

Effectiveness of FX Intervention and the *Flimsiness* of Exchange rate Expectations

Hernando Vargas-Herrera* Mauricio Villamizar-Villegas†

The opinions contained in this document are the sole responsibility of the authors and do not commit Banco de la República nor its Board of Directors

Abstract

Most of the foreign exchange intervention literature overlooks the influence of market uncertainty when evaluating effectiveness. In this paper we take a fresh new look at how this uncertainty amplifies exchange rate effects. Our contribution is twofold. We first posit a partial equilibrium model with frictions to illustrate that when uncertainty is low, intervention is less effective, for agents are willing to bet against the central bank. Conversely, when uncertainty is high, intervention faces a weaker countervailing force from speculators and arbitragers. Second, we empirically test for the incremental effects of *flimsy* exchange rate fundamentals by using a sharp policy discontinuity in the way the Central Bank of Colombia intervened in the FX market. Our results indicate that market uncertainty increases depreciation of domestic currency in approximately 1% following central bank purchases of foreign currency and extends its duration in up to 2 weeks. Additionally, these purchases have an incremental effect in stemming exchange rate volatility in up to 7%.

JEL Classification: C14, C31, E58, F31

Keywords: Sterilized FX intervention, Exchange rate uncertainty, policy discontinuity, incremental effect of intervention, Regression Discontinuity Design

*Banco de la República de Colombia, e-mail: hvargahe@banrep.gov.co

†Banco de la República de Colombia, e-mail: mvillavi@banrep.gov.co

La efectividad de la intervención cambiaria y la influencia de la incertidumbre sobre la tasa de cambio

Hernando Vargas-Herrera

Mauricio Villamizar-Villegas

Las opiniones contenidas en el presente documento son responsabilidad exclusiva de los autores y no comprometen al Banco de la República ni a su Junta Directiva

Abstract

En este trabajo examinamos la influencia de la incertidumbre sobre la tasa de cambio futura en la efectividad de la intervención cambiaria. Nuestra contribución consta de dos partes. Primero, desarrollamos un modelo teórico de equilibrio parcial para ilustrar cómo la efectividad cambiaria aumenta a medida que aumenta la incertidumbre sobre la tasa de cambio futura o de sus determinantes. Segundo, presentamos evidencia empírica de esta relación haciendo uso del esquema de intervención cambiaria del Banco de la República, empleado durante el periodo 2002-2012, a través de opciones put de volatilidad. Nuestros resultados indican que, en presencia de alta incertidumbre en los fundamentales de la tasa de cambio, la efectividad de la intervención esterilizada aumenta en aproximadamente 1% y su duración se extiende hasta por dos semanas. Adicionalmente, encontramos que, en períodos de alta incertidumbre, la intervención reduce la volatilidad cambiaria hasta en un 7% adicional.

Clasificación JEL: C14, C31, E58, F31

Palabras Clave: Intervención cambiaria esterilizada, incertidumbre sobre la tasa de cambio futura, efecto incremental de la intervención cambiaria, regresión discontinua

1 Introduction

There is an ample body of empirical work on whether sterilized foreign exchange intervention (**SFXI**) is effective, i.e. whether a central bank has the ability to alter the level or volatility of the exchange rate. The verdict, however, is still out. In fact, recent empirical surveys such as Fatum and Hutchison (2003), Menkhoff (2013), Villamizar-Villegas and Perez-Reyna (2015), and Arango et al. (2019), show that nearly half of studies find non-significant results.¹ Of the remaining half, most find that the effects are small and short-lived (of less than a month). Nonetheless, SFXI remains a widely accepted policy tool used today by many central banks of emerging and developed economies alike (Neely, 2005).

This lack of consensus might well be due to the fact that isolating the effect of SFXI is empirically difficult and that many studies in the field are plagued with identification problems.² In addition, previous studies have overlooked the influence of uncertainty about the future path of the exchange rate or its fundamentals when evaluating the effectiveness of SFXI. This is an important factor, and one which lies at the heart of our investigation. It provides a bridge with a related strand of literature that highlights the importance of heterogeneity in expectations and exchange rate determination (Ito, 1990). For some authors, “little else matters” (Woodford and Walsh, 2005).

In this paper we evaluate the incremental effect of SFXI brought forth by uncertainty in the future path of the exchange rate. In this context, the concept of uncertainty (or *flimsiness*) is understood as the variance of investors’ distribution of the future exchange, which in turn is related to the variance of exchange rate fundamentals. To the best of our knowledge, there is no other study that analyzes how uncertainty affects the strength of investors’ responses to central bank actions, especially when dealing with foreign exchange interventions.

Our contribution is two-fold. We first posit a partial equilibrium model with frictions in the FX market to illustrate the degree in which SFXI effectiveness is related to the uncertainty of market participants on the future exchange rate. When uncertainty is low, SFXI is less

¹Pioneer surveys include Dornbusch (1980), Dominguez and Frankel (1993), and Edison (1993).

²Some empirical challenges include: (i) measurement error: official SFXI data is scarce and many studies proxy intervention with the use of changes in international reserves, even at the risk of capturing additional confounding factors, such as valuation effects; (ii) omitted variable bias: it is intrinsically challenging to pinpoint the relevant information that monetary authorities used when setting their policy decisions; and (iii) simultaneity bias: a researcher has to overcome the fact that central banks respond to economic conditions and concurrently, the economy responds to central bank actions.

effective, for agents are willing to “bet more money” against the central bank, if it runs against the expected exchange rate or its fundamentals. In contrast, if uncertainty is high, SFXI will face a weaker countervailing force from speculators and arbitragers. In this case, there is less certainty about the inconsistency between SFXI and exchange rate fundamentals, and, consequently, less money is “bet against” intervention.

In our model we assume that while the uncovered interest rate parity (UIP) fails, the covered interest rate parity (CIP) holds. These two assumptions have important implications for the model’s inner workings. Namely, the failure of the UIP condition guarantees that SFXI will have an effect on the exchange rate. However, given that the CPI holds, the forward market allows risk averse investors to place bets on the currency. Uncertainty on the future exchange rate or its fundamentals influences the size of those bets and, consequently, the effectiveness of SFXI.

Second, we present empirical evidence based on a discontinuous regression model that provides a clear-cut identification strategy within a quasi-experimental framework. Our empirical contribution is thus to extend the standard Regression Discontinuity Design (RDD) setting to allow for an incremental effect of policy, by including an interaction term between exchange rate intervention and a measure of *flimsiness*, embedded in a localized non-parametric analysis. Intuitively, using a deterministic intervention policy rule put in place by the Central Bank of Colombia during 2002-2012, we compare episodes in which the intervention rule was barely missed with episodes in which it was barely triggered.

The empirical paper closest to ours is Kuersteiner et al. (2018), who paved the way for non-linear response functions to be applied in a RDD time series environment. Similar to Kuersteiner et al. we employ high frequency central bank data to test for the effects on the exchange rate. In contrast, our empirical contribution centers on the inclusion of the incremental effect of policy given a state variable, in a RDD setting. In other words, we evaluate whether intervention effectiveness is magnified in periods of foreign exchange uncertainty.

Our results indicate that market uncertainty increases depreciation of domestic currency in approximately 1% following central bank purchases of foreign currency and extends its duration in up to 2 weeks.³ This result holds under different measures of *flimsiness* such as exchange rate volatility, dispersion of exchange rate forecasts by market participants, and the

³The exchange rate is expressed as units of domestic currency per unit of foreign currency (COP/USD). We refer to exchange rate depreciation when the COP loses value, or equivalently when COP/USD increases.

volatility of exchange rate fundamentals (yield spread, VIX, oil price volatility, among others). Additionally, these *flimsiness* variables have an incremental effect on SFXI in stemming exchange rate volatility in up to 7%.

Our paper proceeds as follows. Section 2 presents our theoretical partial equilibrium model in which we show that *flimsier* expectations of the future exchange rate augment the effectiveness of SFXI. Section 3 describes the data and the Regression Discontinuity Design framework that forms the basis of our empirical exercise. Section 4 displays our results and Section 5 concludes.

2 A model of SFXI and the *flimsiness* of exchange rate expectations

The following model illustrates how exchange rate uncertainty (*flimsiness*) increases the effectiveness of sterilized foreign exchange intervention (SFXI). For simplicity, we consider a very short time period in which macroeconomic aggregates like foreign and domestic income and price levels are taken as given. Foreign and local interest rates are assumed to be constant as well. In the model, there are two types of non-financially constrained agents: (i) A group of risk-averse “speculators” who bet on the future appreciation or depreciation of local currency using the forward market, and (ii) private banks who arbitrage interest rate differentials (also using the forward market), but with no open net FX positions. This assumption is motivated by how banks in the Colombian FX market operate. Namely, any shift in banks’ forward position is generally matched by an opposite shift in their spot position.

2.1 The FX market

We consider a “net supply” of foreign exchange that has two components. A first component NX , depends positively on the real exchange rate defined (in logs) as $(p^* + e - p)$, where p and p^* denote domestic and foreign price levels, respectively, and e is the price of the foreign currency in domestic units. In the short run, both foreign and domestic price levels are assumed to be constant, so that this component of the FX “net supply” depends positively on the nominal exchange rate, $NX = NX(e)$, $\frac{dNX(e)}{de} > 0$. The second component, K , is exogenous and does not depend on the exchange rate. It may be thought to include the

autonomous and income-dependent parts of the current account balance and those net capital flows that do not respond to the exchange rate. Thus, the FX “net supply” is given by:

$$NX(e) + K. \tag{1}$$

We assume that the uncovered interest rate parity (UIP) does not hold, thereby rendering SFXI effective (by construction) in the model. However, the covered interest rate parity (CIP) does hold and is presented as follows:

$$f = \frac{e(1+i)}{(1+i^*)}, \tag{2}$$

where f denotes the forward FX price, and i and i^* correspond to domestic and foreign nominal interest rates. In particular, banks are the counterpart of the speculators and, therefore, any net forward purchases by the speculators produce net spot purchases by banks in the same amount.

2.2 The speculators problem

The speculators, much like the “off-shore” agents in the Colombian FX market, choose the amount of forward net sales, F , aimed at maximizing the expected utility of their profits in the future, $F(f - e_1)$, where e_1 is the future spot exchange rate. The speculators face uncertainty on the latter and, consequently, on the future return of their bet. f is known (taken as given from the market), but e_1 is not. More specifically, e_1 is assumed to have a normal distribution, so that:

$$f - e_1 \sim N(f - E[e_1], \sigma_{e_1}^2). \tag{3}$$

As such, the “representative speculator’s” problem can be exemplified as follows:

$$\max_F E[U(F(f - e_1))]. \tag{4}$$

By assuming a CARA utility function, $U = -exp^{\lambda w}$, and using the normality assumption in equation (3), the above problem may be stated as a mean-variance optimization model. Notice that $F(f - e_1) \sim N(F(f - E[e_1]), F^2\sigma_{e_1}^2)$. Hence, the optimization problem may be

expressed as:

$$\max_F F(f - E[e_1]) - \frac{\lambda}{2} F^2 \sigma_{e_1}^2 \quad (5)$$

and the first order condition of this problem implies:

$$F = \frac{f - E[e_1]}{\lambda \sigma_{e_1}^2}. \quad (6)$$

Notice that the magnitude of the speculators' net forward sales, $|F|$, depends negatively on the variance of the speculators' distribution of the future exchange rate, $\sigma_{e_1}^2$, and the degree of risk aversion, λ . That is, the greater the uncertainty on the future exchange rate, the lower the magnitude of net forward sales or purchases of the risk-averse speculators.

2.3 Equilibrium

Equilibrium in the spot market requires that:

$$NX(e) + K = -F. \quad (7)$$

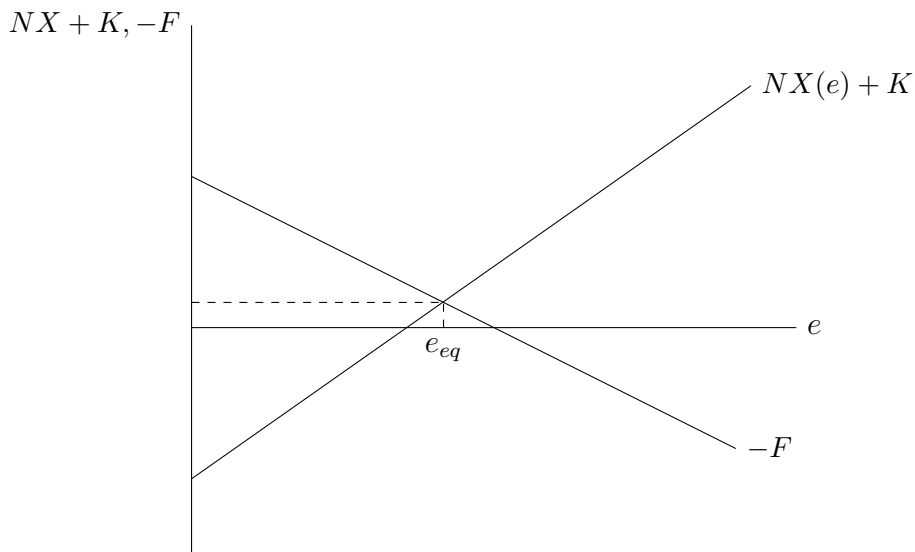
Recall that F are the speculators' amount of net forward sales. Thus, $-F$ are their net forward purchases. The latter produce net spot purchases of the same amount by arbitragers, as explained above. Thus, the LHS and RHS of equation (7) may be interpreted as the spot FX net supply and demand, respectively. The nominal exchange rate, e , adjusts to clear the spot FX market. Based on the types of agents assumed, this model could be considered a simplified characterization of the Colombian FX market in the short run.

The equilibrium level of the spot exchange rate, e , is obtained by substituting (2) and (6) into the equilibrium condition (7):

$$NX(e) + K = \frac{E[e_1]}{\lambda \sigma_{e_1}^2} - \frac{e(1+i)}{\lambda \sigma_{e_1}^2 (1+i^*)} \quad (8)$$

where the LHS of equation (8) depends positively on e , while the RHS depends negatively on e . Graphically, Figure 1 depicts the short term equilibrium in the FX market, where movements along the x-axis (away from the origin), denote a depreciation in domestic currency:

Figure 1: Short term equilibrium in the FX market



2.4 Central bank SFXI effectiveness

We next evaluate the effect of exchange rate uncertainty ($\sigma_{e_1}^2$) on the effectiveness of sterilized sales of foreign currency. Note that SFXI can be expressed as a change in the autonomous component of the FX net supply (i.e. a change in the term K of equation (1), positive for sales of foreign currency). We proceed by differentiating the equilibrium condition of equation (8) as follows:

$$NX_e de + dK = -\frac{(1+i)}{(1+i^*)\lambda\sigma_{e_1}^2} de. \quad (9)$$

Here, $NX_e \equiv \frac{dNX}{de}$ and dK denotes SFXI. Equation (9) then implies that:

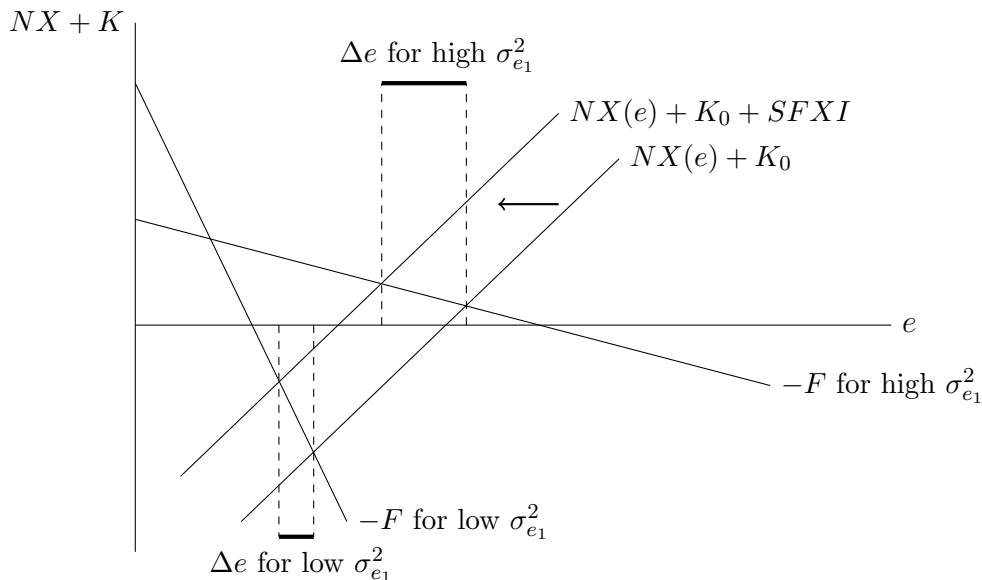
$$\frac{de}{dK} = -\left[NX_e + \frac{(1+i)}{(1+i^*)\lambda\sigma_{e_1}^2} \right]^{-1} < 0 \quad (10)$$

$$\frac{d^2e}{dK d\sigma_{e_1}^2} = -\left[NX_e + \frac{(1+i)}{(1+i^*)\lambda\sigma_{e_1}^2} \right]^{-2} \frac{(1+i)}{(1+i^*)\lambda(\sigma_{e_1}^2)^2} < 0 \quad (11)$$

Equation (10) measures the response of the equilibrium nominal exchange rate to the

increased supply of FX by the central bank. Notice that the currency appreciates, even though the domestic interest rate is kept unchanged (the FX intervention is sterilized). Hence, SFXI is effective. Equation (11) shows that the response of the exchange rate to SFXI increases in magnitude with the variance of the investors' distribution of the future exchange rate. The greater this variance, the larger the reduction of the exchange rate (the more effective is the SFXI). Figure 2 shows this graphically:

Figure 2: FX intervention effectiveness associated with exchange rate variance



Intuitively, a high value of $\sigma_{e_1}^2$ implies that small movements in F significantly shift the “marginal cost” of risk for speculators. Consequently, F does not react strongly to changes in the marginal benefit, $f - E[e_1]$. Thus, the speculators’ offsetting response to SFXI is weak and the latter becomes more effective. For example, if the central bank sells FX in the market, it will produce an appreciation of domestic currency ($\downarrow e$). Given the interest rate differential, by arbitrage this will reduce the forward exchange rate ($\downarrow f$), resulting in lower expected returns to forward sales $\downarrow (f - E[e_1])$ and reduced net forward sales by the speculators. However, the size of this response will be smaller, the greater the variance $\sigma_{e_1}^2$, since any drop in F will significantly decrease risk. Ultimately, the reduction in the speculators’ net forward sales is substantially lower than the central bank FX sales, thereby increasing SFXI effectiveness.⁴

⁴Importantly, the foregoing results assume that the SFXI does not change the speculators’ distribution of the future exchange rate.

In sum, the *flimsier* the expectations of the future exchange rate (the higher $\sigma_{e_1}^2$), the more effective is SFXI. If the speculators' distribution of the future exchange rate is related to the distribution of its fundamentals, then the *flimsiness* of fundamentals will have an impact on SFXI effectiveness. In our empirical analysis, the time-varying exchange rate variance (and that of its fundamentals) are used as a proxy for market uncertainty.

A possible implication of this result is that SFXI may affect not only the level, but also the volatility of the exchange rate in the presence of *flimsier* expectations. In the case of the SFXI that will be evaluated in Section 4, intervention leans against appreciation movements of the currency. Thus, while effective, it will affect not only the mean, but also the observed variance (since only the appreciation shocks will trigger intervention). Therefore, the size of exchange rate effects will increase monotonically with *flimsier* fundamentals. We empirically test for this below.

3 Empirical Evidence

3.1 Data

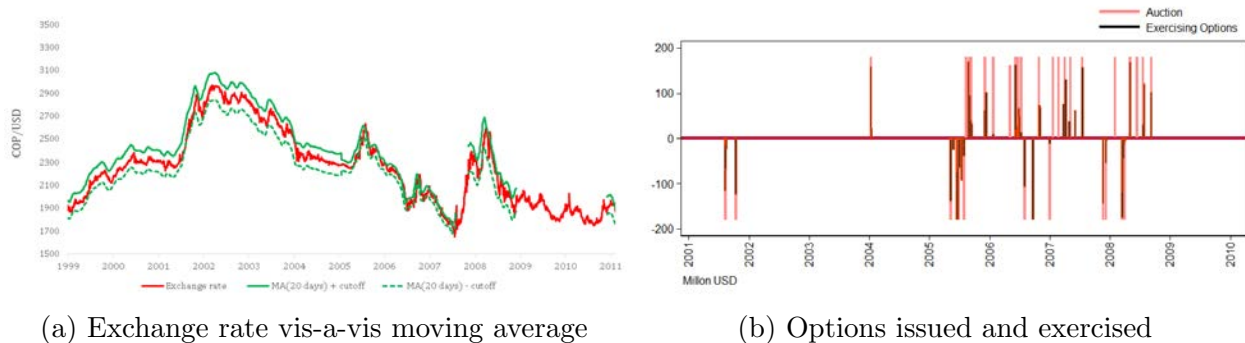
The empirical application focuses on the rule-based FX options put in place by the CBoC during 2002-2012, aimed at stemming exchange rate volatility. In brief, the central bank issued FX options whenever the exchange rate vis-à-vis its last 20-day moving average exceeded an established cutoff value, generally set at $\pm 4\%$ (-4% for puts and $+4\%$ for calls), as seen in Figure 3a.⁵ The mechanism was temporarily suspended during June 26, 2008 to October 6, 2008 and during October 28, 2009 to October 30, 2011. It was permanently stopped on February 6, 2012.

During the sample period, the rule was triggered 231 times. If options from a previous auction were outstanding, then market participants could exercise existing options. If no options were outstanding, then the rule triggered a new auction. As seen in Figure 3b, 38 auctions were triggered by these 231 events, and options were exercised in 75 cases. Purchases (sales) through put (call) options totaled USD \$2.4 billion (USD \$2.3 billion). Daily average values of exercised call option (USD \$68.5 million) were only slightly higher than for average

⁵The cutoff was temporarily modified to $\pm 2\%$ from December 19, 2005 to June 24, 2008 and to $\pm 5\%$ from October 7, 2008 to October 27, 2009.

put options (USD \$57.9 million).

Figure 3: COP-USD exchange rate and rule-based mechanism



As seen in Figure A1 of Appendix A, our measures of *flimsiness* correspond to the monthly volatilities of the: (a) COP/USD exchange rate, (b) overnight yield spread (Colombia-USA), (c) VIX, (d) implicit oil price (Brent) “*IVOLCRUD*”, (e) *MOVE* index which captures expected risks in US Treasury yields, and (f) Emerging market risk index “*MXE-FOCXO*”.

These measures are computed from daily frequency data, so that monthly volatilities ($Flim_t$) vary from day-to-day, $Flim_t = \frac{1}{20} \sum_{j=1}^{20} (Z_{t+1-j} - \bar{Z})^2$, where Z denotes the original daily measure and $\bar{Z} = \frac{1}{20} \sum_{j=1}^{20} Z_{t+1-j}$.

Additionally, as a robustness check we use another measure of *flimsiness* from survey data, namely the dispersion of 1-month-ahead exchange rate forecasts by market participants of the financial sector, constructed from the central bank’s Expectations Survey and dating from 2003 to 2012 (see Figure A2 of Appendix A). Data sources and further description are found in Table 3 of Appendix B.

3.2 Regression Discontinuity Framework

We next evaluate the degree in which uncertainty about the future path of the exchange rate or its fundamentals can either magnify or lessen the effectiveness of SFXI. This is done by extending the methodology in Kuersteiner et al. (2018), who study the effects of the same rule-based mechanism (described in the previous sub-section), within a localized approach.

The authors compare episodes in which the intervention rule was barely missed with episodes in which it was barely triggered. Hence, exchange rate variation within the vicinity of the triggering threshold is as good as randomly assigned and hence forms the basis for identifying causal effects.

More formally, the assignment of treatment, D_t , is completely determined by a cutoff-rule based on an observable (and continuous) running variable, X_t , as follows:

$$D_t = \mathbf{1}\{X_t \geq x_0\} \quad (12)$$

where $\mathbf{1}$ denotes an indicator function and x_0 is the threshold above which treatment is granted. For the case of Colombia, the central bank issued foreign exchange options (D_t) whenever the exchange rate vis-à-vis its last 20-day moving average (X_t) exceeded a given threshold (x_0). The discontinuity arises because no matter how close X_t gets to the cutoff value from above or below, the treatment, or lack of treatment, is unchanged until it crosses the cutoff point. Intuitively, the rule creates a natural experiment when in close vicinity of x_0 . Any endogenous relationship is eliminated by the fact that small variations in the running variable generate a discontinuous jump in the treatment status. If treatment has an effect, then it should be measured by comparing the conditional mean of an outcome variable at the limit on either side of the discontinuity point.

For example, suppose we are interested in the effects of a binary treatment (D_t) in the following linear model:

$$y_t = \alpha + \beta D_t + \epsilon_t \quad (13)$$

In a Regression Discontinuity Design (RDD) framework, any potential bias, defined as $[E(\epsilon_t|D_t = 1) - E(\epsilon_t|D_t = 0)]$, is locally washed out, as follows:

$$\begin{aligned} & \lim_{\gamma \downarrow 0} E(Y_t|X_t = x_0 + \gamma) - \lim_{\gamma \uparrow 0} E(Y_t|X_t = x_0 + \gamma) \\ &= \left(\alpha + \beta + \lim_{\gamma \downarrow 0} E[\epsilon_t|X_t = x_0 + \gamma] \right) - \left(\alpha + \lim_{\gamma \uparrow 0} E[\epsilon_t|X_t = x_0 + \gamma] \right) \\ &= \beta. \end{aligned} \quad (14)$$

That is, the causal effect of policy β is identified since the two conditional means of the error term (with and without treatment) cancel out in the limit, when $X_t = x_0$.

Our empirical contribution is thus to extend the RDD exercise in Kuersteiner et al. (2018) to allow for an incremental effect of policy, by including an interaction term between exchange rate intervention and a measure of *flimsiness*. As such, we follow Jordà (2005) method of local projections to estimate the following model:

$$\arg \min_{\theta} \sum_{j=1}^J \sum_{t=2}^{T-j} (y_{t+j} - a_j - \theta_j D_t - b_j (X_t - x_0) - \tau_j D_t (X_t - x_0) - \psi_j Flim_t - \delta_j D_t Flim_t)^2 K \left(\frac{X_t - x_0}{h} \right) \quad (15)$$

where $\delta = (\delta_1, \delta_2, \delta_3, \dots, \delta_J)'$ accounts for the incremental impact of the *flimsy* variable, j periods after treatment, and $K(\cdot)$ is a triangular kernel with optimal bandwidth h , as described in Imbens and Kalyanaraman (2012). The inclusion of the term $\tau_j D_t (X_t - x_0)$ allows for different specifications of how the running variable affects the outcome, at either side of the cutoff point.

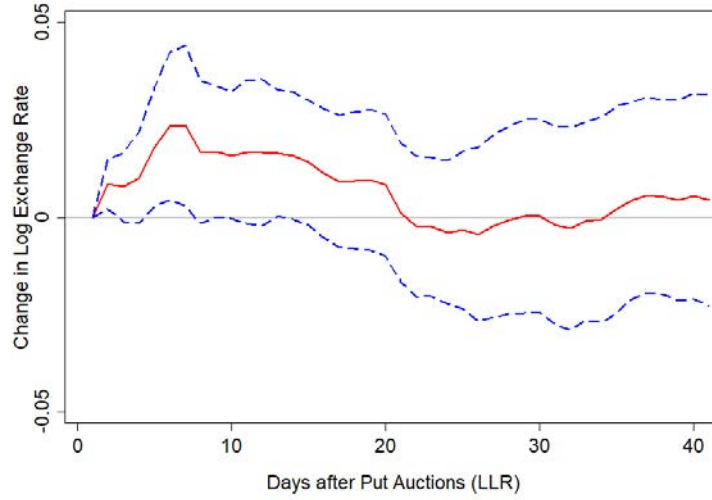
4 Empirical Results

In this section we present the estimated Impulse Response Functions (IRFs) for the incremental effect of the different *flimsy* measures. These figures plot the vector δ of equation (15) across the different time horizons: $j = 1 - 40$ working days. For ease in comparability, all *flimsy* measures are standardized, i.e. so that the impulse shock corresponds to one standard deviation ($Flim_t/\sigma$). Finally, we center our investigation on the effects of put options since, as noted in Kuersteiner et al. (2018), call options sometimes coincided with other methods of SFXI, in some cases offsetting purchases with sales of foreign currency.

4.1 Effectiveness on exchange rate (levels)

As a benchmark case, Figure 4 plots the estimates of an initial model without *flimsiness* which, as expected, match the findings in Kuersteiner et al. (2018). Namely, the peso depreciates (i.e. values in the COP/USD exchange rate increase) in up to 2% during the first week after the auction of put options by the central bank, before the effects subside. This result is similar to those documented in Chamon et al. (2019) for Latin American countries.

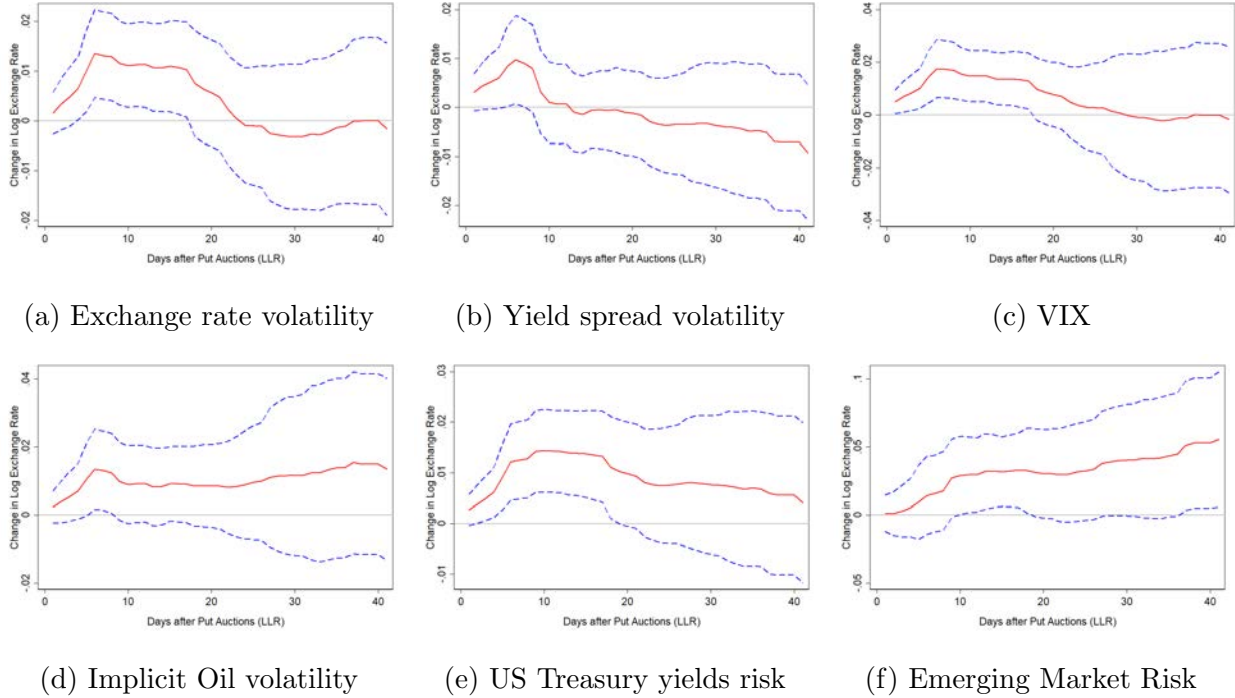
Figure 4: Benchmark case: effects of put options on COP/USD exchange rate



We now turn our attention to the *flimsiness* relating to the exchange rate and its fundamentals. Figure 5a shows that exchange rate volatility magnifies the effect of the intervention by about 1% and during a period of 3 weeks (20 working days). Figure 5b also shows that the effects of SFXI increases by 1% in periods of high yield spread volatility, although in this case the duration of the effects remain significant only during the first week. In turn, high values of the VIX index (5c) augment the effect of intervention by almost 2% and during a period of 3 weeks.

The remaining *flimsy* variables show similar results. High values of implicit oil price volatility (Figure 5d) increase intervention by 1% during the second week. Volatility in US Treasury yields captured by the *MOVE* Index (Figure 5e) augment the effect of intervention by 1.5% and during a period of 3 weeks. Finally, high values of the emerging market risk index (Figure 5f) amplifies intervention effects in close to 2% during the second and third week.

Figure 5: Incremental effects of *Flimsiness* on COP/USD exchange rate



4.2 Effects using survey data

Results are checked under a different view of exchange rate uncertainty. That is, when the uncertainty about the future exchange rate is measured as the dispersion (variance) of expectations among surveyed market participants. Intuitively, high values of this *flimsy* variable indicate greater disagreement about the future exchange rate.⁶

Figure 6 shows the scatter plot and fitted values between this new measure (variance of surveyed responses when asked about the 1-month-ahead exchange rate forecast) and the monthly exchange rate volatility. For expositional purposes, variables are winsorized at the 1% and 99% level. As shown in Figure 6, there is a strong and positive correlation between the two measures.

⁶The relationship between forecast disagreement (dispersion in expectations) and the variance of forthcoming aggregate shocks (market volatility) is made explicit in Lahiri and Sheng (2010).

Figure 6: Scatter plot for exchange rate volatility and dispersion in exchange rate expectations

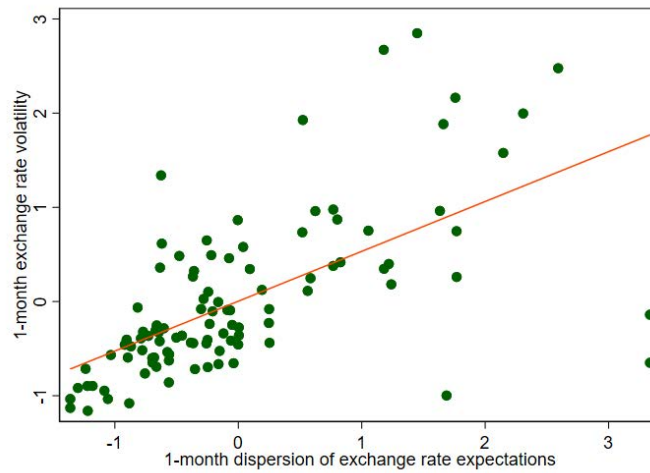
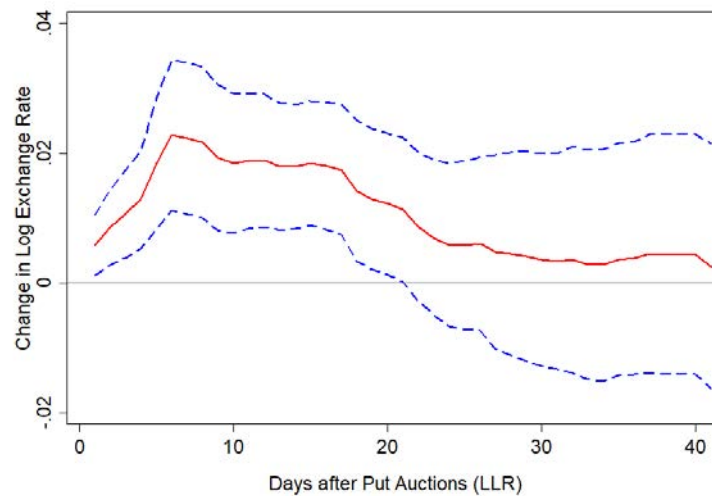


Figure 7 now shows the incremental effect of SFXI, when disagreement among market participants increases, regarding the future stance of the exchange rate. The figure shows a significant incremental effect, similar but larger to that of Figure 5a. In fact, the effect of intervention now increases by up to 2% and the effects last for approximately 3 weeks.

Figure 7: IRFs for 1-month dispersion in agent's FX forecasts



4.2.1 Effectiveness on exchange rate Volatility

We finally evaluate the impact of *flimsy* fundamentals on the effectiveness of SFXI in curbing exchange rate volatility. Namely, in Section 2 we postulated that in the case of the put options used in Colombia, SFXI leans against appreciation movements of the currency. Thus, while effective, it would affect not only the mean of the exchange rate, but also its observed variance. We test for this by evaluating the incremental effect of the different *flimsy* measures on the running variable that triggered interventions in Table 1, and on exchange volatility in Table 2, measured as the square of the running variable.

Recall that the running variable is defined as the exchange rate vis-à-vis its last 20-day moving average (see Figure 3). Auctions of put options were triggered whenever this variable was less than or equal to an established threshold. As such, put options intended to revert an appreciating exchange rate back to its monthly average. Table 1 shows that this was exactly the case, where *flimsy* variables increase the depreciation of domestic currency by a range of 0-2.5%, the strongest exhibited when in moments of high disagreement in exchange rate expectations among surveyed market participants (“FX Dispersion”). In turn, Table 2 shows that FX volatility was significantly reduced by all *flimsy* variables, by a range of 0-6.9%, where again “FX Dispersion” showed the greatest impact.

Table 1: Effects on Running Variable: exchange rate vis-a-vis its 20-day moving average

	3 Days	6 Days	9 Days	12 Days	15 Days	18 Days	21 Days
FX Vol	0.0044 (0.0038)	0.016*** (0.0039)	0.010** (0.0042)	0.0086** (0.0035)	0.0083* (0.0043)	0.0049 (0.0046)	-0.0021 (0.0039)
FX Dispersion	0.013*** (0.0039)	0.025*** (0.0056)	0.017*** (0.0051)	0.013*** (0.0033)	0.014*** (0.0035)	0.0074* (0.0038)	0.00051 (0.0037)
Yield Spread Vol	0.0065* (0.0033)	0.011** (0.0048)	0.0063 (0.0040)	-0.00085 (0.0034)	0.0050* (0.0030)	0.0038 (0.0034)	0.00097 (0.0022)
VIX	0.0100** (0.0041)	0.018*** (0.0054)	0.014*** (0.0044)	0.0095*** (0.0033)	0.011*** (0.0037)	0.0051 (0.0036)	-0.00097 (0.0040)
Implicit Oil Vol	0.0047 (0.0044)	0.015** (0.0066)	0.0083 (0.0050)	0.0069 (0.0042)	0.0092*** (0.0032)	0.0055* (0.0032)	0.0024 (0.0036)
US Treasuries Vol	0.0057** (0.0025)	0.012*** (0.0038)	0.011*** (0.0035)	0.010*** (0.0031)	0.0061** (0.0031)	0.0022 (0.0033)	-0.0033 (0.0033)
EM Risk	0.0045 (0.011)	0.015 (0.016)	0.014 (0.013)	0.017 (0.013)	0.0065 (0.0083)	0.0088 (0.012)	-0.0033 (0.0076)

The sample includes all days from December 24, 2001 to February 3, 2012. Each listed coefficient results from a separate regression discontinuity model implemented using local linear regression on daily data with optimal bandwidth from Imbens and Kalyanaraman (2012), as shown in equation (15). Columns denote outcomes j days since the intervention. Heteroskedasticity-robust standard errors are in parentheses. ***, **, and * denotes statistical significance at the 1, 5, and 10 percent level respectively.

Table 2: Effects on Exchange rate Volatility: Square of the Running Variable

	3 Days	6 Days	9 Days	12 Days	15 Days	18 Days	21 Days
FX Vol	-0.027 (0.019)	-0.042* (0.025)	-0.037** (0.015)	-0.039*** (0.013)	-0.021** (0.0092)	-0.021 (0.028)	0.059*** (0.017)
FX Dispersion	-0.041* (0.021)	-0.058** (0.029)	-0.046** (0.020)	-0.069*** (0.021)	-0.024* (0.013)	-0.034 (0.021)	0.025* (0.014)
Yield Spread Vol	-0.020 (0.020)	-0.030 (0.025)	-0.024 (0.015)	-0.041* (0.021)	0.0018 (0.0069)	-0.012 (0.021)	0.046*** (0.0098)
VIX	-0.021 (0.023)	-0.021 (0.016)	-0.029* (0.016)	-0.042*** (0.013)	-0.023** (0.011)	-0.024* (0.014)	0.029* (0.015)
Implicit Oil Vol	-0.0072 (0.020)	-0.010 (0.022)	-0.030* (0.017)	-0.026* (0.016)	-0.019** (0.0093)	-0.0058 (0.012)	0.024 (0.016)
US Treasuries Vol	-0.026* (0.013)	-0.00051 (0.018)	-0.0064 (0.017)	0.011 (0.025)	-0.021* (0.011)	-0.0090 (0.014)	0.0063 (0.012)
EM Risk	-0.048 (0.051)	0.16 (0.12)	0.075 (0.058)	0.13 (0.095)	-0.014 (0.018)	0.066 (0.10)	-0.058* (0.033)

The sample includes all days from December 24, 2001 to February 3, 2012. Each listed coefficient results from a separate regression discontinuity model implemented using local linear regression on daily data with optimal bandwidth from Imbens and Kalyanaraman (2012), as shown in equation (15). Columns denote outcomes j days since the intervention. Heteroskedasticity-robust standard errors are in parentheses. ***, **, and * denotes statistical significance at the 1, 5, and 10 percent level respectively.

5 Conclusion

In this paper we evaluate the incremental effect of sterilized foreign exchange intervention associated with the degree of uncertainty regarding the future path of the exchange rate. We first posit a partial equilibrium model with frictions to illustrate how the variance of the exchange rate (and that of its fundamentals) increases the intervention effect. Second, we present supporting empirical evidence based on a sharp policy discontinuity in the way the Central Bank of Colombia intervened in the foreign exchange market.

Our results indicate that market uncertainty increases depreciation of domestic currency in approximately 1% following central bank purchases of foreign currency and extends its duration in up to 2 weeks. Additionally, these purchases have an incremental effect in stemming exchange rate volatility in up to 7%. We believe that these results will help shed light on the ongoing debate about whether sterilized foreign exchange intervention is effective. More precisely, we contribute to the literature in evaluating the influence of market uncertainty on the effectiveness of foreign exchange intervention.

6 Bibliography

- ARANGO, L., J. E. GOMEZ-GONZALEZ, D. RODRIGUEZ, AND M. VILLAMIZAR-VILLEGAS (2019): “Meta-Analysis of Sterilized FX Interventions,” Borradores de economía, Mimeo.
- CHAMON, M., D. HOFMAN, N. MAGUD, AND A. WERNER (2019): “Front Matter,” .
- DOMINGUEZ, K. M. AND J. A. FRANKEL (1993): “Does Foreign-Exchange Intervention Matter? The Portfolio Effect,” *American Economic Review*, 83, 1356–69.
- DORNBUSCH, R. (1980): “Exchange Rate Economics: Where Do We Stand?” *Brookings Papers on Economic Activity*, 11, 143–206.
- EDISON, H. (1993): “The Effectiveness of Central-Bank Intervention: A Survey of the Literature after 1982,” Princeton Studies in International Economics, International Economics Section, Departement of Economics Princeton University, 18, International Economics Section, Departement of Economics Princeton University,.
- FATUM, R. AND M. M. HUTCHISON (2003): “Is sterilised foreign exchange intervention effective after all? an event study approach,” *Economic Journal*, 113, 390–411.
- ITO, T. (1990): “Foreign Exchange Rate Expectations: Micro Survey Data,” *The American Economic Review*, 80, 434–449.
- JORDÀ, O. (2005): “Estimation and Inference of Impulse Responses by Local Projections,” *American Economic Review*, 95, 161–182.
- KUERSTEINER, G. M., D. C. PHILLIPS, AND M. VILLAMIZAR-VILLEGAS (2018): “Effective sterilized foreign exchange intervention? Evidence from a rule-based policy,” *Journal of International Economics*, 113, 118–138.
- LAHIRI, K. AND X. SHENG (2010): “Measuring forecast uncertainty by disagreement: The missing link,” *Journal of Applied Econometrics*, 25, 514–538.
- MENKHOFF, L. (2013): “Foreign Exchange Intervention in Emerging Markets: A Survey of Empirical Studies,” *The World Economy*, 36, 1187–1208.
- NEELY, C. J. (2005): “An analysis of recent studies of the effect of foreign exchange intervention,” *Review*, 685–718.
- VILLAMIZAR-VILLEGAS, M. AND D. PEREZ-REYNA (2015): “A Theoretical Approach to Sterilized Foreign Exchange Intervention,” *Journal of Economic Surveys*, doi: 10.1111/joes.12136.
- WOODFORD, M. AND C. E. WALSH (2005): “Interest And Prices: Foundations Of A Theory Of Monetary Policy,” *Macroeconomic Dynamics*, 9, 462–468.

Appendix A Graphs

Figure A1: Standardized monthly volatility in exchange rate and fundamentals

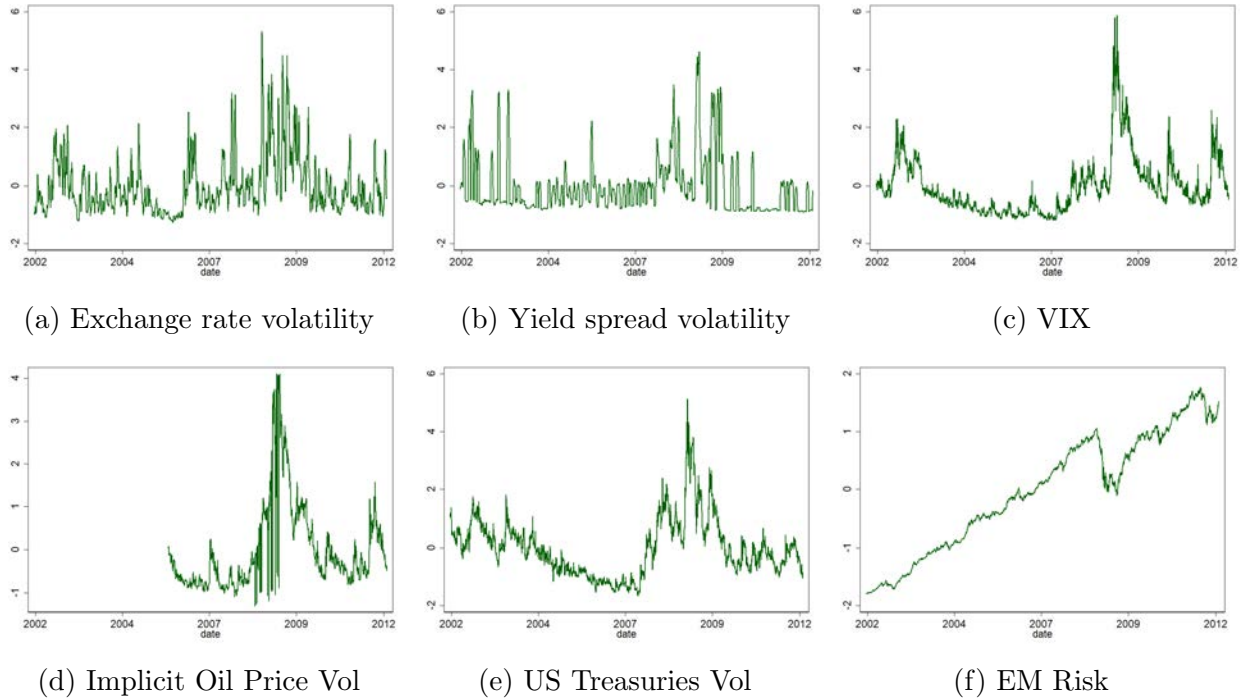
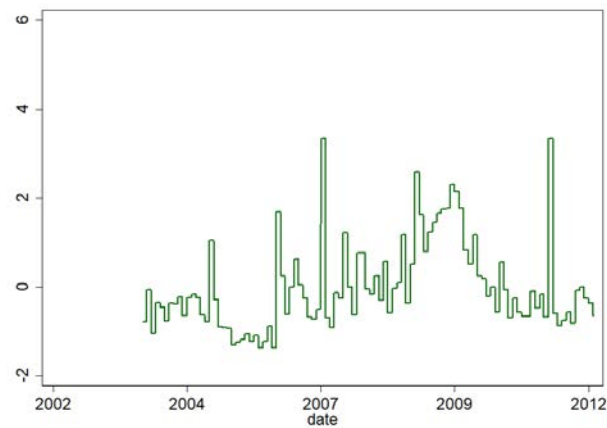


Figure A2: Standardized dispersion in survey data



(a) Dispersion of 1-month ahead exchange rate forecasts

Appendix B Data Description

Table 3: Descriptive Statistics: $\pm 20\%$ below or above threshold

Variable	Put miss		Put trigger	
	Mean	St.Dev	Mean	St.Dev
<i>Flimsy</i> Variables (Standardized)				
FX Vol	0.49	0.83	1.03	1.28
Overnight Yield Spread Vol ($i^{COL} - i^{US}$)	-0.11	0.88	0.80	1.49
VIX	-0.26	0.82	0.30	1.08
Implicit Oil Volatility ($IVOLCRUD$)	-0.15	0.88	0.30	1.36
US Treasury Vol ($MOVE$)	-0.38	1.03	0.67	1.43
Emerging Market Risk Index ($MXEFOCXO$)	0.42	0.70	0.43	0.37
Rule-Based FX Intervention				
Exchange rate (COP/USD)	2,083	235	2,074	188
Frequency of Put Options Triggered (%)	0	0	100	0
Frequency of Put Options Issued (%)	0	0	20	40
Frequency of Put Options Exercised (%)	0	0	38	49
Obs	2,433			

Authors' Calculations. Sample period corresponds to Dec 2001-Feb 2012. All variables are standardized as described in Section 3.1.

