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SIMULTANEOUS MONETARY POLICIES IN THE CONTEXT OF THE TRILEMMA: EVIDENCE FROM THE CENTRAL BANK OF TURKEY*

Yasin Kursat Onder† Mauricio Villamizar-Villegas‡

Abstract

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. However, in the context of the monetary trilemma, both effects can potentially offset each other. Using daily data from the Central Bank of Turkey during the period of 2002 - 2010, 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 pre-announced. We also 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. On the other hand, changes in the policy rate significantly affected inflation but had no discernible effect on output growth.

JEL Codes: E43, E52, E58, F31

Key Words: Central bank intervention, simultaneous policies, monetary shocks, price puzzle, monetary policy trilemma, foreign exchange intervention

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1 Introduction

The *corner* or *bipolar hypothesis* (Eichengreen (1994)) and the *fix or float proposition* (Obstfeld and Rogoff (1995)), postulate that countries tend to move away from intermediate exchange rate regimes towards either hard pegs or fully flexible rates. These concepts, which became conventional wisdom throughout the beginning of the 1990s, began to lose popularity after the East Asia crises of 1997-1998 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).[1]

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 amounts, although with a discretionary (*Optional*) component provided that monetary authorities decided to exceed in the established amount.

In this paper we study how simultaneous central bank policies affect the economy. We extend the framework presented in Romer and Romer (2004) to allow for a bivariate policy model in which policy decisions are governed by dependent decision processes. We thus 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 the intended policy rate. These variables differ from changes in international reserves and the effective policy rate, in the sense that the latter are most

[1] See Villamizar-Villegas and Perez-Reyna (2015).

likely influenced by valuation effects and liquidity demand.

To date, even though there has been some degree of consensus within the literature regarding the effects of central banks' policy rates, empirical studies have yet to converge on the effects of foreign exchange intervention. For instance, surveys by Menkhoff (2013) or Villamizar-Villegas and Perez-Reyna (2015) show that only 15 of 25 and 16 of 32 studies, respectively, find significant effects of foreign exchange interventions on exchange rate levels, although most conclude that these effects are small and short lived. Furthermore, studies that center on the Turkish economy are rather limited. Some even face the challenge of covering restricted periods in which purchases of foreign currency were always preceded by interest rate cuts, making it harder to disentangle policy-specific effects. Akinci et al. (2006), for example, study 11 direct intervention episodes during 2001-2003 using a time-varying parameter model to analyze the effects of interventions on curbing exchange rate volatility. Guimaraes and Karacadag (2004) also analyze the impact of interventions on exchange rate levels and volatility during the same time frame, using a GARCH model.

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 monetary instruments and we differ in our definition of censored interventions. Additionally, we use a more ample and updated time frame which helps us to identify casual effects of simultaneous policies in the context of the monetary trilemma.

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, and none of which center on the Turkish economy. In this sense, we believe that our investigation will shed some light on pressing monetary policy discussions that have long been raised by studies like Dominguez and Frankel (1993), Humpage (1999), Christiano et al. (1999), Kim et al. (2000), Fischer (2001a) and Fischer (2001b), Romer and Romer (2004) and Blanchard et al. (2013). Specifically, we hope to contribute to ongoing policy questions such as: when should a central bank 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?

Our investigation confirms some of the previous findings from the literature, but also yields some new results. Similar to Villamizar-Villegas (2015) 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 to proprietary information used by the CBRT. However, opposite to Romer and Romer (2004) we find that changes in the CBRT policy rate had no discernible effects on industrial output growth. We believe that this result is driven by either differences (asymmetries) in the effects of monetary expansions and contractions (see Angrist et al. (2013)), or by policy restrictions

imposed by the monetary trilemma. 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. The opposite is true for *Announced* interventions which affected exchange rate changes but not volatility.

Overall, our findings provide support to the idea that allowing for free capital flows while having autonomous monetary policy and a managed exchange rate is, in fact, an "impossible trinity". Namely, when comparing the effects of policy shocks (free from anticipatory movements) vis-*à*-vis the effects of observed interventions, we find that the former are lesser in size and duration, and sometimes not even significant at all. This result is similar to that found in Bruno et al. (2015), in which policies are most successful when they complement monetary policy rather than when they act in opposite directions (i.e. leaning against the wind).

This paper proceeds as follows: Section 2 describes the data and emphasizes on 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 of the CBRT. Section 4 presents the results and provides some intuition on how they relate to the monetary trilemma. Finally, section 5 concludes.

2 Data and Context

Our data covers the period of Jan 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. Subsequent to 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.[2] Consequently, we feel that further assumptions are needed after 2010 in order to disentangle the effects of the newly established tools on both the interest rate and the Turkish Lira.

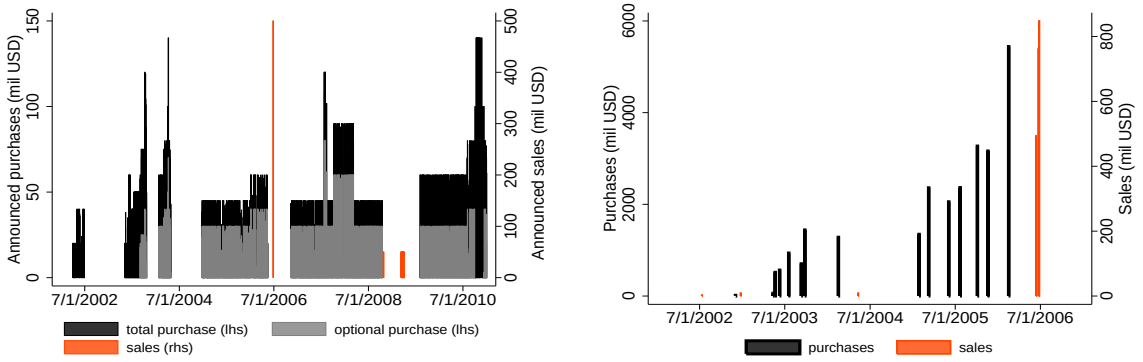
[2]See Kara (2013) for a review of unconventional monetary measures undertaken by the CBRT

2.1 FX 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 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 in the established amount.[3] 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 often infrequent but large, averaging \$1.7 and \$0.3 billion USD, respectively.

Figure 1: Different types of Foreign Exchange Interventions conducted by the CBRT



(a) *Announced* Interventions

(b) *Unannounced* Interventions

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.

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

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

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.

Table 1: Foreign Exchange Interventions Jan 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

SOURCE: Central Bank Data and author's calculations

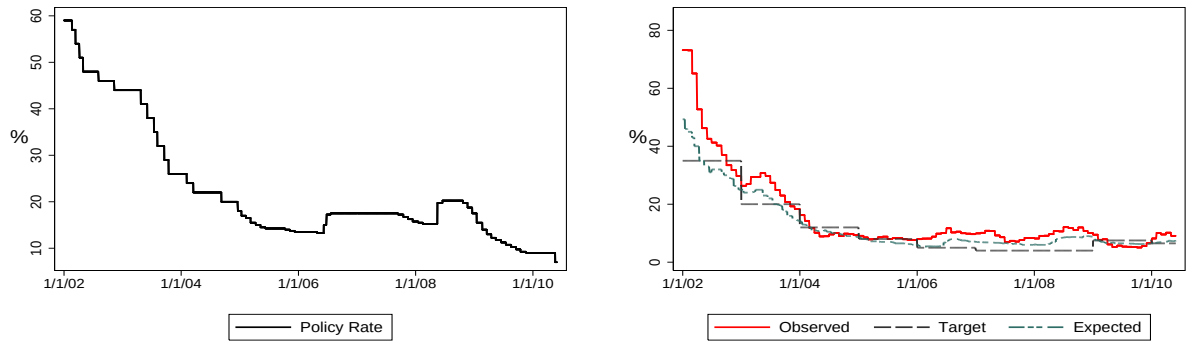
2.2 Policy rate

The policy rate corresponded to the CBRT's overnight borrowing rate between February 20, 2002 and May 16, 2008 (due to the abundant liquidity in the 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.

Figure 2 depicts the resulting policy rate as well as the yearly inflation (observed, target and expected). The right panel shows that at the onset of 2002, inflation (or hyperinflation) levels reached 73.2%, while the target for inflation was set at 35% and the policy rate was set at 59% (depicted in the left panel). 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.

This positive relationship between inflation and interest rates can be misconstrued as evidence of the price puzzle. The reality was that the CBRT raised interest rates to bring inflation levels down to single digits, and only conducted expansionary monetary policy once inflation decreased. In section 5 we show that this true negative relationship can be uncovered by purging the policy rate from systematic responses of policy.

Figure 2: Policy Rate and Yearly Inflation (Observed, Target and Expected)



(a) Policy Rate

(b) Inflation: Observed, Target and Expected

The left panel corresponds to the CBRT policy rate. The right panel corresponds to the observed inflation, to the surveyed 1-year ahead expected inflation forecast and to the yearly target.

2.3 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 economics conditions were such so that it was optimal for the CBRT to conduct only purchases of USD, or (ii) economic conditions were such so that it was optimal for the CBRT to conduct sales of USD, but did not carry them out given some external factor or constraint. The latter describes a censored process that, if estimated with a linear model, would yield inconsistent estimates.[4]

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 like Villamizar-Villegas (2015) that also assume censored policy processes, as well as to analyze the importance of the conditional probability of observing a positive intervention, by comparing both types of estimations.

[4]See Cohen (1949), or Rosenbaum (1961), Barr and Sherrill (1999).

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

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 to properly account for the systematic differences between treatment and control groups (i.e. intervention vs non-intervention episodes). For instance, let us 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 "$s - j$".[5] 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.

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

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

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

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

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 in fact purchased "s".

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' units of foreign currency (from "$s-j$" to "s"), given a purchase of "s". Intuitively, it measures the effect of an observed intervention minus the effect of a counterfactual scenario in which the CBRT had decided to intervene less (i.e. purchasing "j" fewer units of foreign currency). The second and third terms constitute the resulting bias which arises due to the non-randomization of treatment assignment. In this context, it is reasonable to argue that the economy described by the third term is better off than the one described by the second term, mainly because monetary authorities decided to intervene less in the third term. So, for example, when evaluating the effects of policy on inflation, the bias 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.[6]

Fortunately, the Conditional Independence Assumption (**CIA** henceforth) allows us to eliminates 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 selection-on-observables, establishes the foundation based on which *"regressions can also be used to approximate experiments in the absence of random assignment"*.[7] Formally, the CIA can be stated as equation 4:

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

[6] The third term of equation 3 would capture lower values of inflation than the second term.
[7] Angrist and Pischke (2009), pg 18.

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

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

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.

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. We thus proceed by parameterizing this dependence as follows:

$$\begin{aligned} FXI_t^* &= x_{1t}^{'}\beta_1 + \epsilon_{1t} \\ IRI_t &= x_{2t}^{'}\beta_2 + \epsilon_{2t} \end{aligned}$$

$$\begin{pmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{pmatrix} \sim N\left(0, \Sigma\right). \tag{6}$$

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:

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

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 be then 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 precesses characterized by equation 6.

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 parametrize 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:

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

where $\phi(\cdot)$ and $\Phi(\cdot)$ correspond to the pdf and cdf 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 (2015). 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:

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

$$\begin{aligned}\epsilon_{2t} &= IRI_t - E\left[IRI_t \mid x_{2t}\right] \\ &= IRI_t - x_{2t}^{'}\beta_2 \end{aligned} \tag{10}$$

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^*.[8]

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 Jorda (2005)'s methodology of local projections (equation 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) (equation 12). Coefficients and standard errors (bootstrapped) were summed up every period in order to obtain the cumulative effect across time.[9]

$$Y_{it+s} = \eta_0^s + \eta_1^s\epsilon_{1t} + \eta_2^s\epsilon_{2t} + \vartheta_{it+s} \quad \text{for} \quad s = 0, 1, ..., h. \tag{11}$$

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

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

[9] 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 ± 2 lags, for readability purposes only.

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 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), to 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 to equation 7 (for *Announced* Sales) when computing shocks in vector form.

Table 3: Covariances of Bivariate Process

Bivariate model			Uncensored	Censored
FX *Unannounced* Total	-	Policy Rate	-0.05	
			(0.034)	
FX *Announced* Purchases	-	Policy Rate	-0.01	-0.06
			(0.034)	(0.041)
FX *Announced* Sales	-	Policy Rate	0.08**	0.71***
			(0.033)	(0.229)
FX *Unannounced* Purchases	-	Policy Rate		0.40
				(0.289)
FX *Unannounced* Sales	-	Policy Rate		0.10
				(0.206)
FX *Optional* Purchases	-	Policy Rate		-0.08
				(0.064)

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. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively. Standard errors are reported in parentheses.

Interestingly, most of these covariances turn significant if excluding inflation values relative to the yearly target from X_t (all except unannounced trades whose covariance is not significant across all different specifications of X_t). These findings indicates that, under the assumptions of the model, the CBRT's conditional decisions about one instrument 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}.[10] Independence, in this case, is conditional on the set of control variables.

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

4.2 Policy Functions

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 Liras per US 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 specification (3), interventions positively responded to lagged *Announced* purchases of USD (exhibiting some momentum effect) as well as changes in the policy rate, indicating a *leaning against the wind* policy.[11] Additionally, specifications (1) and (2) show a positive effect of industrial output growth on USD purchases (this effect is not significant in specification (3), possibly due to the high correlation between lagged output growth and the policy rate). 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.

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 variables affected the decision to optionally intervene in the foreign exchange market, as if expected by market participants.[12] In this case, the CBRT tried to depreciate domestic currency by purchasing USD whenever inflation was low (relative the the yearly target), whenever industrial output increased, and whenever the monthly exchange rate appreciated.[13] Specification (3) also shows that interventions positively responded to past purchases of *Announced* interventions.

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 past *Unannounced* sales and purchases, respectively.

In sum, these results are similar to those found in Kamil (2008) and Echavarria et al. (2013) which find that central banks are inclined to purchase (sell) foreign currency whenever the exchange rate appreciates (depreciates). In contrast, they show that responses mostly varied depending on whether interventions were pre-announced.

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

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

[13] While interventions were almost all fully sterilized, 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 4: OLS Estimation: $FXI_t^{total} = x'_{1t}\beta_1 + v_t$

FX *Unannounced* Total (Uncensored)	(1)	(2)	(3)
FXI_{t-1}^{total}	0.00	0.00	0.00
	(0.010)	(0.010)	(0.009)
Inflation(π_{t-1})-Target(π^*_{t-1})	-8.01	-8.53	-11.10
	(9.582)	(9.670)	(10.131)
Industrial Production ΔInd_{t-1}	0.68*	0.73*	0.54
	(0.368)	(0.376)	(0.383)
Daily Depreciation Δe_{t-1}	-4.09*	-4.66**	-4.68***
	(2.102)	(2.202)	(2.195)
Weekly Depreciation Δe_{t-5}	-2.07*	-2.37**	-2.70**
	(1.126)	(1.192)	(1.225)
Monthly Depreciation Δe_{t-20}	-0.85*	-1.08***	-0.90**
	(0.491)	(0.668)	(0.466)
Exchange rate VOL_{t-1}		1.41**	1.60**
		(0.669)	(0.694)
Announced Purchases$_{t-1}$			0.51***
			(0.185)
Inflation Surprises ($\pi_{t-1} - \pi^e_{t-1}$)			0.00
			(0.326)
Policy Rate ΔIRI_{t-1}			3.70*
			(2.207)

Specifications $x_{1t}(1-3)$ correspond to the different combinations of covariates. FX Intervention is measured in million USD. All specifications consisted of 2,190 observations. R^2=0.005, 0.005 and 0.007 for OLS specifications 1-3. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively. Standard errors are reported in parentheses. Constant is not reported (estimations with time dummies yield similar results).

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})	-1.50	-0.28
	(1.220)	(0.369)
Industrial Production ΔInd_{t-1}	0.17*	0.05
	(0.089)	(0.033)
Weekly Depreciation Δe_{t-5}	-2.92*	0.71*
	(1.573)	(0.422)
Monthly Depreciation Δe_{t-20}	-0.68***	0.08*
	(0.258)	(0.041)
Exchange rate VOL_{t-1}	-0.49	-0.23
	(0.723)	(0.147)
Policy RateΔIRI_{t-1}	0.49	-0.07
	(1.730)	(0.516)

Specifications $x_{1t}(1-2)$ correspond to the different combinations of covariates. FX Intervention is measured in million USD. All specifications consisted of 2,190 observations. Pseudo R^2=0.09, and 0.20 for Tobit specifications 1-2. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively. Standard errors are reported in parentheses. Constant is not reported (estimations with time dummies yield similar results).

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

FX *Optional* Purchases (censored)	(1)	(2)	(3)
$FXI_{t-1}^{optional}$	0.93***	0.93***	0.65***
	(0.048)	(0.048)	(0.048)
Inflation(π_{t-1})-Target(π^*_{t-1})	-0.52***	-0.51***	-0.43***
	(0.143)	(0.143)	(0.144)
Industrial Production ΔInd_{t-1}	0.53***	0.51***	0.28***
	(0.082)	(0.083)	(0.083)
Monthly Depreciation Δe_{t-20}	-0.60***	-0.48**	-0.44**
	(0.190)	(0.203)	(0.202)
Exchange rate VOL_{t-1}		-0.64	-0.53
		(0.399)	(0.391)
Announced Purchases$_{t-1}$			0.70***
			(0.054)
Unannounced Purchases$_{t-1}$			0.00
			(0.003)
Policy RateΔIRI_{t-1}			3.76
			(3.000)

Specifications $x_{1t}(1-3)$ correspond to the different combinations of covariates. FX Intervention is measured in million USD. All specifications consisted of 2,190 observations. Pseudo R^2=0.06, 0.06 and 0.07 for Tobit specifications 1-3. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively. Standard errors are reported in parentheses. Constant is not reported (estimations with time dummies yield similar results).

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

Announced FXI (Uncensored)	Purchases	Sales
FXI_{t-1}	0.83***	0.16
	(0.021)	(0.139)
Inflation(π_{t-1})-Target(π^*_{t-1})	1.34***	0.40**
	(0.356)	(0.172)
Industrial Production ΔInd_{t-1}	0.07***	-0.10***
	(0.013)	(0.024)
Monthly Depreciation Δe_{t-20}	-0.11**	0.05
	(0.046)	(0.064)
Exchange rate VOL_{t-1}	-0.06	-0.04
	(0.063)	(0.058)
Unannounced Purchases$_{t-1}$	0.002*	0.00
	(0.001)	(0.001)
Unannounced Sales$_{t-1}$	-.002	0.47***
	(0.002)	(0.131)
Inflation Surprises ($\pi_{t-1} - \pi^e_{t-1}$)	-.11***	-0.04***
	(0.035)	(0.012)
Policy RateΔIRI_{t-1}	-1.10*	0.12
	(0.571)	(0.857)

Specifications $x_{1t}(1-2)$ correspond to the different combinations of covariates. FX Intervention is measured in million USD. All specifications consisted of 2,190 observations. R^2=0.73, and 0.79 for OLS specifications 1-2. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively. Standard errors are reported in parentheses. Constant is not reported (estimations with time dummies yield similar results).

Similar to Romer and Romer (2004), the IRI_t policy function of equation 6 was estimated using OLS around meeting dates 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 (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 variables were inflation relative to the yearly target and inflation surprises (i.e. the CBRT conducted contractionary policy in order to lower both observed and expected inflation). Other variables that prompted policy adjustments were lagged values of *Announced* and *Unannounced* Sales and weekly and monthly exchange rate changes. In all specifications, the CBRT did not seem to respond to changes in the US Federal Funds rate.

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

Policy Rate Changes (Uncensored)	(1)	(2)	(3)
ΔIRI_{m-1}	0.35*	0.24	0.20
	(0.202)	(0.171)	(0.176)
Inflation(π_{t-1})-Target(π^*_{t-1})	0.19*	0.22**	0.23**
	(0.099)	(0.099)	(0.103)
Weekly Depreciation Δe_{t-5}	-0.13*	-0.19***	-0.19***
	(0.075)	(0.064)	(0.061)
Monthly Depreciation Δe_{t-20}	0.06*	0.06*	0.06**
	(0.028)	(0.033)	(0.025)
GDP Growth$_{t-1}$	0.01	0.00	0.01
	(0.015)	(0.014)	(0.017)
Inflation Surprises ($\pi_{t-1} - \pi^e_{t-1}$)	-0.15**	-0.18***	-0.19***
	(0.063)	(0.058)	(0.059)
US Fed Funds Rate Δi^*_{t-1}	-1.99	-0.71	-0.51
	(3.244)	(3.136)	(2.831)
Unannounced Sales$_{t-1}$		0.003***	0.003***
		(0.001)	(0.001)
Announced Purchases$_{t-1}$			-0.01
			(0.006)
Announced Sales$_{t-1}$			0.01*
			(0.005)

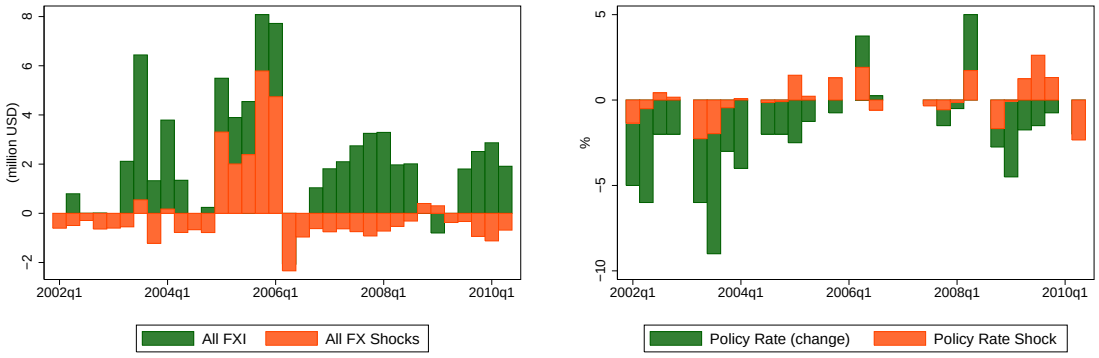
Specifications $x_{2t}(1-3)$ correspond to the different combinations of covariates. All models consisted of 52 observations given that estimations were conducted around meeting dates of the board of directors. R^2=0.59, 0.59, and 0.60 for OLS specifications 1-3. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively. Robust standard errors are reported in parentheses. Constant is not reported.

4.3 Policy Shocks

Figure 3 depicts the resulting monetary shocks $(\epsilon_{1t}, \epsilon_{2t})$ compared to the observed policy instruments (FXI_t, IRI_t). To improve readability, data points were summed into quarterly observations.[14] The deterministic component of policy can be interpreted as the difference between the green and orange bars. As shown, policy shocks greatly differed from observed values, especially during certain time periods. For instance, the left panel of figure 3 shows that the CBRT would have intervened less in the foreign exchange market had it not been for past exchange rate movements. Specifically, during 2002-2005 and 2007-2010, 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 3 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 66%, on average.

Figure 3: Observed Intervention vs. New Measures of Policy Shocks: 2002-2010



(a) FXI vs Policy Shock ϵ_{1t}

(b) ΔIRI vs Policy Shock ϵ_{2t}

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) which was included under that specification (column) so the policy shock is, by construction, orthogonal to that variable.

[14] All foreign exchange shocks and observed values were considered

As it turns out, all residuals are correctly specified across the various intervention variables.

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

Policy Shock vs 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 (0.002)	0.00 (0.001)	0.00 (0.001)	0.00 (0.001)
Unannounced Purchases$_{t-1}$	X	X	0.00 (0.533)	X	X	X	0.00 (0.001)
Unannounced Sales$_{t-1}$	X	0.00 (0.005)	X	0.00 (0.001)	X	X	X
Optional Purchases$_{t-1}$	0.24 (0.271)	0.29 (0.272)	-0.02 (0.222)	X	0.01 (0.011)	0.00 (0.007)	0.27 (0.226)
Announced Purchases$_{t-1}$	X	-0.23 (0.267)	-0.02 (0.031)	X	X (0.009)	0.00	X
Announced Sales$_{t-1}$	-0.02 (0.020)	-0.01 (0.017)	-0.03 (0.025)	0.00 (0.001)	0.00 (0.002)	X	X
Policy Rate Changes$_{t-1}$	X	X	X	X	X	X	X

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

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, changes in inflation, and iv) industrial production growth. To date, even though there has been some consensus within the empirical literature regarding the effects of the policy rate on these variables, studies have yet to converge on the effects of foreign exchange intervention.

In all cases, the effects of both the estimated residuals ($\epsilon_{1t},\ \epsilon_{2t}$) and the observed policy instruments ($FXI_t,\ IRI_t$) were computed.[15] While the former consist of correctly specified

[15]Policy residuals were computed according to specification (3) of Tables 4, 6, 8 and to the only specification presented in Tables 5 and 7.

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. Hence, the left panels of Figures 4-7 depict responses in outcome variables due to policy shocks. Conversely, the right panels of Figures 4-7 depict responses in outcome variables due to observed values of intervention (note that all IRFs not reported in Figures 4-7 were not statistically significant).

4.4.1 Exchange Rate Changes (daily frequency)

Panels (c) and (e) of Figure 4 show the only significant IRFs of policy shocks on exchange rate changes. Namely, *Announced* Purchases of 1 billion USD depreciated domestic currency in up to 5% during days 10-40 after interventions took place. On the other hand, *Announced* Sales of 1 billion USD appreciated domestic currency by up to 2.5%, but only during the first 10 days following the intervention shock. Other policy shocks such as *Unannounced* sales and purchases of foreign currency, as well as changes in the policy rate, appeared to have a null effect on exchange rate changes. These results are in line with those found in Dominguez (1993), Dominguez and Frankel (1993), Humpage (1999), Kim et al. (2000) and Taylor (2004), but are contrary to those found in Disyatat and Galati (2007) and Adler and Tovar (2011). However, most studies in the empirical literature find mixed results.

4.4.2 Exchange Rate Volatility (daily frequency)

Figure 5 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%) than for sales (0.02%). 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%.

Foreign exchange intervention through *Announced* Purchases also reduces exchange rate volatility by up to 8%, as shown in panel (e), but effects subside after 15 days. Finally a 1% increase in the policy rate reduces volatility by almost 5%. However, this result must be interpreted with caution given that the symmetric effects of the policy rate are imposed by the linear setting in equation 10.[16]

[16] We refer to studies such as Angrist et al. (2013) for a view on potential assymetric effects of policy rates.

4.4.3 Changes in Inflation (monthly frequency)

Figure 6 depicts the implied IRFs of changes in inflation. Panel (h) shows that an increase of 1% in the observed policy rate change (ΔIRI_t) has a strong positive effect on inflation (of up to 0.5%) that lasts for 10 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, similar to Romer and Romer (2004), this bias is completely elimiated: an increase of 1% in the policy rate shock lowers inflation by almost 1% and effects are significant only after the first 8 months. This result is in line with the related literature that find evidence of almost a 1 year lag-delay of interest rates on inflation.[17]

The remaining panels of Figure 6 show that foreign exchange shocks have no effects on inflation, which is consistent with the fact that almost all interventions were fully sterilized (this is contrary to the effects found if using observed values of intervention, as shown in panels (d) and (f)).

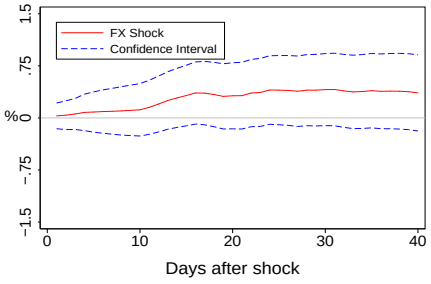
4.4.4 Industrial Production Growth (monthly frequency)

Figure 7 depicts the implied IRFs of industrial production growth. All left panels (corresponding to the effect of the estimated policy shocks) show a null effect of policy on output. That is, once purged from the systematic responses of policy, shocks do not have any significant effects. Results are very different to those found if using observed values of intervention, as shown in panels (b), (d), (f), and (h).

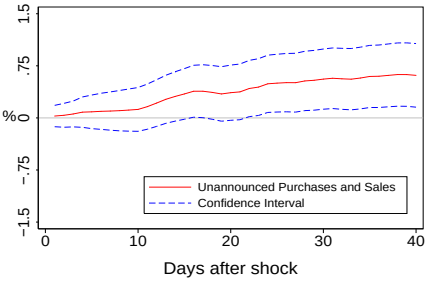
This finding is surprising and opposite to that of Romer and Romer (2004) and Villamizar-Villegas (2015) who find that interest rate incrementals, when properly controlled for, have a negative impact on output. We thus provide a possible explanation for this result in the next subsection.

[17] See for example Romer and Romer (2004) and Angrist and Kuersteiner (2011).

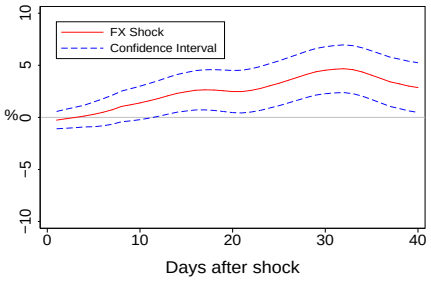
Figure 4: Implied IRFs of Exchange Rate Changes (Δe_t)



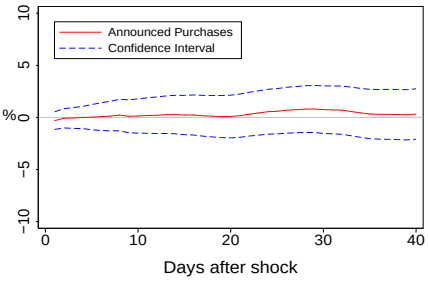
(a) Unannounced Total (Shock)



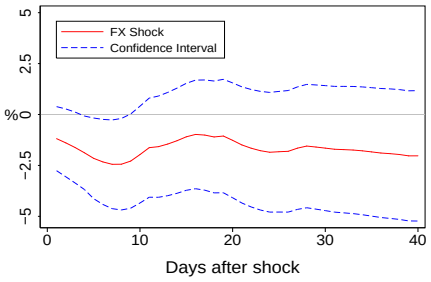
(b) Unannounced Total



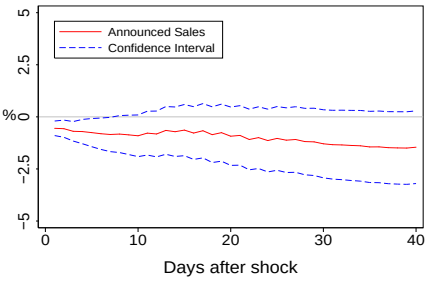
(c) Announced Purchases (Shock)



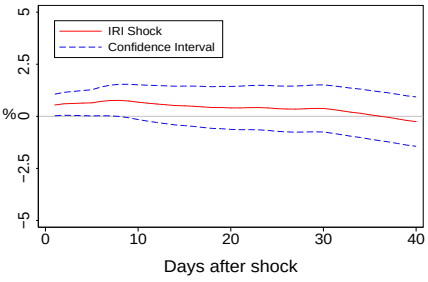
(d) Announced Purchases



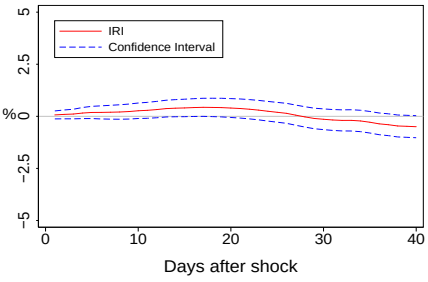
(e) Announced Sales (Shock)



(f) Announced Sales



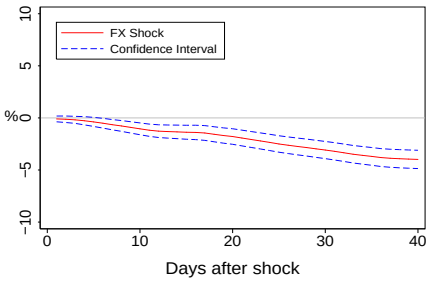
(g) ΔIRI (Shock)



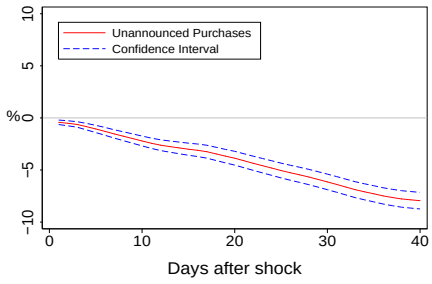
(h) ΔIRI

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% increase in the policy rate.

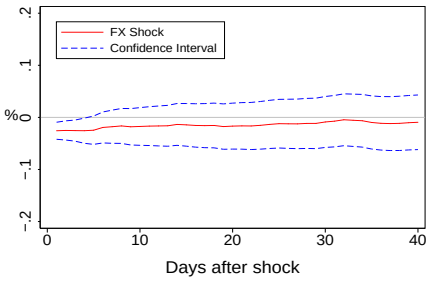
Figure 5: Implied IRFs of Exchange Rate Volatility (VOL_t)



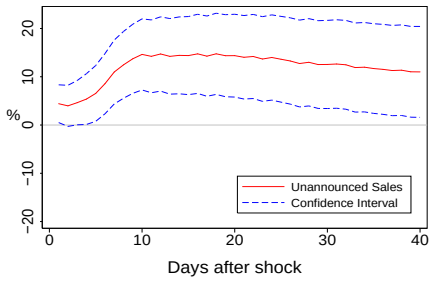
(a) Unannounced Purchases (Shock)



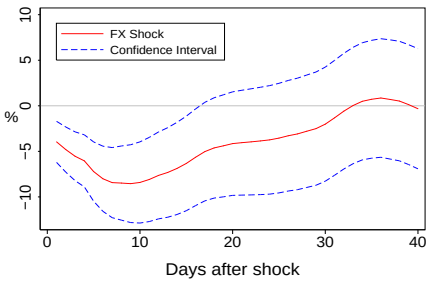
(b) Unannounced Purchases



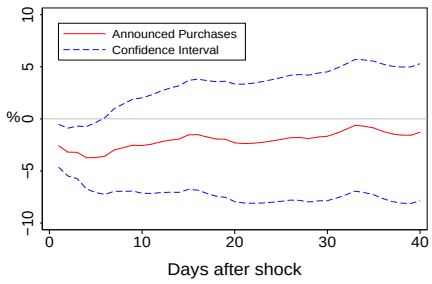
(c) Unannounced Sales (Shock)



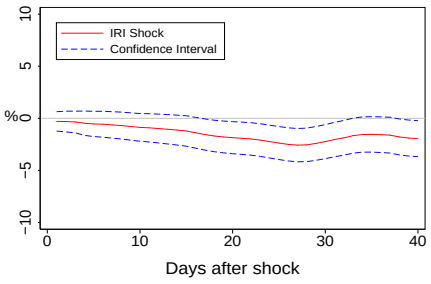
(d) Unannounced Sales



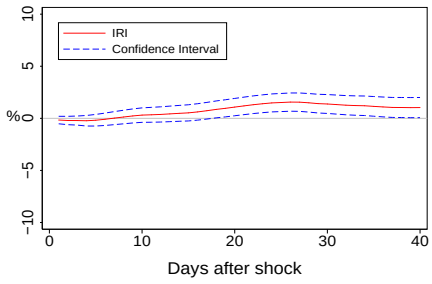
(e) Announced Purchases (Shock)



(f) Announced Purchases



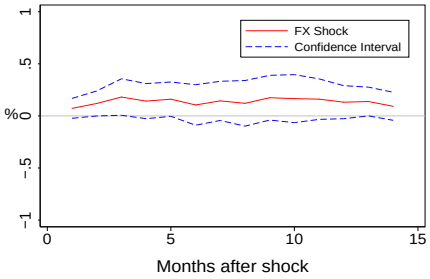
(g) ΔIRI (Shock)



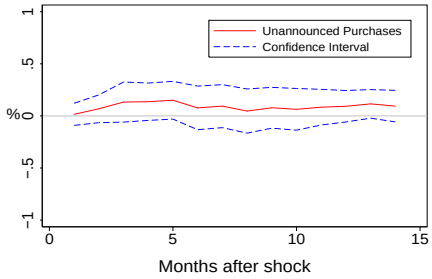
(h) ΔIRI

IRFs (a)-(f) correspond to a response in exchange rate volatility (%) to a 1 billion USD purchase (or sale). IRFs (g)-(h) correspond to a response in exchange rate volatility (%) to a 1% increase in the policy rate.

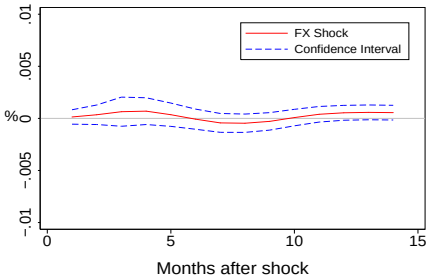
Figure 6: Implied IRFs of Inflation Changes ($\Delta\pi_t$)



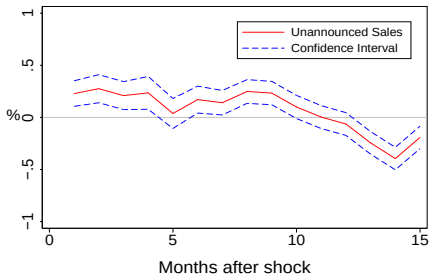
(a) Unannounced Purchases (Shock)



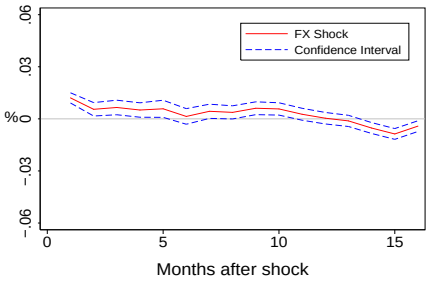
(b) Unannounced Purchases



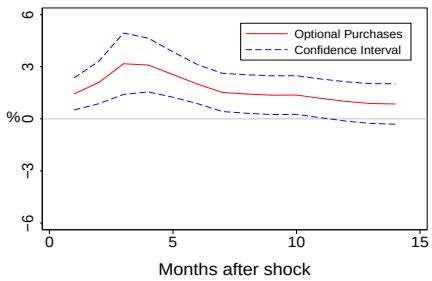
(c) Unannounced Sales (Shock)



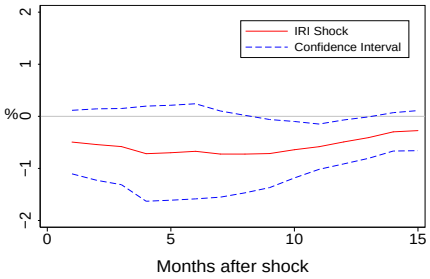
(d) Unannounced Sales



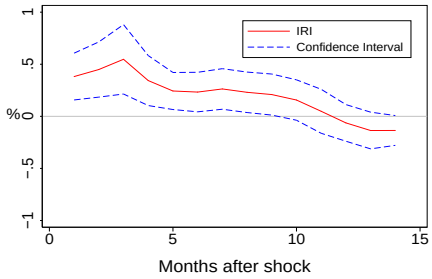
(e) Optional Purchases (Shock)



(f) Optional Purchases



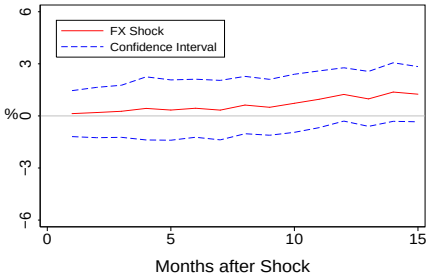
(g) ΔIRI (Shock)



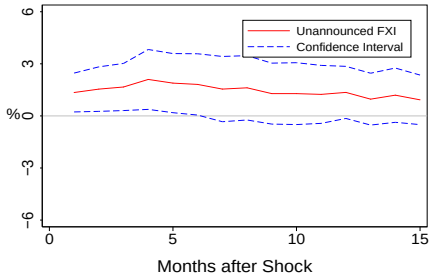
(h) ΔIRI

IRFs (a)-(f) correspond to a response in inflation (%) to a 1 billion USD purchase (or sale). IRFs (g)-(h) correspond to a response in inflation rate volatility (%) to a 1% increase in the policy rate.

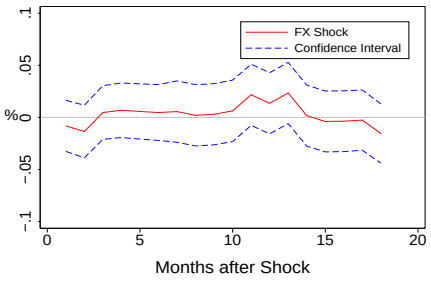
Figure 7: Implied IRFs of Industrial Production (ΔInd_t)



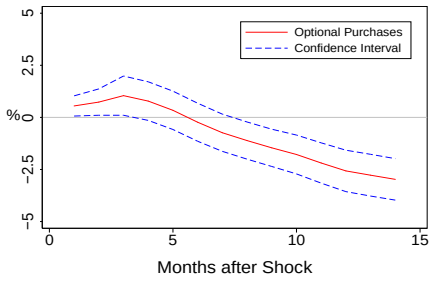
(a) Unannounced Purchases - Sales (Shock)



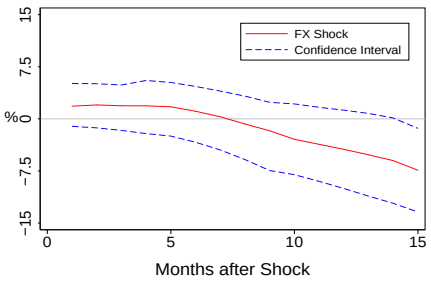
(b) Unannounced Total



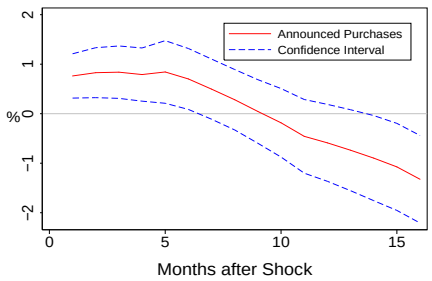
(c) Optional Purchases (Shock)



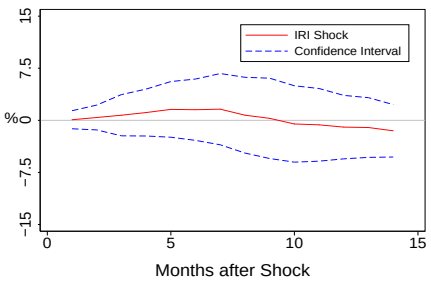
(d) Optional Purchases



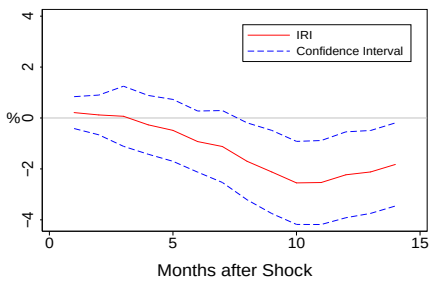
(e) Announced Purchases (Shock)



(f) Announced Purchases



(g) ΔIRI (Shock)



(h) ΔIRI

IRFs (a)-(f) correspond to a response in industrial output growth (%) to a 1 billion USD purchase (or sale). IRFs (g)-(h) correspond to a response in industrial output growth (%) to a 1% increase in the policy rate.

4.5 The Monetary Trilemma

Overall, our findings provide support to the idea that allowing for free capital flows while having autonomous monetary policy and a managed exchange rate is, in fact, an "impossible trinity". To see this point more clearly, consider a world with 2 countries, *home* (h) and *foreign* (f), characterized by equations 13-15:

$$E_t[e_{t+k} - e_t \mid \Omega_t] = i_t^h - i_t^f \tag{13}$$

$$y_t^h = f(e_t, i_t^h) \tag{14}$$

$$\pi_t^h = g(e_t, y_t^h, \pi_t^e), \tag{15}$$

where e_j denotes the log exchange rate in units of country h's currency per unit of country f's currency at time j, i^h and i^f correspond to domestic and foreign returns, respectively, y^h is the home country's output gap (with respect to some equilibrium value), π_t^h and π_t^e correspond to the home country's inflation and expected inflation, respectively, and Ω_t is the relevant information set at time t. Equations 13-15 are simplified versions of the Uncovered Interest rate Parity condition (equation 13), the IS curve (equation 14), and the Phillips curve (equation 15), for some given functions f and g. If we assume a managed exchange rate regime (e.g a hard peg) so that $\Delta e_t = 0$, then equations 13-15 become:

$$i_t^h = i_t^f \tag{16}$$

$$y_t^h = f(\bar{e}, i_t^f) \tag{17}$$

$$\pi_t^h = g(\bar{e}, f(\bar{e}, i_t^f), \pi_t^e). \tag{18}$$

Consequently, monetary autonomy is lost (equation 16) and output only responds to foreign shocks (equation 17). On the other hand, inflation reacts to foreign shocks but also to expected inflation (equation 18).

In sum, we believe that our results are in line with equations 16-18. That is, even though the CBRT did not completely enact a fixed exchange rate regime after 2002, foreign exchange interventions did limit policy effects. Finally, we argue that the impact of the policy rate on inflation must have operated mainly through changes in agents' expectations.[18]

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 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 amounts, although with a discretionary (*Optional*) component provided that monetary authorities decided to exceed in the established amount. However, in the context of the monetary trilemma, foreign exchange and interest rate interventions can potentially offset each other.

In this paper we study how simultaneous central bank policies affect the economy. We allow for a bivariate policy model in which policy decisions are governed by dependent decision processes. We thus model the undertakings of monetary authorities (tailored to the various foreign exchange mechanisms of the CBRT), and purge the intended monetary decisions from responses to high frequency and real-time macroeconomic data. Our investigation confirms some of the previous findings from the literature, but also yields some new results. Similar to Villamizar-Villegas (2015) 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 to proprietary information used by the CBRT. However, opposite to Romer and Romer (2004) we find that changes in the CBRT policy rate had no discernible effects on industrial output growth.

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. The opposite is true for *Announced* interventions which affected exchange rate changes but not volatility. Finally, when comparing the effects of policy shocks (free from anticipatory movements) vis-*à*-vis the effects of observed interventions, we find that the former are lesser in size and duration, and sometimes not even significant at all.

[18] See Villamizar-Villegas and Perez-Reyna (2015) for a theoretical survey on the effects of sterilized foreign exchange interventions and the corresponding channels through which policy operates.

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 US 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 Central Bank of Turkey may have exceeded the predetermined amount of FX purchases. There was a limit on how much authorities could exceed during these transactions. The Central Bank of Turkey 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 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 (5 business days) exchange rate changes. Daily frequency. Units are in log differences.
  - Monthly Depreciation (Δe_{t-20}): Monthly (20 business days) exchange rate changes. Daily frequency. Units are in log differences.
  - US Federal Funds rate (Δi_t^*): Self explanatory. Daily frequency. Units are in changes (%).
  - Inflation Surprises ($\pi_t - \pi_t^e$): Expected inflation corresponds to the 1-year ahead forecasts conducted by the Central Bank of Turkey. Biweekly. Units are in (%).
  - Inflation minus yearly target ($\pi_t - \pi_t^*$): Self explanatory. Monthly frequency. Units are in (%).
- Outcome variables in Y_t
  - Nominal Exchange rate (e_t): Nominal exchange rate in units of Turkish Liras per unit of US dollar (TRY/USD). Daily frequency. Units are in log-differences.
  - Exchange rate volatility (Vol_t): Squared daily exchange rate returns $(\Delta e_t)^2$. 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: 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$_t$	-32.981	-3.480	-2.570
Unannounced FX Sales$_t$	-10.229	-3.480	-2.570
Announced FX Purchases$_t$	-3.757	-3.480	-2.570
Announced FX Sales$_t$	-10.884	-3.480	-2.570
Optional FX Purchases$_t$	-3.791	-3.480	-2.570
Δ Policy Rate$_t$	-6.620	-3.480	-2.570
$\Delta\pi_t$	-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
Δe_t	-8.518	-3.480	-2.570
Δe_{t-20}	-6.336	-3.480	-2.570
Exchange Rate Vol_t	-5.983	-3.480	-2.570
ΔInd_t	-3.070	-3.480	-2.570
Δi_t^*	-5.634	-3.480	-2.570

The minimum lag is determined using the modified akaike's information criterion (MAIC). All variables reject the null hypothesis of a unit root at the 1% level (except for Industrial Production growth, inflation minus its yearly target, and inflation minus its yearly forecast which reject the null at the 10% level.

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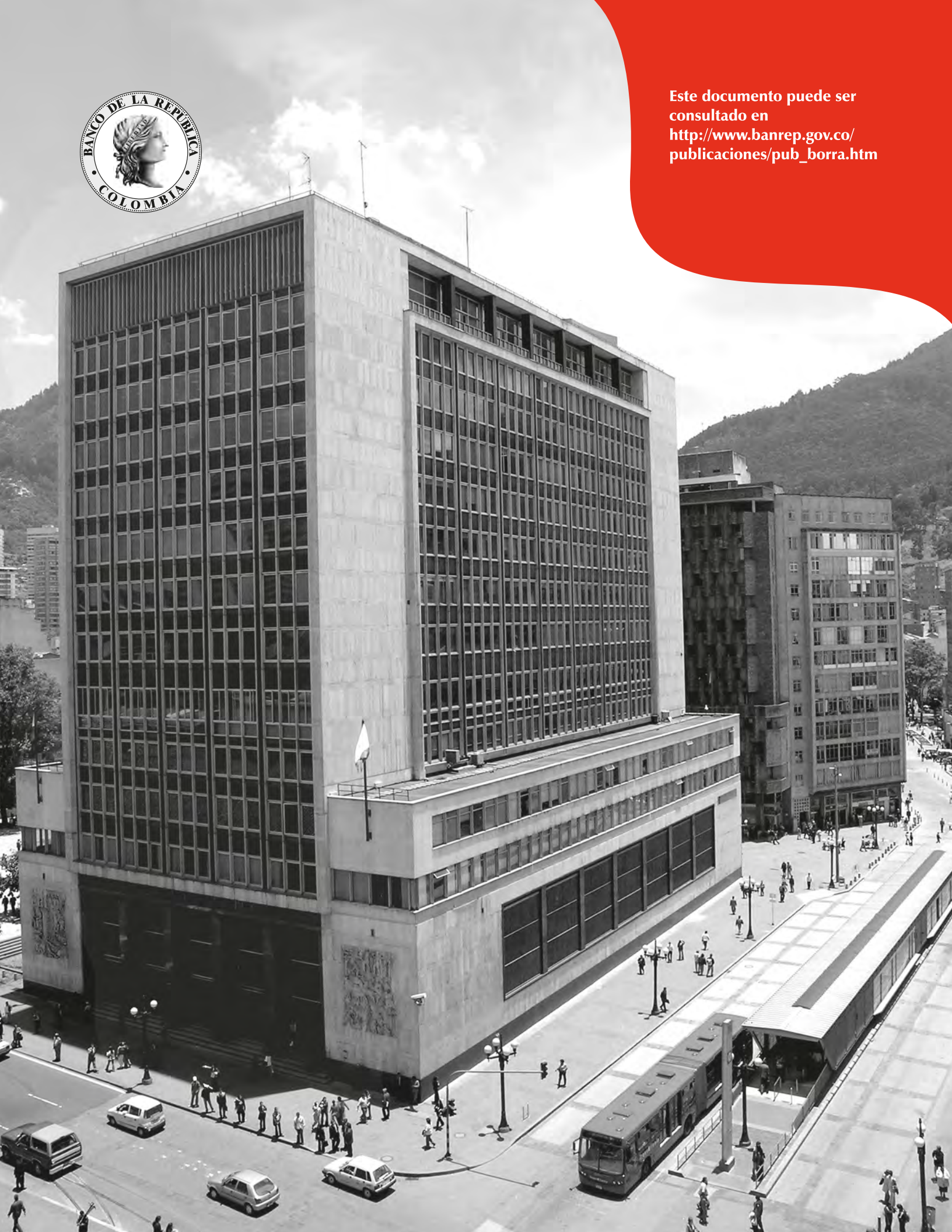

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