after the first nine months (i.e., months 9–12). This result is in line with the related literature that find evidence of almost a one-year lag delay of interest rates on inflation.[28]

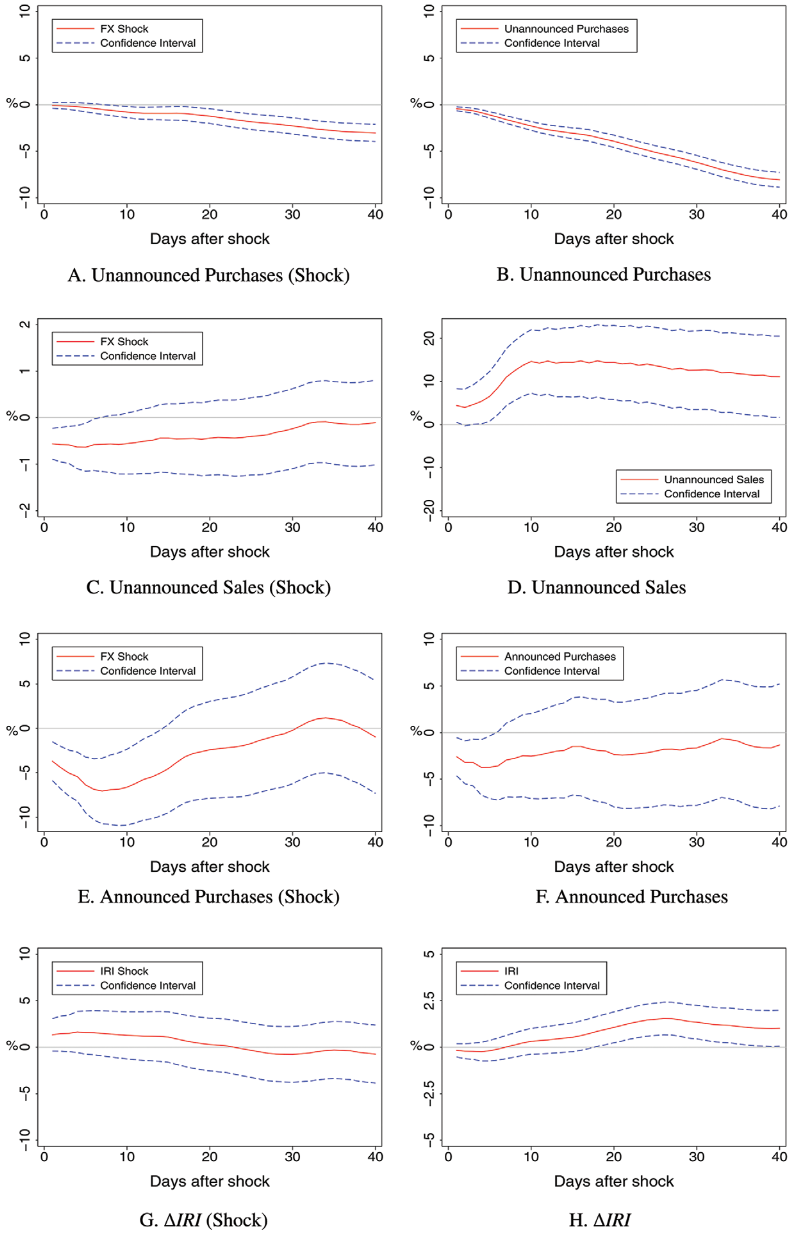
The remaining panels of figure 7 show that foreign exchange shocks have no effects on inflation, which is consistent with the fact that almost all interventions were fully sterilized.

4.4.4 Industrial Production Growth (Monthly Frequency)

Figure 8 depicts the implied IRFs of industrial production growth. As shown, only the policy rate shock has a significant effect on

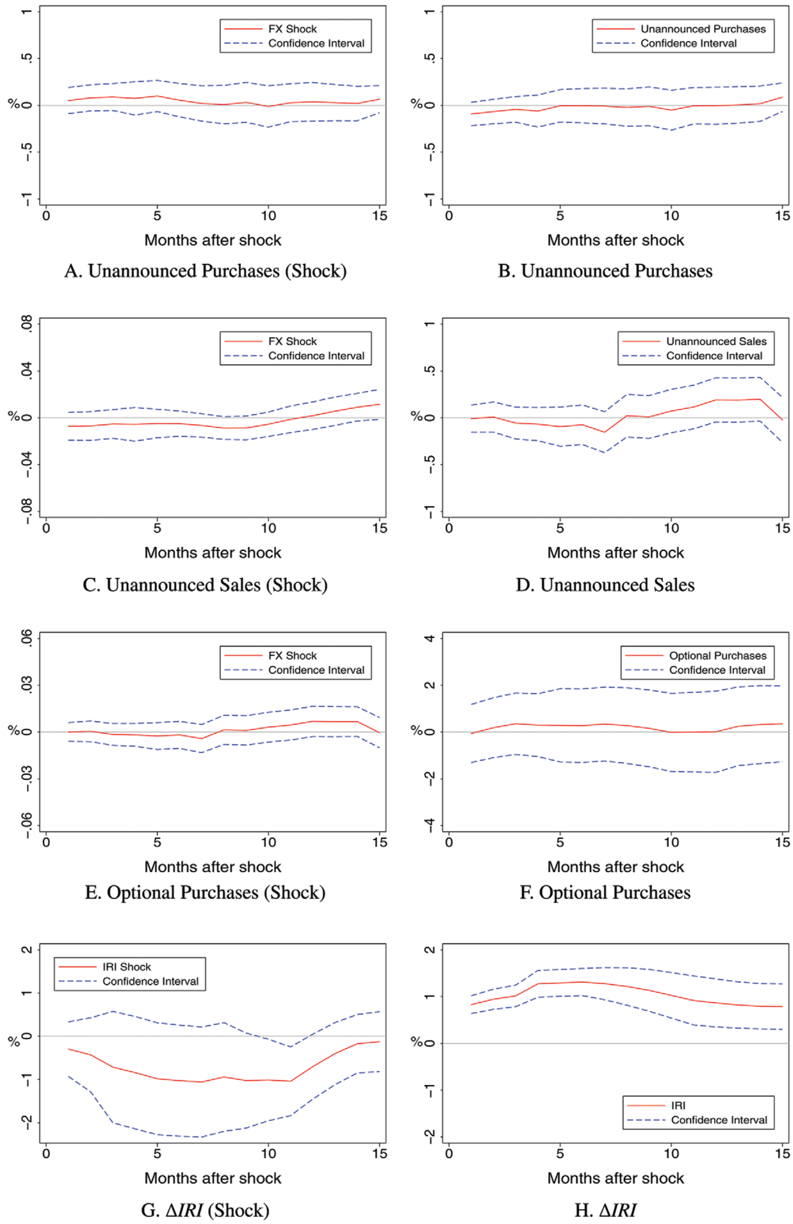
[28] See, for example, Batini and Nelson (2001), Romer and Romer (2004), and Havranek and Rusnak (2012).

Figure 6. Implied IRFs of Exchange Rate Volatility (Vol_t)



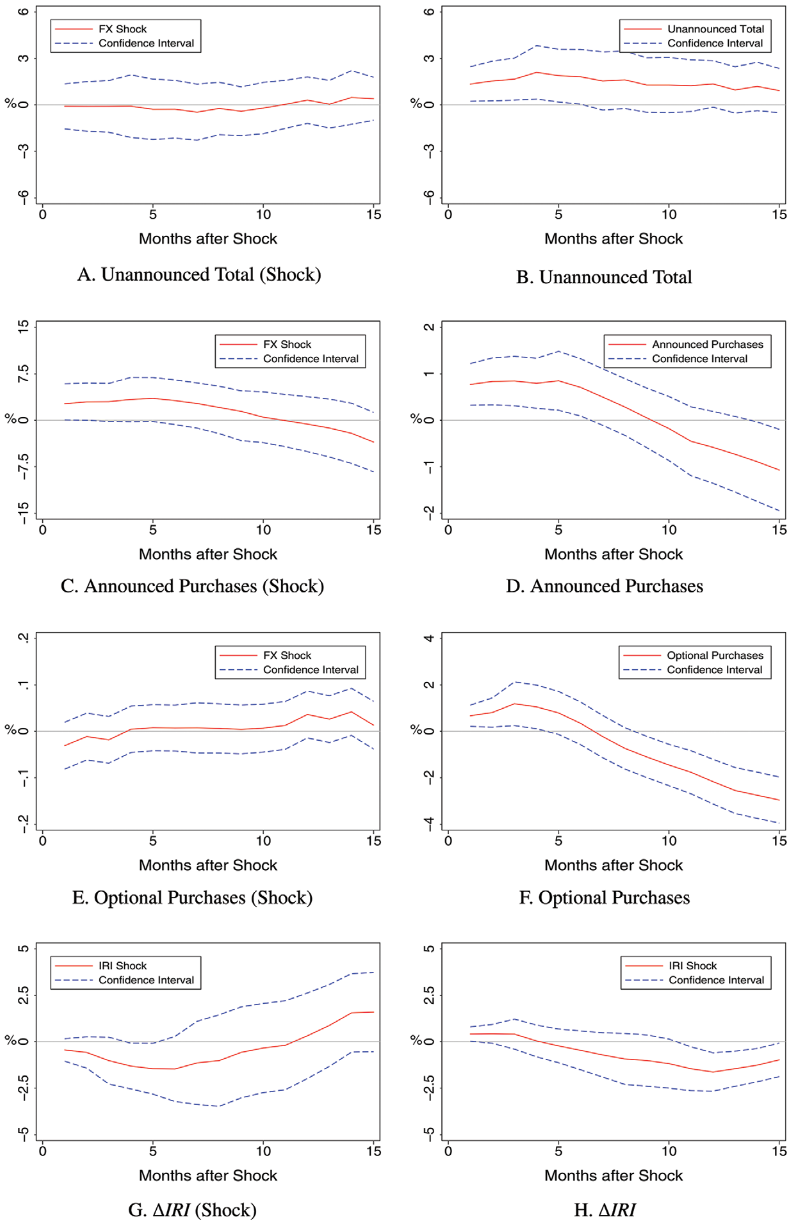
Notes: IRFs A–F correspond to a response in exchange rate changes (%) to a 1 billion USD purchase (or sale). IRFs G–H correspond to a response in exchange rate changes (%) to a 1 percent increase in the policy rate.

Figure 7. Implied IRFs of Inflation Changes ($\Delta\pi_t$)



Notes: IRFs A–F correspond to a response in exchange rate changes (%) to a 1 billion USD purchase (or sale). IRFs G–H correspond to a response in exchange rate changes (%) to a 1 percent increase in the policy rate.

Figure 8. Implied IRFs of Industrial Production (ΔInd_t)



Notes: IRFs A–F correspond to a response in exchange rate changes (%) to a 1 billion USD purchase (or sale). IRFs G–H correspond to a response in exchange rate changes (%) to a 1 percent increase in the policy rate.

industrial output. Namely, panel G shows that a 1 percent increase in the policy rate lowers output growth by up to 2 percent during the second trimester (months 4–6) following a monetary contraction. This result is line with Romer and Romer (2004), Kilinc and Tunc (2014), and Villamizar-Villegas (2016).

4.4.5 Robustness

In essence, these results differ from the foreign exchange intervention literature such as Herrera and Ozbay (2005), Geršl and Holub (2006), Humala and Rodriguez (2010), Echavarria et al. (2013), Adler and Tovar (2014), and Kilinc and Tunc (2014), in that we (i) control for the covariance of simultaneous policies, (ii) include only the period in which the CBRT officially adopted an inflation-targeting regime, and (iii) use a different measure of the policy rate.

In terms of the latter (i.e., different measure of policy), we conduct a robustness exercise presented in appendix 3 in which we compare the effects of using the interbank rate on inflation and output.[29] As depicted in figure 10 in appendix 3, while the effects of both our measure of policy and the interbank rate follow similar paths, they greatly differ in the size of the standard errors. Consequently, results using the interbank rate show a more immediate (significant) response of policy. We thus believe that factors related to liquidity demand, which in turn are highly correlated with inflation and output, can bias the significance level of the obtained estimates.

5. Conclusions

Following the 2001 crisis, the Turkish economy underwent a structural transformation. The Central Bank of the Republic of Turkey was vested with independence and endowed with the primary objective of achieving and maintaining price stability. In 2002, the CBRT officially adopted an inflation-targeting regime. Concurrently, in order to lower exchange rate volatility, the CBRT conducted foreign exchange interventions in one of two ways: (i) through unannounced

[29] Similar to Kilinc and Tunc (2014), we use the overnight repo rate obtained from the Istanbul Stock Exchange (Borsa Istanbul) as a measure of the interbank rate.

interventions, often infrequent but large, and (ii) through announced interventions which consisted of predetermined dates and amounts.

In this paper we study the effects of simultaneous central bank policies in a unified framework. Namely, we analyze the effects of both interest rate and foreign exchange intervention on several macroeconomic variables. To this end, we model the undertakings of monetary authorities (tailored to the various foreign exchange mechanisms of the CBRT) and purge the intended monetary decisions from systematic responses of policy. Our investigation confirms some of the previous findings from the literature but also yields some new results. For instance, we find that the price puzzle disappears once monetary shocks are purged from inflation expectations and global financial conditions. Additionally, we find that unannounced purchases of foreign currency had a significant effect in reducing exchange rate volatility but appeared to have no effect on exchange rate changes. Announced interventions, on the other hand, did have a significant impact on exchange rate changes and volatility.

Appendix 1. Data Description

Source: Central Bank of the Republic of Turkey during January 2002–July 2010.

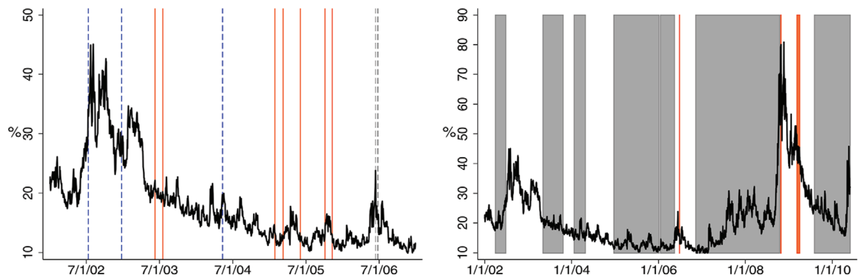
- Policy instruments of the Central Bank of the Republic of Turkey (D_{1t} and D_{2t}):
  - Foreign Exchange Interventions (FXI_t), in millions of U.S. dollars:
    - Unannounced Purchases and Sales: Exercised through direct sales and purchases of USD.
    - Announced Purchases and Sales: Sales and purchases of USD with predetermined dates and amounts.
    - Optional Purchases: During auctions of announced purchases and sales, the CBRT may have exceeded the predetermined amount of FX purchases. There was a limit on how much authorities could exceed during these transactions. The CBRT never optionally exercised sales of USD.
  - Interest Rate Interventions (IRI_t): The policy rate corresponded to the central bank's overnight borrowing rate

between February 20, 2002 and May 16, 2008 (due to the abundant liquidity in the Turkish market); to the overnight lending rate between May 17, 2008 and May 20, 2010 (due to the liquidity shortage); and to the one-week repo lending rate after May 21, 2010. Frequency corresponds to the meeting dates of the board of directors. Units are in changes (%).

- Variables in X_t:
  - Weekly Depreciation (Δe_{t-5}): Weekly (five business days) exchange rate changes. Daily frequency. Units are in log-differences.
  - Monthly Depreciation (Δe_{t-20}): Monthly (twenty business days) exchange rate changes. Daily frequency. Units are in log-differences.
  - U.S. Federal Funds Rate (Δi_t^*): Self-explanatory. Daily frequency. Units are in changes (%).
  - Inflation Surprises ($\pi_t - \pi_t^*$): Expected inflation corresponds to the one-year-ahead forecasts conducted by the CBRT. Biweekly. Units are in (%).
  - Inflation minus Yearly Target ($\pi_t - \pi_t^*$): Self-explanatory. Monthly frequency. Units are in (%).
  - The S&P Goldman Sachs Commodity Price Index, Bloomberg Ticker SPGCCI ($\Delta SPGCCI_t$): Closing price. Daily frequency. Units are in changes (%).
  - VIX Index (VIX_t): Closing price. Daily frequency.
- Outcome Variables in Y_t:
  - Nominal Exchange Rate (e_t): Nominal exchange rate in units of Turkish lira per unit of U.S. dollar (TRY/USD). Daily frequency. Units are in log-differences.
  - Exchange Rate Volatility (Vol_t): Squared daily exchange rate returns (Δe_t). Daily frequency.
  - Industrial Production Growth (ΔInd_t): Industrial production variation. Monthly frequency. Units are in log-differences.
  - Inflation (π_t): Yearly changes for the Turkish Consumer's Price Index (CPI). Monthly frequency. Units are in changes (%).

Appendix 2. Global Financial Conditions and FXI

Figure 9. VIX and Foreign Exchange Interventions

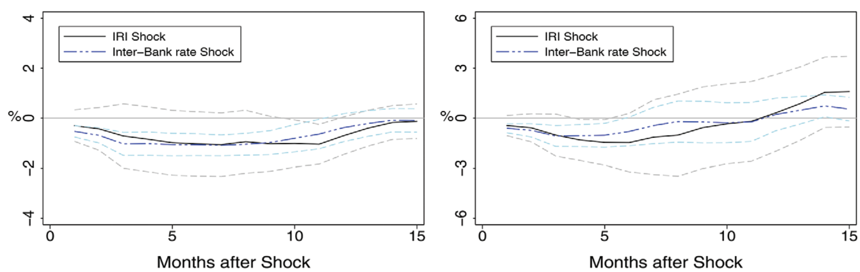


A. Unannounced Interventions

B. Announced Interventions

Appendix 3. Using Alternative Measures of the Policy Rate

Figure 10. Robustness Exercise: Effects of Using Different Measures of Policy



A. Inflation Changes

B. Industrial Production

Notes: IRFs A–B denote a response in inflation (panel A) and industrial output growth (panel B) to a 1 percent increase in the policy rate.

Appendix 4. Statistical Properties

Table 10. Elliott-Rothenberg-Stock Test for Unit Root

Variable (up to 28 Lags)	t-statistic	1% Critical Value	10% Critical Value
Unannounced FX Purchases$_t$	−33.064	−3.480	−2.570
Unannounced FX Sales$_t$	−10.255	−3.480	−2.570
Announced FX Purchases$_t$	−3.771	−3.480	−2.570
Announced FX Sales$_t$	−10.911	−3.480	−2.570
Optional FX Purchases$_t$	−3.808	−3.480	−2.570
Policy Rate (ΔIRI_t)	−6.631	−3.480	−2.570
Inflation ($\Delta\pi_t$)	−4.183	−3.480	−2.570
Inflation (π_t) – Expected (π_t^e)	−2.648	−3.480	−2.570
Inflation (π_t) – Target (π_t^*)	−2.640	−3.480	−2.570
Exchange Rate (Δe_t)	−8.201	−3.480	−2.570
Monthly Exchange Rate (Δe_{t-20})	−6.361	−3.480	−2.570
Exchange Rate Volatility (Vol_t)	−5.916	−3.480	−2.570
Industrial Production (ΔInd_t)	−3.066	−3.480	−2.570
U.S. Federal Funds Rate (Δi_t^*)	−9.476	−3.480	−2.570
Commodity Price Index ($\Delta SPGCCI_t$)	−7.837	−3.480	−2.570
VIX Index$_t$	−2.816	−3.480	−2.570

Notes: The minimum lag is determined using the modified Akaike information criterion (MAIC). All variables reject the null hypothesis of a unit root at the 1 percent level (except for industrial production growth, inflation minus its yearly target, inflation minus its yearly forecast, and the VIX index, which reject the null at the 0 percent level).

References

Adler, G., and C. E. Tovar. 2011. "Foreign Exchange Intervention: A Shield Against Appreciation Winds?" IMF Working Paper No. 11/165.

———. 2014. "Foreign Exchange Interventions and Their Impact on Exchange Rate Levels." *Monetaria* II (1): 1–48.

Akinci, O., O. Y. Culha, U. Ozlale, and G. Sahinbeyoglu. 2006. "The Effectiveness of Foreign Exchange Interventions under a Floating

Exchange Rate Regime for the Turkish Economy: A Post-Crisis Period Analysis." *Applied Economics* 38 (12): 1371–88.

Angrist, J. D., and J.-S. Pischke. 2009. *Mostly Harmless Econometrics: An Empiricist's Companion.* Princeton University Press.

Baillie, R. T., and W. P. Osterberg. 1997. "Why Do Central Banks Intervene?" *Journal of International Money and Finance* 16 (6): 909–19.

Barr, D. R., and E. T. Sherrill. 1999. "Mean and Variance of Truncated Normal Distributions." *American Statistician* 53 (4): 357–61.

Batini, N., and E. Nelson. 2001. "The Lag from Monetary Policy Actions to Inflation: Friedman Revisited." *International Finance* 4 (3): 381–400.

Blanchard, O. 2013. "Monetary Policy Will Never Be the Same." Technical Report. IMF Blog.

Bonser-Neal, C., and G. Tanner. 1996. "Central Bank Intervention and the Volatility of Foreign Exchange Rates: Evidence from the Options Market." *Journal of International Money and Finance* 15 (6): 853–78.

Canzoneri, M., and R. Cumby. 2013. "Optimal Foreign Exchange Intervention in an Inflation Targeting Regime: Some Cautionary Tales." *Open Economies Review* 25 (3): 429–50.

Chang, Y., and S. J. Taylor. 1998. "Intraday Effects of Foreign Exchange Intervention by the Bank of Japan." *Journal of International Money and Finance* 17 (1): 191–210.

Cohen, A. C. 1949. "On Estimating the Mean and Standard Deviation of Truncated Normal Distributions." *Journal of the American Statistical Association* 44 (248): 518–25.

Disyatat, P., and G. Galati. 2007. "The Effectiveness of Foreign Exchange Intervention in Emerging Market Countries: Evidence from the Czech Koruna." *Journal of International Money and Finance* 26 (3): 383–402.

Domac, I., and A. Mendoza. 2004. "Is There Room for Foreign Exchange Interventions under an Inflation Targeting Framework? Evidence from Mexico and Turkey." Policy Research Working Paper No. 3288, World Bank.

Dominguez, K. M. 1993. "Does Central Bank Intervention Increase the Volatility of Foreign Exchange Rates?" NBER Working Paper No. 4532.

Dominguez, K. M., and J. Frankel. 1993. "Does Foreign-Exchange Intervention Matter? The Portfolio Effect." *American Economic Review* 83 (5): 1356–69.

Echavarria, J. J., L. F. Melo, S. Tellez, and M. Villamizar. 2013. "The Impact of Pre-announced Day-to-Day Interventions on the Colombian Exchange Rate." BIS Working Paper No. 428.

Eichengreen, B. 1994. *International Monetary Arrangements for the 21st Century.* Washington, DC: Brookings Institution.

Fatum, R., and M. Hutchison. 1999. "Is Intervention a Signal of Future Monetary Policy? Evidence from the Federal Funds Futures Market." *Journal of Money, Credit and Banking* 31 (1): 54–69.

———. 2003. "Is Sterilised Foreign Exchange Intervention Effective After All? An Event Study Approach." *Economic Journal* 113 (487): 390–411.

Fischer, S. 2001a. "Exchange Rate Regimes: Is the Bipolar View Correct?" *Journal of Economic Perspectives* 15 (2): 3–24.

———. 2001b. "The International Financial System: Crises and Reform." The Robbins Lectures at the London School of Economics, October 29–31.

Geršl, A., and T. Holub. 2006. "Foreign Exchange Interventions Under Inflation Targeting: The Czech Experience." *Contemporary Economic Policy* 24 (4): 475–91.

Guimaraes, R., and C. Karacadag. 2004. "The Empirics of Foreign Exchange Intervention in Emerging Market Countries: The Cases of Mexico and Turkey." IMF Working Paper No. 04/123.

Havranek, T., and M. Rusnak. 2012. "Transmission Lags of Monetary Policy: A Meta-Analysis." Working Paper No. 2012/10, Research Department, Czech National Bank.

Herrera, A. M., and P. Ozbay. 2005. "A Dynamic Model of Central Bank Intervention." Working Paper No. 0501, Central Bank of the Republic of Turkey.

Humala, A., and G. Rodriguez. 2010. "Foreign Exchange Intervention and Exchange Rate Volatility in Peru." *Applied Economics Letters* 17 (15): 1485–91.

Humpage, O. F. 1999. "U.S. Intervention: Assessing the Probability of Success." *Journal of Money, Credit and Banking* 31 (4): 731–47.

Jordà, Ò. 2005. "Estimation and Inference of Impulse Responses by Local Projections." *American Economic Review* 95 (1): 161–82.

Kamil, H. 2008. "Is Central Bank Intervention Effective Under Inflation Targeting Regimes? The Case of Colombia." IMF Working Paper No. 08/88.

Kara, H. 2013. "Safeguarding Macroeconomic and Price Stability amid Capital Flow Volatility." Paper prepared for the BIS Meeting of Central Bank Chief Economists, Basel, Switzerland, March 2013.

Kearns, J., and R. Rigobon. 2002. "Identifying the Efficacy of Central Bank Interventions: The Australian Case." NBER Working Paper No. 9062.

Kilinc, M., and C. Tunc. 2014. "Identification of Monetary Policy Shocks in Turkey: A Structural VAR Approach." Working Paper No. 1423, Research and Monetary Policy Department, Central Bank of the Republic of Turkey.

Kim, S.-J., T. Kortian, and J. Sheen. 2000. "Central Bank Intervention and Exchange Rate Volatility: Australian Evidence." *Journal of International Financial Markets, Institutions and Money* 10 (3–4): 381–405.

Menkhoff, L. 2013. "Foreign Exchange Intervention in Emerging Markets: A Survey of Empirical Studies." *World Economy* 36 (9): 1187–1208.

Neil, B., and J.-F. Fillion. 1999. "An Intraday Analysis of the Effectiveness of Foreign Exchange Intervention." Working Paper No. 99-4, Bank of Canada.

Obstfeld, M., and K. Rogoff. 1995. "The Mirage of Fixed Exchange Rates." *Journal of Economic Perspectives* 9 (4): 73–96.

Rey, H. 2015. "Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence." NBER Working Paper No. 21162.

Rincón, H., and J. Toro. 2010. "Are Capital Controls and Central Bank Intervention Effective?" Borradores de Economia No. 625, Banco de la República de Colombia.

Romer, C. D., and D. H. Romer. 2004. "A New Measure of Monetary Shocks: Derivation and Implications." *American Economic Review* 94 (4): 1055–84.

Rosenbaum, S. 1961. "Moments of a Truncated Bivariate Normal Distribution." *Journal of the Royal Statistical Society: Series B* (Methodological) 23 (2): 405–408.

Taylor, M. P. 2004. "Is Official Exchange Rate Intervention Effective?" *Economica* 71 (281): 1–11.

Villamizar-Villegas, M. 2016. "Identifying the Effects of Simultaneous Monetary Policy Shocks." *Contemporary Economic Policy* 34 (2): 268–96.

Villamizar-Villegas, M., and D. Perez-Reyna. 2017. "A Theoretical Approach to Sterilized Foreign Exchange Intervention." *Journal of Economic Surveys* 31 (1): 343–65.