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Hernán Rincón and Jorge Toro[**]

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Abstract

Capital controls and intervention in the foreign exchange market are two controversial policy options that many countries have adopted in the past in order to influence the exchange rate and moderate capital flows. Colombia has a long record in the use of these policies with mixed results and often non negligible costs. The objective of this paper is to evaluate for the case of Colombia the effectiveness of capital controls and central bank intervention for depreciating the exchange rate, reducing its volatility, and moderating the exchange rate vulnerability to external shocks. The paper uses high frequency data from 1993 to 2010, and a GARCH model of the peso/US dollar exchange rate return. The main findings indicate that neither capital controls nor central bank intervention used separately were successful for depreciating the exchange rate. On the contrary, they augmented its volatility. Nonetheless, when both policies were used simultaneously, a statistical significant effect was obtained by which the interaction of capital control and intervention in the foreign exchange market were effective to produce a daily average depreciation of the exchange rate, without increasing its volatility. This result however should be taken with caution given the special economic circumstances that characterized 2008, when most of this interaction happened.

JEL Classification: F31, F32, E58, C52.

Keywords: Capital controls (Tobin tax), central bank intervention, GARCH regression model of the exchange rate return, effectiveness.

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1. Introduction

The good performance of most emerging economies during the recent financial crisis and the beginning of recovery of the global economy, have revitalized international capital inflows to these economies. As a result, currencies in many emerging economies are again facing strong appreciation pressures. That phenomenon has been particularly acute in Colombia where the peso has appreciated by more than 11% during the first nine months of 2010. A similar trend -although not as severe- is also affecting other Latin American economies such as Brazil, Mexico, Chile and Peru, as well many Asian economies.

The impact that an excessive currency appreciation could have on the tradable sectors has increased demands on governments and central banks to adopt policies to reverse this trend. Problems related with a massive surge of capital inflows and strong appreciations are well known. They have to do with deterioration of current account balances, the formation of asset price bubbles, excessive foreign indebtedness and increasing financial fragility, that could put at risk the incipient economic recovery of these economies.

Facing this scenario, economic authorities confront the dilemma of imposing restrictions on capital mobility and intervening in the foreign exchange market (forex) -aware of the distortions that this may cause-, or sticking to policies of free capital movements and floating exchange rate that have been so successful in the past for consolidating inflation targeting regimes. In principle, introducing capital controls or relying on forex intervention to try to dampen an excessive exchange rate appreciation may be justified if the capital inflows that are behind it are perceived to be temporary.[1] That can be the case if it is assumed that developed economies should eventually start to raise interest rates to avoid inflationary pressures, once economic recovery has been achieved.

In this paper we focus our attention on the effectiveness of capital controls and forex intervention to attain its objective of moderating an exchange rate appreciation trend or even reverse it. Assessing effectiveness is crucial, taking into account that these policies could cause significant efficiency and economic costs. From an institutional point of view, intervention in the foreign exchange market may weaken the inflation targeting scheme, by introducing the exchange rate as a secondary target, which could compete with the inflation rate as a primary target. Moreover, sterilization entails well known quasi-fiscal cost that, depending on interest rate differentials, could become quite significant. Costs related with capital controls of the type analyzed in this paper, generally results from the distortions that this policy could create either by reducing competitiveness of the financial system, by becoming an obstacle for the development of domestic capital markets (as capital controls may discourage the development of domestic long-term financial instruments), or by reducing risk sharing between the local and international capital markets.

Colombia has a wide experience in the use of both capital controls and intervention in the foreign exchange market. In addition, there have been several efforts in the past for assessing the effectiveness of these policies with differing conclusions. Regarding intervention in the foreign

[1] Against this general principle, China and India have utilized capital controls despite that the conditions behind the appreciation pressure on their currencies are of a permanent character.

exchange market, it has been found that its effectiveness is at most short-lived and in many cases unable to modify the level of the exchange rate (Appendix A.1). Furthermore, it has been observed that in some instances, intervention increase exchange rate volatility. Regarding capital controls, the Colombian literature has found that in general they are able to reduce short-term flows and induce a shift from short-term to long-term capital inflows (Appendix A.2). It has also been shown that capital controls used as a macroeconomic policy tool could help to increase autonomy of monetary policy by relaxing to some extent the dilemmas inherent to the impossible trinity (Villar and Rincón, 2003).[2]

In this paper we undertake a new effort for assessing effectiveness of both capital controls and foreign exchange intervention for the case of Colombia, taking advantage of the abundant literature on this issue and the availability of a detailed data base. This evaluation will be made based on the capacity of these policies for depreciating the exchange rate, reducing its volatility, and moderating the exchange rate vulnerability to external shocks during the last two decades. The results of this analysis may shed light on the dilemmas that policymakers in Colombia and elsewhere are currently confronted due to renewed capital inflows and exchange rate appreciation.

This paper has seven sections including this introduction. The second offers a brief review of the Colombian experience with capital controls and forex intervention since the nineties. The third shows some preliminary statistics and empirical regularities of the Colombian nominal exchange rate (the peso/US dollar exchange rate) for the period under study. The fourth section presents the regression model and discusses its main characteristics. We use daily information for the entire period between 1993:01:04 and 2010:07:30 and a GARCH model of the peso/US dollar exchange rate return. The fifth section gives some methodological notes on the variables used in the regression model. The sixth presents the results of the estimations. Finally, the last section summarizes the conclusions and draws the main lessons from the Colombian experience with capital controls and forex intervention.

2. A review of the Colombian experience with capital controls and forex intervention since 1990s

2.1 *Capital controls* (*a price-based regulation*)

Colombian started the elimination of administrative controls on foreign borrowing in February 1992. The non-financial private sector was allowed to contract foreign loans for any purpose, provided they had a maturity longer than one year. However, by that time, the domestic financial system was not allowed to intermediate working-capital foreign loans. Shortly afterwards, in September 1993, most of administrative controls were lifted. Financial institutions were authorized to intermediate foreign loans and restrictions on loans maturity and final use of resources for domestic residents were eliminated. Nonetheless, as up to date, domestic financial institutions cannot have foreign liabilities except for foreign-exchange-denominated lending with equal or shorter maturity.

[2] Excellent reviews of the international literature on capital controls or forex intervention are Sarno and Taylor (2001), Bank for International Settlements (2005), Edwards (2007), and Ostry et al. (2010).

The liberalization of foreign lending in September 1993 was, however, accompanied by a compulsory non-remunerated reserve requirement on short term loans different from trade financing, which remained on place up to April 2000. This deposit had the effects of a tax (Tobin type of tax) on short term capital inflows. Thus, the new capital control adopted by the Colombian authorities in 1993 can be interpreted as a substitution of administrative controls for price-based regulations.

Initially, in September 1993, only foreign loans with a shorter term than 18-month maturity were required to make the non-remunerated deposit in the central bank. The amount of the deposit was equivalent to 47% of the foreign loan dollar-value and had to be kept during 12 months, or alternatively redeemed with a discount that reflected the opportunity cost of those resources. The reserve requirement was reduced to zero in April 2000, once the peso was let free to float; an inflation targeting regime for monetary policy was in place, the economy was recovering from the deepest recession in almost one century (GDP plunged -4.2% in 1999), and the economy was experiencing a rapid drop in international reserves and strong pressures towards a currency devaluation.[3] During 1993-2000 both the foreign borrowing period, the time the deposit had to be maintained at the central bank, and the percentage of the reserve requirement changed broadly, even, at some point of time short-run foreign indebtedness became prohibitive (Appendix A.3 summarizes the central bank legislation on the reserve requirement since 1993).

Years later, in May 2007, in a context where the country was facing a rapid currency appreciation and a surge in capital inflows, the central bank decided to activate capital controls by imposing a reserve requirement of 40% on both foreign borrowing and portfolio inflows of all maturities which had to be kept at the central bank during 6 months.[4] This reserve requirement was reduced to zero in October 2008 at the outset of the international financial crisis.

2.2 *Forex intervention*

Following the introduction of a floating exchange rate regime and the adoption of an inflation targeting scheme for monetary policy in 1999, the Colombian central bank put in place in November 1999 an option-based foreign exchange intervention mechanism aimed at accumulating foreign reserves and controlling the volatility of the exchange rate. Two years later, the central bank extended the option-intervention mechanism to also include reduction of foreign reserves, thus making the option mechanism fully symmetrical. Later on, in September 2004, facing an escalating appreciation of the currency, the central bank introduced direct and discretionary intervention operations, that were on place until May 2007.

The main characteristic of the option mechanism is its transparency and reliance on an auction system. The intervention is carried out in an open manner and with rules that are publicly known. Options for accumulating (put options) or decreasing (call options) international reserves give

[3] A comprehensive analysis of the Colombian economy for the 90s is presented by Villar and Rincon (2003).

[4] As a prudential measure, between December 2004 and June 2006, authorities reintroduced controls on portfolio inflows of nonresidents which required one year as a minimum investment period. Also, on July 2007, they put in place thresholds on bank's currency derivative positions.

the holder the right to sell (buy) foreign exchange to (from) the central bank. The amount of the options to be auctioned is set by the Board of Directors of the central bank at its own discretion. The options are valid between the first and the last working day of the month immediately following the day of the option. Options for controlling volatility of the exchange rate (put or call) can be held by the central bank the same day that the nominal exchange rate deviates 4% from its last 20 working day moving average. This condition also applies for the exercise of the option within the following month of the day of the auction. Since its introduction, the amount of the auction for volatility purpose was set by the Board of Directors at US$ 180 million, which has not been modified.

Discretionary interventions are not subject to any public known rule, but internally follow the directions set by the Board of Directors, which changes over time. These interventions are secret. Nonetheless, the amount of intervention is publicly disclosed the following month. For carrying out discretionary interventions, the central bank participates in the foreign exchange market as any other trader, secretly announcing its bids for buying (or rarely selling) foreign exchange.

By mid-2008, the central bank introduced preannounced interventions as yet another intervention modality. In this case, the central bank publicly announce in advance both the amount of the daily intervention in the foreign exchange market, as well as the period in which it intends to do so. The intervention amount was set at US$ 20 million daily and started in June 2008, but was interrupted in October of that year, at the outset of the international financial crisis. That type of intervention was again carried out between March and June 2010, by purchasing US$ 20 million daily, which allowed the central bank to accumulate US$ 1600 million of additional international reserves. On average preannounced interventions amounted to 1.7% of the daily size of the Colombian foreign exchange market. In September 2010, in the context of a mounting appreciation pressure, the central bank initiated a new round of preannounced interventions. The effectiveness of this type of intervention will be evaluated separately when estimating the model.

3. Empirical regularities of the Colombian nominal exchange rate and basic statistics[5]

We used daily information for the entire period between 1993:01:04 and 2010:07:30 on the nominal exchange rate of the Colombian peso with respect to the US dollar (E). Saturdays and Sundays, days on which there are no transactions in the foreign exchange market, were eliminated from the sample for both the exchange rate and the rest of the variables described below. The exchange rate value for holidays was kept constant and equal to that of the previous working day.[6] Once these adjustments were made, the total sample size reached 4584 observations (261 observations per year), which was the sample used in the calculations of the basic statistics and initial regressions.

The Colombian peso depreciated until 2003. With some interruptions this was followed by a

[5] The various tests that were implemented and the estimations were made using the 7.20 version of RATS. Any result that is discussed but not reported may be requested directly from the authors.

[6] In the preliminary estimations we also adjusted the sample for the holidays in the United States and Colombia, giving them the same treatment as weekends, and the results did not change.

sustained appreciation trend which by mid 2008 took the exchange rate to levels similar to those seen by the end of the nineties. Then a pronounced depreciation took place during the first six months of the international financial crises, but since March 2009 the appreciation trend restarted (Figure 1). From the point of view of the nature of the time series, a non-stationary behavior of the exchange rate seems to be solved with the first difference in the series. This is corroborated later on by using a unit root test.

The return, that is the daily percentage variation of the exchange rate, the squared return, and its absolute value show a variance (volatility) that changes over time but behaves in a similar way during particular periods of time, thus forming clusters: large/small shocks in the returns tend to be followed by large/small changes in the same variable (Figure 1). For example, the high volatility that was seen towards the end of the nineties and the beginning of the 2000 decade, as well as that observed at the end of 2008 and during 2009 are clear. These episodes coincided with periods of high international financial turbulence. In contrast, volatility is minimal or moderate in the mid-nineties and in the middle of the 2001-2010 decade.

Finally, it is interesting to note that the periods of greater volatility coincide with the periods of devaluation/appreciation thus creating a U-shaped relationship.[7] Also the functions of autocorrelation and partial autocorrelation of the returns, the squared returns, and returns in absolute value have a hyperbolic drop instead of an exponential one which would indicate a high persistence in volatility (they are not shown here). In other words, the volatility of the returns behaves like a long memory process, as it is stated by Terasvirta (2008), something that could not be completely corroborated by the "short-range dependence" or "short memory" test in the version modified by Lo (1991).[8]

The descriptive statistics of the daily return show different facts to highlight (Table 1). In the first place, the mean of the variable is positive, which indicates a tendency towards peso devaluation in the last eighteen years. Furthermore its size rises with the control on capital flows and foreign exchange intervention by the central bank. This means both types of policies would increase the devaluation of the peso. However, this would be done at the cost of an increase in exchange rate volatility as shown by the behavior of the variance: a rise from 0.31 for the total of the sample to 0.61 in the period in which both capital controls and foreign exchange intervention were present. This suggests that intervention policies might have generated a trade-off between devaluation and volatility of the local currency.

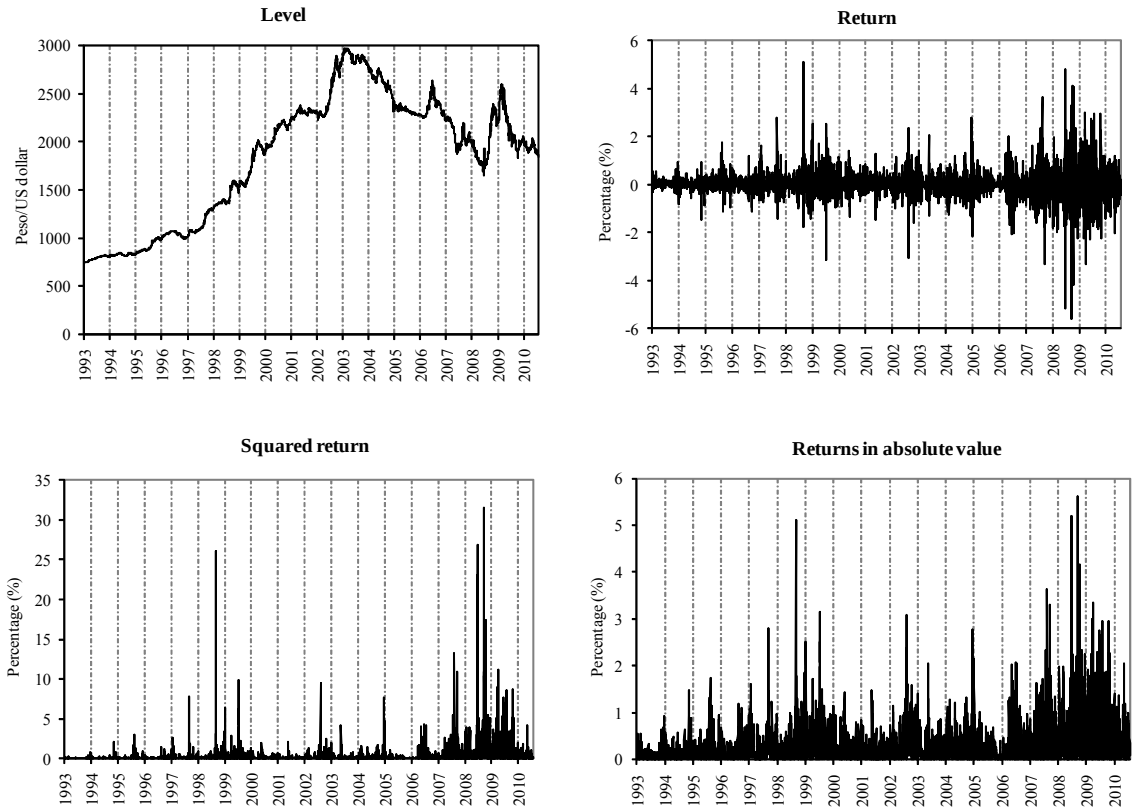
In turn, the skewness (asymmetry) of the return distribution rises with the capital control or forex intervention, but when both are present, it falls drastically (from 0.20 to 0.03). This would indicate that the simultaneous use of both policies correct the biases of the return away from the mean, which is reflected in a more symmetrical distribution of the return. On the other hand, the kurtosis of the return distribution becomes greater with the capital control and lower with the

[7] This empirical regularity should be interpreted cautiously here since we are not controlling for possible simultaneity between the mean and the variance of the exchange rate return, or between them and the policy decisions we are interested on. Such control is made in the estimations below.

[8] The calculated value of the statistic was 2.015, 1.678 and 1.851 for the returns, squared returns and the absolute value returns while the critical values of 1%, 5% and 10% of the statistic for the right tail are 2.098, 1.862 and 1.747 (Ibid., Table II, page 1288), respectively.

forex intervention, while when both are used it declines slightly (from 14 to 13). In other words, it appears that the simultaneous intervention in the capital market and in the foreign exchange market would help a little to smooth out the behavior of the returns.

Figure 1 Daily peso/US dollar exchange rate



Source: Authors' calculations.

The skewness and, in particular, the excess of kurtosis of the distribution and the volatility clustering indicates a fat tail distribution which would lead one to conclude that the returns on the exchange rate do not have a *normal* distribution. As a complement, we generated a histogram (not shown here) of the distribution of the return frequencies versus those of a normal distribution and obtained the same result –fatter tails and greater skewness than those in a normal distribution. These results are corroborated by the rejection of the normality assumption based on the Jarque-Bera test.

Table 1 Descriptive statistics of the daily peso/US dollar exchange rate return

Complete sample			
Daily(5) Data From 1993:01:05 To 2010:07:30			
Observations	4584	Skipped/Missing	0
Sample Mean	0.02	Variance	0.31
Standard Error	0.56	of Sample Mean	0.01
t-Statistic (Mean=0)	2.41	Signif Level	0.02
Skewness	0.20	Signif Level (Sk=0)	0.00
Kurtosis (excess)	13.62	Signif Level (Ku=0)	0.00
Jarque-Bera	35.46	Signif Level (JB=0)	0.00
Median	0.00		
Período in which the capital control was impossed			
Daily(5) Data From 1993:01:05 To 2010:07:30			
Observations	2109	Skipped/Missing	2475
Sample Mean	0.05	Variance	0.33
Standard Error	0.58	of Sample Mean	0.01
t-Statistic (Mean=0)	3.88	Signif Level	0.00
Skewness	0.28	Signif Level (Sk=0)	0.00
Kurtosis (excess)	19.01	Signif Level (Ku=0)	0.00
Jarque-Bera	31.79	Signif Level (JB=0)	0.00
Median	0.01		
Período in which forex intervention was used			
Daily(5) Data From 1993:01:05 To 2010:07:30			
Observations	1257	Skipped/Missing	3327
Sample Mean	0.05	Variance	0.48
Standard Error	0.69	of Sample Mean	0.02
t-Statistic (Mean=0)	2.71	Signif Level	0.01
Skewness	0.26	Signif Level (Sk=0)	0.00
Kurtosis (excess)	13.39	Signif Level (Ku=0)	0.00
Jarque-Bera	9.41	Signif Level (JB=0)	0.00
Median	0.01		
Período in which both the capital control and forex intervention were used			
Daily(5) Data From 1993:01:05 To 2010:07:30			
Observations	764	Skipped/Missing	3820
Sample Mean	0.12	Variance	0.61
Standard Error	0.78	of Sample Mean	0.03
t-Statistic (Mean=0)	4.37	Signif Level	0.00
Skewness	0.03	Signif Level (Sk=0)	0.73
Kurtosis (excess)	12.63	Signif Level (Ku=0)	0.00
Jarque-Bera	5.08	Signif Level (JB=0)	0.00
Median	0.09		

Source: Authors' calculations.

4. The regression model

The regression model which we start with is one from the family of GARCH models that allows us to simultaneously estimate the mean and variance of the return of the nominal exchange rate. The stylized facts just described and the literature reviewed categorically show that this is the most appropriate procedure for analyzing the mean and the variance of financial variables such as the exchange rate (Engle et al., 1990; Andersen and Bollerslev, 1998).

The AR(1)-GARCH(1,1) regression model in logarithms for the mean of the short term return of

the exchange rate, indexed by time t, is the following (the expected signs are in parenthesis):[9]

$$\Delta e_t = \underset{(+)}{\beta_0} + \underset{(+)}{\beta_1 \Delta e_{t-1}} + \underset{(+)}{\beta_2 \Delta spread_t} + \underset{(+)}{\beta_3 \Delta vix_t} + \underset{(-)}{\beta_4 \Delta Dif_t} + \underset{(+)}{\beta_5 TAX_t^i} + \underset{(+)}{\beta_6 \hat{I}_t} + \underset{(-)}{\beta_7 \Delta pc_t} + u_t \quad (1)$$

[10]

where the dependent variable Δe is the peso/US dollar exchange rate return [Δe_t=($Ln\ E_t$-$Ln\ E_{t-1}$) *100], the constant β_0 represents the expected long term mean return and u_t is the unexpected short term return, that is assumed to be normally distributed *i.i.d.* (identically and independently) with a mean of zero and conditional h variance.[11] Later on, we will evaluate if the assumed normality and independence of the errors is supported by the data. Δ is the first-difference operator. β_5 and β_6, the coefficients we are mostly interested, measure the short-run effects on the mean return of the exchange rate of capital controls and central bank intervention in the foreign exchange market respectively. We conclude that the capital control and forex intervention were effective if they induced a daily average devaluation of the peso.[12,13]

The explanatory variables of the model are: i) *spread*: Measure the risk in the financial sector of Emerging Markets; ii) *vix*: Measure the risk in the financial markets of the industrialized countries; iii) *Dif*: The differential between the domestic rate and the foreign rate iv) TAX^j: The tax equivalent to the compulsory non-remunerated reserve requirement on capital inflows as a measure of capital controls. This constitutes our first variable of interest (the index j indicates the alternative measurement of the *TAX* variable, as explained below; v) $\hat{I}$: The instrumental variable that measures the central bank intervention in the foreign exchange market, which is our second interest variable;[14] and vi) *pc*: A measure of the foreign exchange pressures from the current account through commodity prices (in Appendix A.4 we give a detailed description of the series

[9] Unfortunately we had to work with the time series in first differences, given their time series properties. This does not allow us to have a long run (cointegration) interpretation of the coefficients and effects of the explanatory variables, which would be desirable from the economic point of view.

[10] As is traditional in the literature where the exchange rate is studied and in order to compare with other results, we estimated a GARCH type model on the order of p=1 and q=1. This, however, is justified to model the data analyzed when we implement different specification tests. By simplicity, the autoregressive component m from equation (1) is shown to be equal to the unit. In the estimations, it took different values based on the tests that evaluate the structure of the return lags. This will be made explicit later on.

[11] In general, the equation (1) errors are shown in the standardized fashion: $u_t = z_t\sqrt{h_t}$, where z is simply the standardized error such that $z_t \sim N(0,1)$.

[12] This interpretation on the effectiveness of both policies not necessarily coincides with that of the central bank, which may be related with a change in the exchange-rate-return long trend.

[13] If these policies were effective they would increase the future spot exchange rate relative to the expected spot rate in such a way that would reduce the incentives for international capitals to come in. In terms of the uncovered interest parity hypothesis this implies that the yield of the local asset -measured in dollars- relative to the yield of the foreign asset would be reduced, thus discouraging capital inflows.

[14] The literature has identified at least three channels through which foreign exchange intervention affects the exchange rate: signaling channel (Mussa, 1981), portfolio channel (Dooley and Isard, 1983), and the microstructure channel (Lyons, 2001).

used). The logarithmic exchange rate series, the logarithm of the *spread* and *vix*, the interest differential and the logarithm of prices of commodities were differentiated once to achieve stationarity of the time series.

The lagged dependent variable captures the possible persistence of the peso devaluation/appreciation; *spread*, the consequence on the exchange rate return of shocks to risk in the Emerging Markets; *vix*, the effect of the perception of risk in the financial markets of the industrialized countries; *Dif*, the influence of capital movements due to interest differential; *TAX*, the effect of the control on capital inflows; $\hat{I}$, the consequence of the central bank intervention in the foreign exchange market; and *pc*, the effect of real flows due to variations on commodity prices, since Colombian mainly exports are those type of goods (we use the prices for nineteen *commodities* based on the Bloomberg Commodity Index CRB (Reuters/Jefferies)).[15]

The short term conditional variance or conditional volatility for the exchange rate return of the peso, indexed by time *t*, is given by (the expected signs are in parenthesis):

$$h_t = \alpha_0 + au_{t-1}^2 + bh_{t-1} + \underset{(+)}{\alpha_1}|\Delta spread_t| + \underset{(+)}{\alpha_2}|\Delta vix_t| + \underset{(+)}{\alpha_3}|\Delta Dif_t| + \underset{(0/-)}{\alpha_4} TAX_t^i + \underset{(-)}{\alpha_5}\hat{I}_t + \underset{(-)}{\alpha_6}|\Delta pc_t| \quad (2)$$

where α_0 represents the long term conditional variance ($\alpha_0 \geq 0$), *h* the conditional variance of the return ($b \geq 0$), u^2 is the unexpected squared return ($a \geq 0$). Note that *h* is stationary if and only if $a + b < 1$. The variables defined above, some of which are introduced into equation (2) in absolute value, explain the changes with respect to the long term conditional variance α_0. The coefficients we are interested on are α_4 and α_5, which measure, respectively, the effects of the capital controls and central bank intervention on the volatility of the peso/US dollar exchange rate return. We will conclude that the capital control was effective in the short term if it made possible to reduce or, at least, not increase the volatility of the return. In a similar manner, we will conclude that the central bank intervention was effective if it reduced the daily average volatility of the return.[16]

The justification for including the ARCH component, which is the u^2 term, is that it gathers volatility by groups or *clusters* that are typical of the exchange rate return and of other financial variables, as we showed in the previous section. In addition, the ARCH term helps to incorporate the excess of kurtosis of the return distribution into the variance equation. The lagged variance captures the assumption of its non-constancy over time (Bollerslev, 1986).

5. Some methodological notes on the variables

Before continuing, it is necessary to make some methodological clarifications on the variables incorporated into the regression model which is similar to those estimated by Edwards and Rigobon (2005) for the Chilean case and Clements and Kamil (2008) for Colombia.

[15] Exports of *commodities* represented around 55% of the total Colombian exports for the year 2009.

[16] Again, this interpretation of the effectiveness of both policies may not coincide with that of the central bank, which may be related with a lasting smoothing effect on the volatility of the exchange rate return.

In the first place, the exchange rate was lagged one day since the value on *t* reported by the central bank corresponds to the actual value observed on *t*-1.

The daily variation of the EMBI^{+} (*Emerging Markets Bond Index* +) is used as the measurement of the *spread* to depict the foreign debt risk of Emerging Markets. In order to capture the external risk shocks exclusively, Colombia was excluded from the construction of this indicator.

We used two alternative measurements of the interest differential: the daily differential and the 90-day one. The foreign rates are the overnight LIBOR and the 90-day LIBOR and the domestic ones are the daily interbank rate (TIB) and that of the 90-day deposits (CDT). The estimations reported below are carried out using the 90-day differential.

The tax equivalent to the compulsory non-remunerated reserve requirement on capital inflows, which as we will see, can be characterized as a Tobin tax, is calculated in three alternative ways. The first is simply a dummy variable that takes the value of one when there is a control and zero in the other case (TAX^{d}). Notice that this measure does not capture changes in the intensity of the control, as the next two do. The second one utilizes the Ocampo and Tovar (1997) derivation which was complemented by Rincon (2000). In simple terms the tax equivalent that the control imposes on economic agents that borrow abroad has two components. The first one is the financial cost itself of the foreign credit. The second one is the opportunity cost of the compulsory deposit that must be kept at the central bank for a particular period of time. Thus, the tax is simply the relative cost of the non-remunerated deposit to the total cost. If there were no control, only the financial cost would exist.

If we assume that *tm* is the time (in months) that a deposit or reserve requirement on foreign debt had to be kept in the central bank, then the present value of a one-dollar reserve-deposit (*PV-RR*) is expressed as:

$$PV - RR = \{1 - [(1 + \theta \Delta E^{\in})/(1 + i)]\}^{tm} \qquad (3)$$

Where θ =1, when the reserve requirement was denominated in dollars (as was the case between September 1993 and May 1997), and θ =0, when it was denominated in pesos (as was the case starting in May 1997). E is the nominal exchange rate as we defined it before; $\in$ indicates devaluation/appreciation expectations for the peso; i is the pertinent, domestic, nominal interest rate. In implementing this equation, we built two alternative measurements for the peso/US dollar exchange rate return expectations. The first consists of a simple average of k lags and k leads ahead of the return, a measurement we justified on the assumption that the agents' return expectations could have come from a linear combination of adapted and rational expectations. The second measurement captures a rational behavior on the part of the agents. It consists of the fitted value of a model in first differences for the return -the dependent variable- calculated as the logarithmic difference between the exchange rate in period *t* and its moving average one year ahead, on explanatory variables that are lags of the logarithmic difference between the exchange rate in period *t* and the exchange rate one year before, of the *spread* of Colombian public debt and of the daily foreign-domestic interest differential.

Now, if the relevant nominal interest rate over a foreign loan requested by a Colombian agent is

defined as the sum of the three-month LIBOR rate i^{LIBOR} plus the *spread* of the public debt bonds, which it is assumed to reflect the country-risk for Colombia, $i^{*}=i^{\text{LIBOR}}+spread$, the loan period (in months) is referred to as *tc* and the percentage of the reserve requirement as ε, then the total annual cost of a foreign loan (z), including the cost of the reserve requirement, can be written as:

$$z = \{[(1 + i^{*})(1 + \Delta E^{\in})]^{tc} + \varepsilon(PV - RR)(1 + i)^{tc}\}^{(1/tc)} - 1 \quad (4)$$

Starting with the *PV-RR* equation and the cost equation (z), the tax equivalent of the reserve requirement for foreign debt ($TAX^{O\text{-}T\text{-}R}$) is found as:

$$TAX^{O-T-R} = \{(1 + z)/[(1 + i^{*})(1 + \Delta E^{\in})]\} - 1 \qquad (5)$$

In practical terms, the value of the tax is calculated using the different values of *tc* and the respective percentages of the reserve requirement ε established by the central bank, the institution that is authorized to establish and modify the control. In order to get a single measurement of the tax, we took a simple average for all of the *tc* values, that is, *tc* = 3, 6, 9, 12, 18, 24, 36 and 60 months (Appendix A.5).

Due to the possible endogeneity between the exchange rate returns and the measure of the expected devaluation created by construction with the $TAX^{O\text{-}T\text{-}R}$ measurement, we calculated an alternative version of the tax using the formulation proposed by Edwards and Rigobon (2005) for the Chilean case. According to these authors, the equivalent tax on the capital inflows for *tc* months is given by (we changed the authors' original notation simply to adjust it to the notation used in this document):[17]

$$TAX^{E-R} = \frac{\varepsilon}{1-\varepsilon}\frac{i^{*}tm}{tc} \qquad (6)$$

Just as in the previous case, the tax is calculated on the basis of the different values for *tc* and the respective reserve requirement percentages ε (Appendix A.6).

Now, the indicator of the central bank's intervention in the foreign exchange market (I) is constructed as the relationship between the daily net value of the intervention (purchases minus sales of dollars) and the average daily size of the market (using a one month window). Due to the possible endogeneity between the mean and volatility of the exchange rate return and the intervention indicator we constructed an instrument for this last variable. We roughly followed the econometric approaches utilized by Guimaraes and Karacadag (2004) for the cases of Mexico and Turkey, Disyatat and Galati (2007) for the case of the Czech Republic and Toro and Julio (2005) and Kamil (2008) for Colombia.

[17] The equation assumes that the reserve requirement is always in local currency.

We calculated the instrument for forex intervention ($\hat{I}$) as the fitted value of the following (random) reaction function of the central bank (the expected signs are in parenthesis):[18]

$$I_t = \underset{(+)}{\theta_0} + \underset{(-)}{\theta_1 I_{t-1}} + \underset{(-)}{\theta_2 \Delta e_{t-1}} + \underset{(-)}{\theta_3 \Delta De_t} + \underset{(-)}{\theta_4 INFS_{t-1}} + \upsilon_t \qquad (7)$$

The lagged *I* variable in equation (7) captures the possible intervention persistence and the lag of the return controls for those immediate changes in the exchange rate that could induce an instant reaction from the authorities: If the peso appreciates, the authorities tend to buy dollars and vice versa.

The third term (*De*), which we have labeled misalignment of the nominal exchange rate, seeks to capture the response of the authorities to deviations in the "equilibrium" level of the exchange rate: If the exchange rate of the peso is above its level of "equilibrium," the authorities are inclined to sell dollars and vice versa. Since the "equilibrium" exchange rate is a non-observable variable, we estimated it by applying the Hodrick and Prescott filter over the logarithm of the observed peso/US dollar exchange rate (we extended the series backward and forward before applying the filter to avoid the well-known problem of biases at the tails when this procedure is used). We measured the foreign exchange misalignment simply as the residual of the difference between the observed value and the filtered value of the exchange rate.

The last term in equation (5), the *INFS* variable, seeks to capture the inflationary surprises for the central bank. This variable is measured as the difference between the observed value of monthly inflation and the inflation target for the respective month: If the surprise was positive in the *t-1* period, that is, if the observed inflation was above the target during the previous period, the authorities would be expected to purchase fewer dollars in period *t*.

Finally, in the estimation of the regression model given by equations (1) and (2), we included two interaction variables, firstly between the TAX^j variable and the *spread,* in order to deduce whether or not the capital control helped to isolate the domestic foreign exchange market from the shocks in Emerging Markets; and secondly, between the TAX^j variable and the $\hat{I}$ variables, to assess if the combination of the capital control and foreign exchange intervention allowed the central bank to be more effective. If the capital control was effective in achieving the first task, the coefficient of the interaction variable should be negative and significant in the equation of the mean and of the variance. If the control and the forex intervention were effective in carrying out the second task, the coefficient of the interaction variable should be positive and statistically significant in the equation of the mean and negative and statistically significant in the equation of the variance.

6. The estimations

In this section, we estimate the AR(*m*)-GARCH(1,1) model represented by equations (1) and (2) simultaneously where we assume for presentation that *m=1*. First of all, we carry out different diagnostic and specification tests and later, we present and discuss the estimates on the adjusted model based on the results of the statistical tests for the sample 1993:01:04 - 2008:12:08, which

[18] In Colombia, the central bank is the foreign exchange authority.

covers the period when the capital control and the different types of forex intervention were present simultaneously. Then, we present the results for three sub-samples (1993:01:04 - 1999:09:30; 1999:10:01 - 2008:12:08; and 2008:01:01 - 2010:07:30). The first two subsamples were required by the results of the statistical tests that showed a structural change by the end of the nineties. The third subsample is motivated by our own interest of assessing the effectiveness of preannounced interventions. As will be seen, the model that adjusts best to the data is an integrated GARCH (IGARCH).

6.1 Sample 1993:01:04 - 2008:12:08

i.) *Diagnostic and specification tests*

First of all, we identified the structure of the lags for the autoregressive process of the return or, in other words, the *m* value of the *AR* process in equation (1), which, according to Akiake's information criteria, corrected for degrees of freedom (called *CAIC* criterion), and Schwarz's is equal to 12. Afterwards, we corroborated the presence of an ARCH process in the data through the Engle test (1982).

Secondly, and as shown by the preliminary statistics on the return, we found a fat tail distribution and a failure to fulfill normality; we used the Kolmogorov-Smirnov test to evaluate the distribution of the unexpected returns *u* of equation (1). The tests reported that the distribution was neither normal nor *t-student* and for this reason we used a function of *generalized* GED distribution (Generalized Error Distribution).[19] The GED distribution was also used by Toro and Julio (2005), Castaño et al. (2008), and Echavarria et al. (2009), who also estimated models from the GARCH family for the Colombian peso exchange rate.

Thirdly, we carried out tests on the presence of non-linearities or asymmetries in the conditional variance given by equation (2). For those, we used the Engle and Ng test (1995) in the simplified version proposed by Frances and van Dijk (2000, equation (4.71), page 160) and did not find evidence in favor of that behavior.

Finally, we evaluated the presence of serial correlation through the Ljung-Box Q statistic and rejected the null hypothesis of non-autocorrelation in the standardized squared errors and in absolute value for some lags at the 5% significance level. We should note that all of the estimations of equations (1) and (2) throughout the document were carried out for Maximum Likelihood using the BHHH (Berndt, Hall, Hall and Hausman) non-linear optimization method (Estima, 2007).

The first estimates showed unexpected results. In the first place, a long term variance turned out to be negative, something that, by definition, cannot possibly happen. Secondly, the estimated coefficients *a* and *b* for equation (2) turned out to be larger than one, which could indicate that

[19] It is said that a random variable (continuous) X is *GED* distributed if its probability density function has the following form: $f(X_t) = exp\left[(-\frac{|X_t|}{\lambda})^{2/\upsilon}/2\right]/\lambda\left(2^{\frac{\upsilon}{2}+1}\right)\Gamma(1+\upsilon/2)$, where the (positive) parameter υ defines the shape of the distribution (the fatness of the distribution tails), the (positive) parameter λ defines the scale and Γ is the Gamma function. Note that if υ (or *shape parameter*) is equal to the unit, one gets normal distribution as a special case.

the conditional variance *h* is not stationary since the hypothesis that it is a *long memory* process was not completely corroborated by the test that was used. Note that the non-stationarity of peso volatility is not strange to the trend of the exchange rate for other currencies around the world as has been documented by Baillie, Bollerslev and Mikkelsen(1996) and Davidson (2004). In the Colombian case, Castaño et al. (2007) found a similar result. The implications of this finding is that volatility could become explosive and the standard GARCH model is non-stationary and, therefore, inappropriate for analyzing the data.[20]

Therefore, and based on the statistical findings, we use a AR(12)-IGARCH(1,1) model which imposes the $a + b = 1$ restriction on equation (2). Moreover, due to the results noted above, we imposed the restriction that the long term conditional variance is equal to zero (a=0). Notice that under these two restrictions, Nelson (1990) showed that the IGARCH(1,1) model is "strictly stationary" although "non-stationary in covariance." Nevertheless, he showed that the model could be consistently estimated by Maximum Likelihood. Castaño et. al. (Ibid.) also reported evidence in favor of the IGARCH model when it comes to modeling and predicting the volatility of the return on the exchange rate for the Colombian peso.[21]

ii.) *Preliminary estimations*

In this section, we show and discuss the results of the simultaneous estimation of the AR(12)-IGARCH(1,1) model for the mean and variance of the exchange rate return given by equations (1) and (2). We estimated a regression for each calculation of the tax equivalent to the deposit on foreign debt namely, when TAX^d is used, when the implementation of equation (5) ($TAX^{O\text{-}T\text{-}R}$) is used, and lastly, when equation (6) ($TAX^{E\text{-}R}$) is calculated. In addition, for each definition of the tax, we estimate three alternative specifications. The first keeps the explanatory variables defined by equations (1) and (2), the second incorporates the TAX^i**spread* interaction variable and the third, the $TAX^i*\hat{I}$ interaction variable.

The estimates indicate, in the first place, that when the capital control is statistically significant (above the 5% level), the return on the exchange rate rises although it does so by a minimal percentage (Tables 2.1-2.3). However, the cost is a rise in the variance, as the results for the volatility equation indicate (in one out of three cases). The coefficient of the TAX^i**spread* interaction variable came out significant in only one case and with the expected sign which do not provide sufficient evidence to conclude that the control has helped to stem the devaluation pressures and reduce the volatility of the exchange rate in the presence of external risk shocks. Finally, the $TAX^i*\hat{I}$ interaction variable was insignificant in the mean equation for all cases; however, in the variance equation it became statistically significant increasing the return volatility. The results for mean and variance of the exchange rate return coincided with those found by Edwards and Rigobon (2005) for the Chilean case. However, our results did not coincide with theirs for the TAX^i**spread* interaction variable. The increase in foreign exchange

[20] A comment we received is that a possible explanation for these findings is the use of data in first differences, which have not only empirical consequences but also problems with the economic interpretation of the results. We did not explore further on this hypothesis.

[21] They also used daily information on the exchange rate of the peso for their study and their sample covered the period between January 3, 2000 and July 31, 2006.

volatility from the control corroborates what was found by Clements and Kamil (2008) in the case of Colombia.

The foreign exchange intervention, in turn, turned out to be non-significant in all cases in the mean return equation. In other words, the forex intervention has not helped to prevent the appreciation/devaluation of the peso. However, it significantly raises volatility just like the capital control does. The inability of intervention to affect the exchange rate return contradicts most of the findings of the Colombian literature (Appendix A.1). Nevertheless, this estimation coincides with previous research that also found that intervention increases volatility. The fact that there is capital control and foreign exchange intervention at the same time has no effect on the mean return but their simultaneous presence does increase volatility. The latter coincides with the initial findings when we explored the statistical properties of the data on the peso/US dollar exchange rate.

The rest of control variables such as the measure of risk perception in Emerging and Global Markets, the interest rate differential and the prices of commodities, turn out to be, in general, significant and with the expected signs both in the equation for the mean of the return and also in the one for its volatility. It is interesting to note two things: the first one is that a determining variable of the mean return for the exchange rate in portfolio models such as the interest differential (*Dif*) turns out to be non-significant in all of the regressions. However, it is a central determinant of its volatility as the results indicate –the differential variation raises the volatility of the exchange rate return without any statistical ambiguity. The second one is the important role played by the behavior of the price of commodities in determining the mean of the return, where, in most of the cases an increase in those prices reduce the exchange rate return, that is, appreciate the peso.

Table 2.1 Effect of the capital control and forex intervention on the peso/US dollar exchange rate mean return and its volatility

Definition of the tax: TAX^d
Sample: 1993:01:04 - 2008:12:08

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constant	0.006	1.56		0.008	1.95	*	0.006	1.43	
Δe_{t-1}	0.186	12.97	***	0.181	12.60	***	0.189	13.07	***
$\Delta spread_t$	0.002	1.43		0.012	5.10	***	0.002	1.53	
Δvix_t	0.002	3.61	***	0.002	3.22	***	0.002	3.52	***
ΔDif_t	-0.001	-0.42		-0.001	-0.78		-0.001	-0.46	
TAX^d_t	0.006	1.02		0.005	0.81		0.006	1.14	
$\hat{I}_t$	-0.001	-0.04		0.000	0.26		0.000	0.24	
Δpc_t	-0.022	-4.88	***	-0.022	-4.89	***	-0.022	-4.93	***
$TAX^d_t * \Delta spread_t$	---	---		-0.014	-5.12	***	---	---	
$TAX^d_t * \hat{I}_t$	---	---		---	---		-0.001	-0.28	
Equation for the variance of the return									
a	0.234	15.85	***	0.237	15.70	***	0.236	16.01	***
b	0.766	51.96	***	0.763	50.67	***	0.764	51.90	***
$\lvert\Delta spread_t\rvert$	0.001	2.37	**	0.001	2.80	**	0.001	2.31	**
$\lvert\Delta vix_t\rvert$	-0.001	-1.49		-0.001	-1.96	*	-0.001	-1.51	
$\lvert\Delta Dif_t\rvert$	0.000	3.26	***	0.000	3.15	***	0.000	3.28	***
TAX^d_t	0.001	1.88	*	0.001	1.64		0.001	1.91	*
$\hat{I}_t$	0.000	3.61	***	0.000	3.54	***	0.000	0.75	
$\lvert\Delta pc_t\rvert$	0.001	1.17		0.002	1.32		0.001	1.20	
$TAX^d_t * \Delta spread_t$	---	---		-0.001	-1.71	*	---	---	
$TAX^d_t * \hat{I}_t$	---	---		---	---		-0.001	-0.13	
Shape	1.880	46.15	***	1.888	45.52	***	1.867	46.48	***
Observations	4143			4143			4143		
Log Likelihood	1149			1138			1149		

Source: Authors' calculations.
The explanatory variables are: e, natural logarithm of the peso/US dollar nominal exchange rate; *spread*, measurement of the risk in the financial markets in emerging countries; *vix*, measurement of risk in the financial markets in industrialized countries; *Dif*, the interest differential between Colombia and abroad; TAX, the tax equivalent to the reserve requirement on capital inflows; $\hat{I}$, the instrument for forex intervention; *pc*, prices of commodities. Δ is the first difference operator, $|.|$ is the absolute value operator, and *Shape* is the estimated value of the GED distribution shape parameter. The mean equation only reports one lag of the dependent variable. The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively.

Table 2.2 Effect of the capital control and forex intervention on the peso/US dollar exchange rate mean return and its volatility

Definition of the tax: $TAX^{O\text{-}T\text{-}R}$
Sample: 1993:01:04 - 2008:12:08

Variables	Model 1		Model 2		Model 3	
	Coefficients	*Stat.-t* Sign.	Coefficients	*Stat.-t* Sign.	Coefficients	*Stat.-t* Sign.
Equation for the mean of the return						
Constante	0.007	2.11 **	0.007	2.24 **	0.007	2.10 **
Δe_{t-1}	0.186	12.92 ***	0.185	12.89 ***	0.188	12.98 ***
$\Delta spread_t$	0.002	1.33	0.003	1.84 *	0.002	1.26
Δvix_t	0.002	3.36 ***	0.002	3.31 ***	0.002	3.47 ***
ΔDif_t	-0.001	-0.43	-0.001	-0.49	-0.001	-0.43
$TAX^{O\text{-}T\text{-}R}{}_t$	0.000	1.96 *	0.000	1.90 *	0.000	1.71 *
$\hat{I}_t$	0.000	0.00	-0.001	-0.04	0.000	0.39
Δpc_t	-0.023	-5.09 ***	-0.023	-5.11 ***	-0.023	-5.14 ***
$TAX^{O\text{-}T\text{-}R}{}_t * \Delta spread_t$	---	---	0.000	-0.90	---	---
$TAX^{O\text{-}T\text{-}R}{}_t * \hat{I}_t$	---	---	---	---	-0.001	-0.52
Equation for the variance of the return						
a	0.237	16.08 ***	0.237	15.95 ***	0.237	16.28 ***
b	0.763	51.66 ***	0.763	51.46 ***	0.763	52.38 ***
$\lvert\Delta spread_t\rvert$	0.001	2.55 **	0.001	2.81 **	0.001	2.56 **
$\lvert\Delta vix_t\rvert$	-0.001	-1.11	-0.001	-1.24	0.000	-1.12
$\lvert\Delta Dif_t\rvert$	0.000	3.26 ***	0.000	3.23 ***	0.000	3.22 ***
$TAX^{O\text{-}T\text{-}R}{}_t$	0.000	0.51	0.000	0.43	0.000	0.70
$\hat{I}_t$	0.000	3.46 ***	0.000	3.20 ***	0.000	1.67
$\lvert\Delta pc_t\rvert$	0.002	1.46	0.002	1.34	0.002	1.43
$TAX^{O\text{-}T\text{-}R}{}_t * \Delta spread_t$	---	---	-0.001	-1.03	---	---
$TAX^{O\text{-}T\text{-}R}{}_t * \hat{I}_t$	---	---	---	---	0.000	1.89 *
Shape	1.882	46.79 ***	1.880	46.01 ***	1.863	45.90 ***
Observations	4143		4143		4143	
Log Likelihood	1149		1148		1147	

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.

Table 2.3 Effect of the capital control and forex intervention on the peso/US dollar exchange rate mean return and its volatility

Definition of the tax: TAX^{E-R}
Sample: 1993:01:04 - 2008:12:08

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constante	0.007	2.11	**	0.007	2.24	**	0.007	2.20	**
Δe_{t-1}	0.186	12.92	***	0.184	12.78	***	0.184	12.82	***
$\Delta spread_t$	0.002	1.34		0.003	2.05	**	0.002	1.30	
Δvix_t	0.002	3.56	***	0.002	3.33	***	0.002	3.60	***
ΔDif_t	-0.001	-0.38		-0.001	-0.45		-0.001	-0.40	
TAX^{E-R}_t	0.000	2.01	**	0.000	1.88	*	0.000	1.79	*
$\hat{I}_t$	-0.001	-0.02		-0.001	-0.03		-0.001	-0.02	
Δpc_t	-0.022	-5.00	***	-0.023	-5.02	***	-0.022	-5.00	***
$TAX^{E-R}_t * \Delta spread_t$	---	---		-0.001	-1.59		---	---	
$TAX^{E-R}_t * \hat{I}_t$	---	---		---	---		-0.001	-0.09	
Equation for the variance of the return									
a	0.238	16.11	***	0.238	16.06	***	0.233	15.99	***
b	0.762	51.66	***	0.762	51.34	***	0.767	52.65	***
$\lvert\Delta spread_t\rvert$	0.001	2.65	**	0.001	2.89	***	0.001	2.71	**
$\lvert\Delta vix_t\rvert$	-0.001	-1.12		-0.001	-1.30		-0.001	-0.94	
$\lvert\Delta Dif_t\rvert$	0.000	3.28	***	0.000	3.28	***	0.000	3.10	***
TAX^{E-R}_t	-0.001	-0.03		-0.001	-0.09		0.000	0.64	
$\hat{I}_t$	0.000	3.52	***	0.000	3.42	***	0.000	1.38	
$\lvert\Delta pc_t\rvert$	0.002	1.44		0.002	1.40		0.001	1.10	
$TAX^{E-R}_t * \Delta spread_t$	---	---		-0.001	-1.07		---	---	
$TAX^{E-R}_t * \hat{I}_t$	---	---		---	---		0.000	2.09	**
Shape	1.881	46.22	***	1.879	46.02	***	1.879	45.40	***
Observations	4143			4143			4143		
Log Likelihood	1150			1147			1147		

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.

Due to the size of the sample analyzed, an additional mandatory test is a stability or perseverance test of the parameters in the model.[22] If there are structural changes, biases appear in the estimates and the predictions incorporate greater uncertainty. Here, we implement the Lundbergh and Terasvirta test (2002) in the version proposed by Franses and van Dijk (2000, equation (4.105), p. 186) and the Nyblom fluctuations test (1989). The results for both tests reject the null hypothesis of the perseverance of the parameters.[23]

In order to incorporate this result, and to evaluate separately the effectiveness of the preannounced forex intervention, we decided to use three sub-samples. The criteria for selecting the first two subsamples is based on the changes in the monetary and foreign exchange regimes that occurred at the end of the 90's, which could have produced the structural change that was detected. The last subsample is based on the important change that happened during 2008 in the nature of the central bank intervention in the forex market.

The first sub-sample covers the period when the exchange rate was controlled through a *crawling-peg* and an exchange rate band, and the monetary policy was guided by money aggregates (1993:01:04 and 1999:09:30). The second covers the period with a floating exchange rate and an inflation targeting monetary regime (1999:10:01 and 2008:12:08). We categorized these sub-samples by following what was suggested by Villar and Rincon (2003) in the first case and Gomez et al. (2002) in the second case.[24] As stated above, the third sub-sample includes only the period of preannounced forex intervention (2008:01:01 – 2010:07:30). It must be noticed that for this particular sub-sample it is not necessary to instrument the forex intervention variable since the feedback effects between intervention and the exchange rate return do not occur. Thus, for the estimations we used directly the market-size-weighted preannounced intervention variable.

6.2 Estimations for the sub-samples[25]

In this section, we will show and discuss the results of the simultaneous estimations of the AR(2)-IGARCH(1,1), AR(12)-IGARCH(1,1), and AR(1)-IGARCH(1,1) models for the mean and variance of the exchange rate return for the three sub-samples, respectively. Just like with the sample 1993:01:04 - 2008:12:08, we estimated a regression for each definition of the tax equivalent to the deposit for foreign indebtedness and, at the same time, we estimated the three specifications implemented for each definition: the first keeps the explanatory variables defined

[22] The coefficients can change over time because the structure of the economy changes or the economic policy regime, because the parameters of the regression model depend on other variables outside of the model and these change or because the parameters are random variables.

[23] In the first case, the *LM* (Lagrange Multiplier) static is equal to 4.14 and the critical value of $\chi 2$ test with 3 degrees of freedom and a significance level of 1% is 11.34. In the second, the statistic for the joint test of the coefficients is equal to 14.03 with a *p-value* of 0.00.

[24] Strictly speaking, Gomez (2006) argues that the Colombian inflation targeting regime started in January 2001. In the process of estimating we made this differentiation in the sample and the results did not change with respect to those reported.

[25] The diagnostic and specification tests for each one of the sub-samples are not discussed or reported here but can be requested from the authors.

by the equations (1) and (2), the second incorporates the $TAX^j*spread$ interaction variable and the third, the $TAX^j*\hat{I}$ interaction variable. In order to guarantee comparability with previous results, we kept the same assumptions with regard to the distribution of the unexpected returns, the other assumptions on their behavior, and the method of estimation and optimization.

The estimates are summarized in Table 3 and the results of individual regressions are shown in Appendix A.7. To make reading easier, the table summary only shows the predominant results even if they do not necessarily coincide with those of any regression in particular.

First of all, the capital control turned out to be non-significant in all the sub-samples and when it is significant, the return falls and the volatility of the return increases.[26] The result for the mean of the return contrasts with what was found for the largest sample, which in econometric terms could be explained by the finding of a structural change. The second result corroborates what we found before, that is, that the capital control raises the return volatility. Note that once the empirical problems generated by the structural change are solved, we find that the foreign exchange policy does not seem to benefit from the capital control. On the contrary, it might bring about costs, something that differs from former findings.

Secondly, like in the previous case and without ambiguity now, forex intervention does not seem to have any effect on the mean of the return in any of the sub-samples but it did raised volatility, at least in the first sub-sample. In the second and third sub-samples the effect of the forex intervention on volatility was absorbed by the behavior of fundamentals, by the volatility itself (h in equation (2)) and by the term capturing the clustering property of the return (u^2 in equation (2))

The interaction variables delivered interesting results as explain below. During the first sub-sample both interaction variables turned out to be statistically non-significant to affect the mean or the variance equation. This indicates that during that time the combined policies were ineffective either to reduce the short-run pressures on the forex market when facing external shocks or to modify the daily average exchange rate return.

During the second sub-sample the interaction between the capital control and the external shock (*spread*) unambiguously increased the return with no effect on its volatility, which suggests that the capital control was unable to isolate the economy from external shocks. A more remarkable result, that started to be noticed in the second sub-sample, and will be confirmed in the third one, is that when the capital control and the forex intervention were used simultaneously, a statistically significant positive effect was obtained, thus making the return higher as expected, though at this stage the magnitude of that effect was somewhat small, and only valid in two out of the three cases analyzed.[27] Moreover, the interaction between control and intervention did not affect the return volatility, a result that enhances the effectiveness of this policy.

[26]On this regard, Cordella (1998) argues that capital controls could induce instead of restrain capital inflows if they are effective in reducing a country's vulnerability to external shocks. In such a case, capital control would appreciate instead of depreciate a country's currency.

[27] This result holds, even if we exclude the preannounced intervention from this sub-sample. Nonetheless, the standard error of the coefficient of the interaction variable $TAX*I$ increases, which suggests that the preannounced intervention reduce the uncertainty on its impact on the exchange rate return.

Table 3 Effect of the capital control and forex intervention on the peso/US dollar exchange rate mean return and its volatility: summary for the sub-samples

Variable	*Equation for the mean of the return*	*Equation for the variance of the return*
Controlled exchange rate and monetary policy guided by money aggregates (1993:01:04 - 1999:09:30)		
$TAX^j{}_i$	NS/S and returns falls	NS/S and volatlity increases
$\hat{I}_t$	NS	S and volatility increases
$TAX^j{}_t * \Delta spread_t$	NS	NS
$TAX^j{}_t * \hat{I}_t$	NS	NS
Floating exchange rate and inflation targeting monetary regime (1999:10:01 - 2008:12:08)		
$TAX^j{}_i$	NS/S and returns falls	S and volatility increases
$\hat{I}_t$	NS	NS
$TAX^j{}_t * \Delta spread_t$	S and return increases (devaluation)	NS
$TAX^j{}_t * \hat{I}_t$	NS/S and returns increases (devaluation)	NS
Preannounced forex intervention (2008:01:01 - 2010:07:30)		
$TAX^j{}_i$	NS	NS
$\hat{I}_t$	NS	NS
$TAX^j{}_t * \Delta spread_t$	S and return decreases (apprecation)	NS
$TAX^j{}_t * \hat{I}_t$	S and return increases (devaluation)	NS

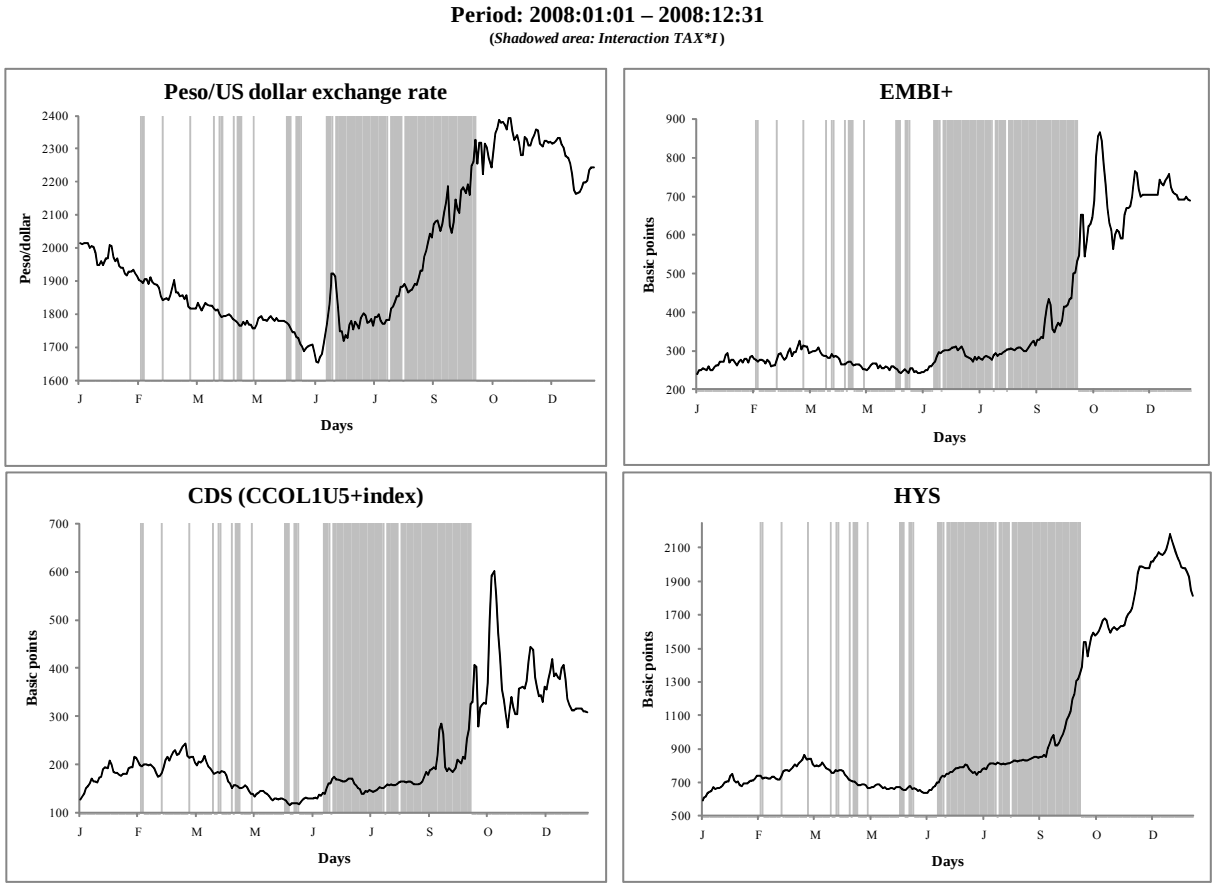
Source: Tables A.7-1 - A.7-9.
NS: No significance at 1%, 5% or 10% level.
S: Significance at 1%, 5% or 10% level.

The effectiveness of the interaction variables is clearly confirmed in the third sub-sample when for all the three alternative measures of *TAX* both interaction variables turned out to be statistically significant and with the expected signs in the mean equation. In addition, none of them appeared increasing the volatility of the return.

The latest finding is of particular interest for the current policy debate in Colombia. As shown in tables A.7.4-A.7.9, the interaction between the capital control and the forex intervention variable ($TAX^j * \hat{I}$ or $TAX^j * I$) turned out to be significant and with a higher coefficient in the third sub-sample than what was found in the second one. The capital control had been established since May 6 2007, and then in June 24 of 2008, the central bank initiated a preannounced forex intervention while maintaining the capital control. The interaction of these two policies lasted 75 working days until October 6 2008. Several weeks before the beginning of this policy overlapping period, important events were happening in the world financial markets that started to put upward pressure on risk perception. In particular, risk measures like the $EMBI^+$; the Credit

Default Swaps on 5yr corporate Colombian debt; and the High Yield Spread were all increasing. As a result, days before the outset of the preannounced intervention, the Colombian exchange rate had ceased to appreciate, and was starting to show an incipient depreciation trend (Figure 2).

Figure 2 Peso/US dollar exchange rate and international risk indicators in the prelude of the financial crises



Source: Banco de la República and Bloomberg.

As can be seen, the interaction of control and intervention since June 24 gave a boost to the ongoing depreciation trend. The exchange rate even overshoots during the first few days of intervention, and then maintained a depreciation trend all along the interaction period. So it is not a surprise that the interaction of control-intervention turned out to be significant for increasing the exchange rate return in this sub-sample. Another fact that may have contributed to this result is that before the interaction period the capital control had been progressively reinforced, by extending it to a larger number of operations (imports financing; several modalities of foreign credit) while at the same time the regulation regarding the minimum permanence period of foreign direct investment in Colombia was extended from one to two years.[28] This upgrading of capital controls together with the preannounced intervention at the right moment were key

[28] Moreover, as we said above, a ceiling on derivative positions had been imposed in 2007, and then tightened in 2008. In addition, in May 2007 the non-remunerated deposit was extended to portfolio inflows by foreign residents.

factors that helped to achieve the desired effect of depreciating the exchange rate, without increasing volatility.

The rest of the explanatory variables change their size and sign depending on the sample that was analyzed (Appendix A.7). The variable *spread* resulted significant but with an opposite sign to what was expected in the equation for the mean of the return in the first sub-sample. This indicates that an increase in the risk in emerging countries reduced the exchange rate return for the peso during the period of managed exchange rate and monetary aggregates as policy instruments. This result can be explained by the reaction function of monetary authorities during that policy regime, which led them to tighten monetary policy to defend the exchange rate during periods of negative external shocks, thus inducing a peso appreciation. In contrast, since 1999 up to now, that is, during the floating exchange rate and inflation targeting period, both the *spread* and *vix* variables unambiguously turned out to be statistically significant and had the expected signs. Accordingly, a positive variation in any of those variables increases the foreign exchange rate return, making the exchange rate recovering its stabilization role. In the case of the *spread*, its changes unambiguously increase the foreign exchange rate volatility in the second sub-sample.

Contrary to what was expected, the variations in the interest differential did not have any statistically significant effect on the mean of the return in the first two sub-samples, while –in the first sub-sample- unambiguously induced a greater volatility of the exchange rate. However, in the third sub-sample, and when it is statistically significant, it reduced the return, as expected. This result might have to do with the fact that during the first subsample, and to some extent the second one, the risk perception abroad on the Colombian economy was relatively high, due to an unsolved fiscal situation and a high public debt, which discouraged foreign capitals to come in despite positive interest rate differentials.

As for the volatility of the return in the last subsample, it is fully determined by the volatility itself and by the term capturing the clustering property of the return. This seems clear evidence of the effects on the volatility of the local forex market caused by the turbulence in the international financial markets during the period.

Finally, it is interesting to notice the important role played since the end of the nineties by the behavior of the real foreign sector, represented by the price of commodities (*pc*), on determining the exchange rate return. It is also important to observe the high persistence of the exchange rate return, as measured by the coefficient of the lagged return.

7. Conclusions

The policy debate on how to manage the renewal of international capital inflows and the resulting appreciation trend is currently a crucial issue in many emerging economies. In an effort to prevent the possible damage that an excessive currency appreciation could cause on their economies, an increasing number of countries have decided to intervene in the foreign exchange market, and some of them have also imposed capital controls. Intervening in the foreign exchange market and/or imposing restrictions on capital mobility are costly policies, in terms of market efficiency. Hence these decisions should be based on a cost-benefit analysis. On this

regard, the key question is whether these policies are effective.

In this paper we evaluated the effectiveness of capital controls and central bank intervention in the foreign exchange market for depreciating the exchange rate, reducing its volatility, and diminishing the exchange rate vulnerability to external shocks. For this purpose, the paper used high frequency data for the 1993 to 2010 period and a GARCH model of the peso/US dollar exchange rate return.

The key general finding indicates that, when used separately, neither capital control nor central bank intervention were successful for inducing a currency depreciation, that is increasing the exchange rate return. In addition, as a side effect, these policies increased the exchange rate volatility. Nonetheless, when the capital control and intervention in the foreign exchange market were used simultaneously, the interaction of both policies turned out to be statistically significant for increasing the exchange rate return (depreciate the peso), with no significant effect on the exchange rate volatility.

This result, however, should be taken with caution. The circumstances under which these policies turned out to be most effective on its purpose for depreciating the exchange rate were quite specific and short lived. Indeed, the preannounced intervention started to interact with the existing capital control in a moment when the exchange rate was already depreciating as a result of an increasing risk perception in the prelude of the financial crisis. Thus, the interaction of these two policies gave a boost to the ongoing depreciation trend. It is uncertain what the effectiveness of these two policies acting together would be under different economic circumstances.

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Appendices

Appendix A.1 Literature review on the effectiveness of the forex intervention in Colombia

Authors Period of analysis (mm/yy)	Observed exchange rate Average daily return (%)	 Average daily volatility (%)	Type of intervention being evaluated	Econometric results Return Mean	 Variance	Data and econometrics Data frequency	 Procedure	 Asummed distribution	 Intervention indicator
Toro and Julio (2005)									
Sep/04 - Apr/05	-0.12	0.39	Discretionary intervention	Increase (devaluation) Length: Non estimated	Increase	Intra-day	GARCH(1,1)	GED	Non weighted
Kamil (2008)									
Sep/04 - Mar/06	-0.02	0.28	Buy (options and discretionary)	Increase (devaluation) Length: "short-lived"	Fall	Daily	2S-IV,* TOBIT, GARCH	Normal	Non weighted
Jan/07 - Apr/07	-0.07	0.34		Non effect	Non effect	Daily		Normal	Non weighted
Echavarría, Vásquez and Villamizar (2009)									
Apr/99 - Aug/08	0.02	0.43	Buy (options and discretionary)	Increase (devaluation) Length: from 1 to 6 months	Fall	Daily	2S-IV,* TOBIT, EGARCH	t-student	Non weighted
Echavarría, López and Misas (2009)									
Jan/00 - Aug/08	0.04	0.39	Net buy (options, volatility and discretionary)	Increase (devaluation) Length: 1 month	---	Monthly	SVAR, Variance decomposition	White noise	Non weighted

Source: Authors' compilation.
* There is not correction of the estandard errors when using an Instrumental Varaibles procedure.

Appendix A.2 Literature review on the effectiveness of the capital control (the compulsory non-remunerated reserve requirement on capital inflows) in Colombia

Authors Period of analysis (mm/yy)	Type of capital inflows being studied	Efectiveness of the control (Yes: It reduced influjos)	Data and econometrics Data frequency	 Procedure
Cárdenas and Barrera (1997)				
Feb/85 - Jun/95	Total private	No, but it changed the term structure	Monthly	OLS
Ocampo and Tovar (1997)				
Jan/90 - Jun/96	Cash Commerce Nonfinancial services	Yes, and it changed the term structure	Monthly	OLS
Rocha and Mesa (1998)				
1990/I - 1997/III	Total private	No, but it changed the term structure	Quarterly	Cointegration
Rincon (2000)				
Oct/93 - Aug/98	Short term	Yes	Monthly	Cointegration
Villar and Rincon (2003)*				
Sep/93 - Sept/99	---	It helped autorities to increase autonomy in the short term.	Monthly	2S-IV** and cointegration
Cárdenas (2007)				
Jan/00 - Sep/07	Long term	No	Monthly	OLS
Concha, Galindo and Quevedo (2007)	Short term	Yes	Monthly	Cointegration
Jan/98 - Aug/07	Long term	No		and GARCH
Clements and Kamil (2009)				
Jul/06 - Jul/08	Credit	Yes	Weekly	OLS
	Portfolio	No		
	Foreing check accounts	No		
	Total inflows, except foreing direct investment	No		

Source: Authors' compilation.
* They do not ustudy the direct effect of capital controls on capital inflows. Instead, they build up a model of the real exchange and interest rates to test whether or not contols helped autorities to increase autonomy by relaxing the dilemmas inherent to the impossible trinity.
** Instrumental Variables procedure.

Appendix A.3 Summary of legislation regarding the compulsory non-remunerated reserve requirement on capital inflows

Resolutions of the Banco de la Republica		Maximun term for the loan subjet to deposit (months)	Porcentage of the loan	Time of the deposit (tm)		Currency
Number/Year	Date (mm/dd)	(tc)	(ε)	(Days)	(Months)	
21/93	Sep/2	18	47.0%		12	US dollars
7/94	Mar/15	36	93.0%		12	US dollars
			64.0%		18	"
			50.0%		24	"
22/94	Aug/12	60	140.0%	1-30	1	US dollars
			137.2%	31-60	2	"
			134.5%	61-90	3	"
			131.8%	91-120	4	"
			129.2%	121-150	5	"
			126.6%	151-180	6	"
			124.1%	181-210	7	"
			121.6%	211-240	8	"
			119.2%	241-270	9	"
			116.8%	271-300	10	"
			114.5%	301-330	11	"
			112.2%	331-360	12	"
			110.0%	361-390	13	"
			107.8%	391-420	14	"
			105.7%	421-450	15	"
			103.6%	451-480	16	"
			101.5%	481-510	17	"
			99.5%	511-540	18	"
			97.5%	541-570	19	"
			95.6%	571-600	20	"
			93.7%	601-630	21	"
			91.8%	631-660	22	"
			90.0%	661-690	23	"
			88.2%	691-720	24	"
			86.4%	721-750	25	"
			84.7%	751-780	26	"
			83.0%	781-810	27	"
			81.4%	811-840	28	"
			79.7%	841-870	29	"
			78.2%	871-900	30	"
			76.6%	901-930	31	"
			75.1%	931-960	32	"
			73.6%	961-990	33	"
			72.1%	991-1020	34	"
			70.7%	1021-1050	35	"
			69.3%	1051-1080	36	"
			67.9%	1081-1110	37	"
			66.5%	1111-1140	38	"
			65.2%	1141-1170	39	"
			63.9%	1171-1200	40	"
			62.7%	1201-1230	41	"
			61.4%	1231-1260	42	"
			60.2%	1261-1290	43	"
			59.0%	1291-1320	44	"
			57.8%	1321-1350	45	"
			56.7%	1351-1380	46	"
			55.5%	1381-1410	47	"
			54.4%	1411-1440	48	"
			53.3%	1441-1470	49	"
			52.3%	1471-1500	50	"
			51.2%	1501-1530	51	"
			50.2%	1531-1560	52	"
			49.2%	1561-1590	53	"
			48.2%	1591-1620	54	"
			47.3%	1621-1650	55	"
			46.3%	1651-1680	56	"
			45.4%	1681-1710	57	"
			44.5%	1711-1740	58	"
			43.6%	1741-1770	59	"
			42.8%	1771-1800	60	"
3/96	Feb/15	48	85.0%	1-180	6	US dollars
			83.0%	181-270	9	"
			79.0%	271-360	12	"
			75.0%	361-450	15	"
			70.0%	451-540	18	"
			65.0%	541-630	21	"
			60.0%	631-720	24	"
			54.0%	721-810	27	"
			48.0%	811-900	30	"
			42.0%	901-990	33	"
			36.0%	991-1080	36	"
			29.0%	1081-1170	39	"
			23.0%	1171-1260	42	"
			17.0%	1261-1350	45	"
			10.0%	1351-1440	48	"
5/96	Mar/15	36	50.0%		18	US dollars
4/97	Mar/12	60	50.0%		18	US dollars
5/97	Mar/20	All	30.0%		18	US dollars&Pesos
1/98	Jan/30	All	25.0%		12	Pesos
10/98	Sep/18	All	10.0%		6	Pesos
6/00	Apr/28	All	0.0%		0	---
2/07	May/6	All	40.0%		6	Pesos
10/08	Oct/8	All	0%		0	---

Source: Authors' compilation.

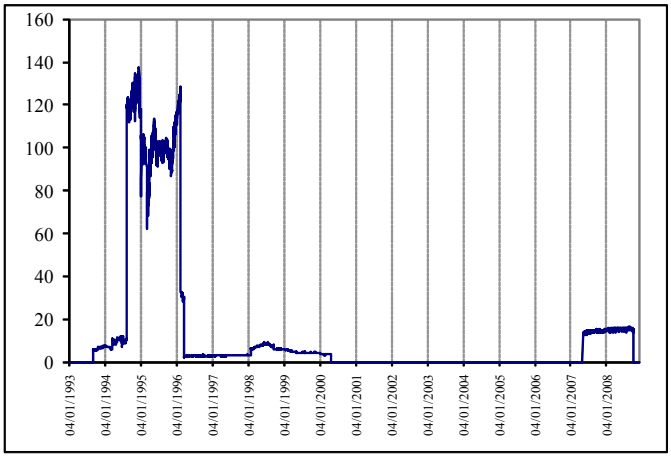
Appendix A.4 Series and sources

- 90-day CDs: It is the weighted average of 90-day CD rates of banks and financial corporations. The holidays and other days that were missing from the series were assigned the data from the immediately preceding day. Therefore, the series was available for the same dates as those used for the representative market rate (TRM in Spanish). Source: Statistics Section, Division of Economic Studies, Banco de la República.
- EMBI+: It is the difference in interest rate paid by the bonds denominated in dollars and the US Treasury Bonds (the holidays and other days missing from the series had the data from the immediately preceding day. Therefore, the series was available for the same dates as those used for the TRM. Source: Foreign Sector Section, Department of Planning and Inflation, Banco de la República.
- VIX: It is the Chicago Board Options Exchange Volatility Index, which "reflects a market estimate of future volatility (30 day usually), based on the weighted average of the implied volatilities for a wide range of strikes. 1st & 2nd month expirations are used until 8 days from expiration, then the 2nd and 3rd are used". Source: Bloomberg (*Ticker*: *VIX+Index*).
- Net foreign exchange intervention (millions of dollars): The intervention of Banco de la Republica in the interbanking foreign currency market. If the number is positive, it means the purchases were larger than the sales. The holidays and other days missing from the series had the data from the immediately preceding day. Therefore, the series was available for the same dates as those used for the TRM. Source: Monetary and Reserves Division, Banco de la República.
- Weighted intervention: It is the "net foreign exchange intervention" series weighted by a moving average of 20 observations of the "size of the foreign exchange market."
- 90-day LIBOR (*London-Interbank Offered Rate*): It is the London interbanking rate for 90-day loans. The holidays and other days missing from the series had the data from the immediately preceding day. Therefore, the series was available for the same dates as those used for the TRM. Source: Monetary and Reserves Division, Banco de la República.
- *Overnight* LIBOR: It is the London interbanking rate for one-day loans. The holidays and other days missing from the series had the data from the immediately preceding day. Therefore, the series was available for the same dates as those used for the TRM. Source: Monetary and Reserves Division, Banco de la República.
- Size of the foreign currency market (millions of dollars): The total amount transacted in the foreign currency interbanking market through operations registered in the DATATEC system (previously known as CITIINFO). The holidays and other days missing from the series had the data from the immediately preceding day. Therefore, the series was available for the same dates as those used for the TRM. Source: Monetary and Reserves Division, Banco de la República.
- TRM: It is the nominal daily exchange rate reported by the Banking Superintendency (now Financial Superintendency). Source: Statistics Section, Division of Economic Studies and Monetary and Reserves Division, Banco de la República.
- Interbanking rate (TIB in Spanish) or the Banking Superintendency basic rate. The series has existed since 1995:01:03 and which is why the data between 1993:01:04 and 1995:02:28 are taken from the survey done by Banco de la Republica (the series between 1993:01:04 and 1995:02:28 is known as "TIB modal"). The holidays and other days missing from the series had the data from the immediately preceding day. Therefore, the series was available for the same dates as those used for the TRM. Source: Statistics Section, Division of Economic Studies, and Monetary and Reserves Division, Banco de la República.
- TAX^i ($i = d$, *O-T-R*, *E-R*): It is the tax equivalent to the reserve requirements on foreign

debt. It is calculated as explained above. Source: Authors' calculations.

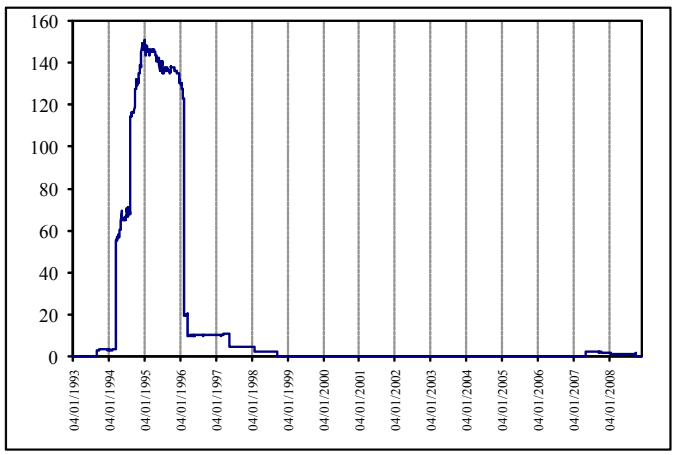
- C*ommodity* price index: It is the arithmetic mean of commodity prices with monthly readjustment. Source: *Bloomberg* (*ticker*: *CRY*).
- CDS: It is a Credit Default Swaps "designed to transfer the credit exposure of fixed income products between parties. The buyer of a credit swap receives credit protection, whereas the seller of the swap guarantees the credit worthiness of the product". Source: Bloomberg (*Ticker*: *CCOL1U5+Index*, which is based on 5yr corporate Colombian debt.
- HYS: It is the BofA Merrill Lynch US High Yield Index, which "tracks the performance of U.S. dollar denominated below investment grade corporate debt publicly issued in the U.S. domestic market. Qualifying securities must have a below investment grade rating (based on an average of Moody's, S&P and Fitch) and an investment grade rated country of risk (based on an average of Moody's, S&P and Fitch foreign currency long term sovereign debt ratings)". Source: Bloomberg (*Ticker*: *H0A0+Index*).

Appendix A.5 Path of TAX^{O-T-R} (equation (5))



Source: Authors' calculations.

Appendix A.6 Path of TAX^{E-R} (equation (6))



Source: Authors' calculations.

Appendix A.7 Effect of the capital control and forex intervention on the peso/US dollar exchange rate mean return and its volatility

A.7-1
Definition of the tax: TAX^d
Sample: 1993:01:04 - 1999:09:30

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constante	0.031	4.86	***	0.031	4.82	***	0.030	1.80	*
Δe_{t-1}	0.218	9.88	***	0.218	9.82	***	0.221	9.96	***
$\Delta spread_t$	-0.003	-2.51	**	0.001	0.26		-0.003	-2.40	**
Δvix_t	0.000	0.30		0.000	0.18		0.000	0.33	
ΔDif_t	-0.001	-0.26		-0.001	-0.22		-0.001	-0.59	
$TAX^d{}_t$	-0.014	-1.82	*	-0.013	-1.79	*	-0.012	-0.72	
$\hat{I}_t$	0.000	0.06		0.000	0.07		-0.001	-0.08	
Δpc_t	-0.004	-0.68		-0.004	-0.58		-0.006	-0.90	
$TAX^d{}_t * \Delta spread_t$	---	---		-0.005	-0.94		---	---	
$TAX^d{}_t * \hat{I}_t$	---	---		---	---		0.001	0.08	
Equation for the variance of the return									
a	0.267	11.74	***	0.271	11.60	***	0.271	11.70	***
b	0.733	32.19	***	0.729	31.19	***	0.729	31.55	***
$\lvert\Delta spread_t\rvert$	0.000	1.00		0.001	1.36		0.001	1.89	*
$\lvert\Delta vix_t\rvert$	-0.001	-1.41		-0.001	-1.44		-0.001	-1.77	*
$\lvert\Delta Dif_t\rvert$	0.001	2.84	***	0.001	2.71	**	0.001	3.05	***
$TAX^d{}_t$	0.001	1.62		0.001	1.68	*	-0.001	-0.37	
$\hat{I}_t$	0.000	3.95	***	0.000	3.77	***	0.001	2.83	***
$\lvert\Delta pc_t\rvert$	0.001	0.56		0.001	0.35		0.004	1.55	
$TAX^d{}_t * \Delta spread_t$	---	---		-0.001	-1.36		---	---	
$TAX^d{}_t * \hat{I}_t$	---	---		---	---		-0.001	-2.37	**
Shape	1.933	31.41	***	1.935	31.71	***	1.938	30.96	***
Observations	1754			1754			1754		
Log Likelihood	50			49			47		

Source: Authors' calculations.

The explanatory variables are: e, natural logarithm of the peso/US dollar nominal exchange rate; *spread*, measurement of the risk in the financial markets in emerging countries; *vix*, measurement of risk in the financial markets in industrialized countries; *Dif*, the interest differential between Colombia and abroad; TAX, the tax equivalent to the reserve requirement on capital inflows; $\hat{I}$, the instrument for forex intervention; *pc*, prices of commodities. Δ is the first difference operator, $|.|$ is the absolute value operator, and *Shape* is the estimated value of the GED distribution shape parameter. The mean equation only reports one lag of the dependent variable. The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively.

A.7-2
Definition of the tax: $TAX^{O\text{-}T\text{-}R}$
Sample: 1993:01:04 - 1999:09:30

Variables	Model 1		Model 2		Model 3	
	Coefficients	*Stat.-t* Sign.	Coefficients	*Stat.-t* Sign.	Coefficients	*Stat.-t* Sign.
Equation for the mean of the return						
Constante	0.019	4.80 ***	0.020	4.95 ***	0.019	4.86 ***
Δe_{t-1}	0.210	9.56 ***	0.214	9.72 ***	0.211	9.48 ***
$\Delta spread_t$	-0.003	-2.46 **	-0.004	-2.30 **	-0.003	-2.56 **
Δvix_t	0.000	0.33	0.000	0.30	0.000	0.44
ΔDif_t	0.001	0.33	0.001	0.47	0.000	0.32
$TAX^{O\text{-}T\text{-}R}{}_t$	0.000	1.15	0.000	1.15	0.000	0.95
$\hat{I}_t$	-0.001	-0.03	0.000	0.02	-0.001	-0.05
Δpc_t	-0.007	-1.07	-0.007	-1.11	-0.008	-1.14
$TAX^{O\text{-}T\text{-}R}{}_t * \Delta spread_t$	---	---	0.000	0.94	---	---
$TAX^{O\text{-}T\text{-}R}{}_t * \hat{I}_t$	---	---	---	---	0.000	-0.09
Equation for the variance of the return						
a	0.267	12.06 ***	0.265	11.86 ***	0.265	12.07 ***
b	0.733	33.11 ***	0.735	32.92 ***	0.735	33.57 ***
$\lvert\Delta spread_t\rvert$	0.000	1.27	0.001	1.44	0.000	1.23
$\lvert\Delta vix_t\rvert$	-0.001	-1.55	-0.001	-1.60	-0.001	-1.44
$\lvert\Delta Dif_t\rvert$	0.001	3.21 ***	0.001	3.05 ***	0.001	2.88 ***
$TAX^{O\text{-}T\text{-}R}{}_t$	-0.001	-0.15	0.000	0.17	0.000	0.80
$\hat{I}_t$	0.000	3.94 ***	0.000	3.70 ***	0.000	2.19 **
$\lvert\Delta pc_t\rvert$	0.002	1.15	0.002	1.10	0.002	1.11
$TAX^{O\text{-}T\text{-}R}{}_t * \Delta spread_t$	---	---	-0.001	-0.77	---	---
$TAX^{O\text{-}T\text{-}R}{}_t * \hat{I}_t$	---	---	---	---	0.000	1.42
Shape	1.944	31.78 ***	1.933	31.51 ***	1.927	31.45 ***
Observations	1754		1754		1754	
Log Likelihood	53		52		52	

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.

A.7-3
Definition of the tax: TAX^{E-R}
Sample: 1993:01:04 - 1999:09:30

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constante	0.021	5.07	***	0.021	5.12	***	0.022	5.26	***
Δe_{t-1}	0.211	9.55	***	0.210	9.55	***	0.213	9.49	***
$\Delta spread_t$	-0.004	-2.61	**	-0.004	-2.29	**	-0.003	-2.52	**
Δvix_t	0.000	0.62		0.000	0.61		0.000	0.50	
ΔDif_t	0.000	0.23		0.000	0.17		0.000	0.21	
TAX^{E-R}_t	0.000	0.23		0.000	0.37		0.000	0.03	
$\hat{I}_t$	0.000	0.01		-0.001	-0.11		-0.001	-0.18	
Δpc_t	-0.006	-0.87		-0.006	-0.87		-0.006	-0.96	
$TAX^{E-R}_t * \Delta spread_t$	---	---		0.000	0.41		---	---	
$TAX^{E-R}_t * \hat{I}_t$	---	---		---	---		0.000	0.17	
Equation for the variance of the return									
a	0.267	12.15	***	0.261	11.72	***	0.265	12.22	***
b	0.733	33.36	***	0.739	33.19	***	0.735	33.91	***
$\lvert\Delta spread_t\rvert$	0.000	1.35		0.001	1.50		0.000	1.33	
$\lvert\Delta vix_t\rvert$	-0.001	-1.55		-0.001	-1.57		-0.001	-1.48	
$\lvert\Delta Dif_t\rvert$	0.001	3.35	***	0.001	3.22	***	0.001	2.92	***
TAX^{E-R}_t	-0.001	-0.41		-0.001	-0.14		0.000	0.83	
$\hat{I}_t$	0.000	4.02	***	0.000	3.83	***	0.000	2.04	**
$\lvert\Delta pc_t\rvert$	0.002	1.10		0.002	1.03		0.002	1.09	
$TAX^{E-R}_t * \Delta spread_t$	---	---		0.000	-0.91		---	---	
$TAX^{E-R}_t * \hat{I}_t$	---	---		---	---		0.000	1.45	
Shape	1.933	31.77	***	1.947	30.98	***	1.912	31.69	***
Observations	1754			1754			1754		
Log Likelihood	53			53			1149		

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.

A.7-4
Definition of the tax: TAX^d
Sample: 1999:10:01 - 2008:12:08

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constante	-0.008	-0.92		-0.005	-0.52		-0.004	-0.47	
Δe_{t-1}	0.171	8.58	***	0.166	8.33	***	0.172	8.61	***
$\Delta spread_t$	0.018	6.27	***	0.015	5.20	***	0.018	6.22	***
Δvix_t	0.003	3.15	***	0.003	2.98	***	0.003	3.10	***
ΔDif_t	-0.001	-0.62		-0.001	-0.57		-0.001	-0.58	
TAX^d_t	-0.028	-1.45		-0.015	-0.75		-0.038	-1.37	
$\hat{I}_t$	0.005	1.05		0.002	0.55		0.002	0.51	
Δpc_t	-0.031	-5.39	***	-0.031	-5.45	***	-0.031	-5.40	***
$TAX^d_t * \Delta spread_t$	---	---		0.031	3.56	***	---	---	
$TAX^d_t * \hat{I}_t$	---	---		---	---		0.006	0.58	
Equation for the variance of the return									
a	0.214	9.90	***	0.210	9.80	***	0.214	9.93	***
b	0.786	36.28	***	0.790	36.80	***	0.786	36.45	***
$\lvert\Delta spread_t\rvert$	0.003	3.33	***	0.003	3.28	***	0.003	3.36	***
$\lvert\Delta vix_t\rvert$	-0.001	-0.17		-0.001	-0.19		-0.001	-0.23	
$\lvert\Delta Dif_t\rvert$	0.000	1.27		0.000	1.26		0.000	1.26	
TAX^d_t	0.009	1.87	*	0.011	2.11	**	0.012	1.19	
$\hat{I}_t$	0.000	0.39		0.000	0.52		0.000	0.52	
$\lvert\Delta pc_t\rvert$	-0.003	-1.61		-0.003	-1.83	*	-0.003	-1.77	*
$TAX^d_t * \Delta spread_t$	---	---		0.005	0.80		---	---	
$TAX^d_t * \hat{I}_t$	---	---		---	---		-0.001	-0.30	
Shape	1.806	27.59	***	1.806	27.57	***	1.806	27.61	***
Observations	2396			2396			2396		
Log Likelihood	1047			1043			1047		

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.

A.7-5
Definition of the tax: $TAX^{O\text{-}T\text{-}R}$
Sample: 1999:10:01 - 2008:12:08

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constante	-0.006	-0.70		-0.005	-0.62		-0.004	-0.48	
Δe_{t-1}	0.170	8.48	***	0.170	8.50	***	0.189	9.38	***
$\Delta spread_t$	0.017	6.21	***	0.013	4.53	***	0.017	6.19	***
Δvix_t	0.003	3.15	***	0.003	2.97	***	0.003	3.08	***
ΔDif_t	-0.001	-0.64		-0.001	-0.47		-0.001	-0.60	
$TAX^{O\text{-}T\text{-}R}{}_t$	-0.003	-1.37		-0.002	-1.07		-0.008	-2.55	**
$\hat{I}_t$	0.003	0.74		0.003	0.57		0.002	0.49	
Δpc_t	-0.030	-5.31	***	-0.029	-5.23	***	-0.030	-5.37	***
$TAX^{O\text{-}T\text{-}R}{}_t * \Delta spread_t$	---	---		0.005	6.41	***	---	---	
$TAX^{O\text{-}T\text{-}R}{}_t * \hat{I}_t$	---	---		---	---		0.004	2.19	**
Equation for the variance of the return									
a	0.217	9.87	***	0.214	9.79	***	0.215	9.97	***
b	0.783	35.61	***	0.786	36.04	***	0.785	36.35	***
$\lvert\Delta spread_t\rvert$	0.003	3.28	***	0.003	3.16	***	0.003	3.41	***
$\lvert\Delta vix_t\rvert$	-0.001	-0.13		-0.001	-0.20		-0.001	-0.18	
$\lvert\Delta Dif_t\rvert$	0.000	1.22		0.000	1.21		0.000	1.24	
$TAX^{O\text{-}T\text{-}R}{}_t$	0.002	2.29	**	0.002	2.46	**	0.001	1.00	
$\hat{I}_t$	0.000	0.69		0.001	0.98		0.001	0.82	
$\lvert\Delta pc_t\rvert$	-0.003	-1.95	*	-0.003	-2.13	**	-0.003	-2.35	**
$TAX^{O\text{-}T\text{-}R}{}_t * \Delta spread_t$	---	---		0.000	0.48		---	---	
$TAX^{O\text{-}T\text{-}R}{}_t * \hat{I}_t$	---	---		---	---		0.000	0.36	
Shape	1.805	27.52	***	1.798	27.50	***	1.803	27.66	***
Observations	2396			2396			2396		
Log Likelihood	1044			1032			1042		

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.

A.7-6
Definition of the tax: TAX^{E-R}
Sample: 1999:10:01 - 2008:12:08

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constante	-0,006	-0,71		-0,006	-0,66		-0,005	-0,55	
Δe_{t-1}	0,172	8,55	***	0,167	8,38	***	0,188	9,31	***
$\Delta spread_t$	0,017	6,21	***	0,013	4,41	***	0,017	6,19	***
Δvix_t	0,003	3,11	***	0,003	3,15	***	0,003	3,08	***
ΔDif_t	-0,001	-0,61		-0,001	-0,55		-0,001	-0,60	
TAX^{E-R}_t	-0,020	-1,15		-0,015	-0,93		-0,061	-2,49	**
$\hat{I}_t$	0,003	0,75		0,002	0,56		0,002	0,53	
Δpc_t	-0,030	-5,33	***	-0,029	-5,16	***	-0,031	-5,36	***
$TAX^{E-R}_t * \Delta spread_t$	---	---		0,042	7,29	***	---	---	
$TAX^{E-R}_t * \hat{I}_t$	---	---		---	---		0,034	2,34	**
Equation for the variance of the return									
a	0,216	9,93	***	0,216	9,80	***	0,216	9,78	***
b	0,784	36,08	***	0,784	35,66	***	0,784	35,44	***
$\lvert\Delta spread_t\rvert$	0,003	3,32	***	0,003	3,08	***	0,003	3,23	***
$\lvert\Delta vix_t\rvert$	-0,001	-0,20		-0,001	-0,22		-0,001	-0,17	
$\lvert\Delta Dif_t\rvert$	0,000	1,19		0,000	1,17		0,000	1,19	
TAX^{E-R}_t	0,014	2,30	**	0,014	2,40	**	0,009	0,95	
$\hat{I}_t$	0,001	0,77		0,001	0,91		0,000	0,67	
$\lvert\Delta pc_t\rvert$	-0,003	-2,03	**	-0,003	-1,80	*	-0,003	-1,75	*
$TAX^{E-R}_t * \Delta spread_t$	---	---		0,000	-0,06		---	---	
$TAX^{E-R}_t * \hat{I}_t$	---	---		---	---		0,003	0,51	
Shape	1,801	27,57	***	1,800	27,50	***	1,805	27,56	***
Observations	2396			2396			2396		
Log Likelihood	1045			1027			1042		

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.

A.7-7
Definition of the tax: TAX^d
Sample: 2008:01:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constante	-0,039	-1,27		-0,041	-1,34		-0,025	-0,77	
Δe_{t-1}	0,136	3,79	***	0,126	3,54	***	0,131	3,58	***
$\Delta spread_t$	0,068	6,36	***	0,080	6,45	***	0,068	6,30	***
Δvix_t	0,004	0,86		0,003	0,67		0,005	1,17	
ΔDif_t	-0,005	-1,64		-0,006	-1,96	**	-0,005	-1,45	
TAX^d_t	0,008	0,15		0,002	0,04		-0,036	-0,61	
I_t	0,043	1,49		0,040	1,39		0,015	0,47	
Δpc_t	-0,157	-8,48	***	-0,144	-7,75	***	-0,147	-7,95	***
$TAX^d_t * \Delta spread_t$	---	---		-0,037	-1,78	*	---	---	
$TAX^d_t * I_t$	---	---		---	---		0,138	1,88	*
Equation for the variance of the return									
a	0,183	3,98	***	0,180	3,81	***	0,195	3,87	***
b	0,817	17,77	***	0,820	17,31	***	0,805	15,95	***
$\lvert\Delta spread_t\rvert$	0,002	0,24		0,001	0,14		0,004	0,39	
$\lvert\Delta vix_t\rvert$	0,002	0,59		0,002	0,57		0,002	0,50	
$\lvert\Delta Dif_t\rvert$	-0,002	-0,64		-0,002	-0,67		-0,001	-0,40	
TAX^d_t	0,017	0,65		0,019	0,77		0,008	0,32	
I_t	-0,002	-0,23		-0,001	-0,14		-0,004	-0,44	
$\lvert\Delta pc_t\rvert$	0,012	0,70		0,013	0,78		0,011	0,64	
$TAX^d_t * \Delta spread_t$	---	---		0,013	0,58		---	---	
$TAX^d_t * I_t$	---	---		---	---		0,022	0,55	
Shape	1,630	11,44	***	1,670	11,43	***	1,637	11,52	***
Observations	674			674			674		
Log Likelihood	765			763			763		

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.

A.7-8
Definition of the tax: $TAX^{O\text{-}T\text{-}R}$
Sample: 2008:01:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constante	-0,039	-1,27		-0,041	-1,34		-0,025	-0,77	
Δe_{t-1}	0,136	3,79	***	0,126	3,55	***	0,131	3,58	***
$\Delta spread_t$	0,068	6,36	***	0,080	6,41	***	0,068	6,31	***
Δvix_t	0,004	0,87		0,003	0,67		0,005	1,17	
ΔDif_t	-0,005	-1,64		-0,006	-2,03		-0,005	-1,46	
$TAX^{O\text{-}T\text{-}R}{}_t$	0,001	0,14		0,000	0,06		-0,002	-0,60	
I_t	0,043	1,49		0,040	1,39		0,015	0,49	
Δpc_t	-0,157	-8,48	***	-0,145	-7,79	***	-0,147	-7,96	***
$TAX^{O\text{-}T\text{-}R}{}_t * \Delta spread_t$	---	---		-0,002	-1,72	*	---	---	
$TAX^{O\text{-}T\text{-}R}{}_t * I_t$	---	---		---	---		0,009	1,83	*
Equation for the variance of the return									
a	0,183	3,98	***	0,178	3,78	***	0,195	3,87	***
b	0,817	17,75	***	0,822	17,40	***	0,805	15,97	***
$\lvert\Delta spread_t\rvert$	0,002	0,24		0,001	0,13		0,004	0,38	
$\lvert\Delta vix_t\rvert$	0,002	0,59		0,002	0,57		0,002	0,50	
$\lvert\Delta Dif_t\rvert$	-0,002	-0,62		-0,002	-0,68		-0,001	-0,38	
$TAX^{O\text{-}T\text{-}R}{}_t$	0,001	0,64		0,001	0,79		0,001	0,31	
I_t	-0,002	-0,24		-0,001	-0,14		-0,004	-0,44	
$\lvert\Delta pc_t\rvert$	0,012	0,69		0,013	0,77		0,011	0,64	
$TAX^{O\text{-}T\text{-}R}{}_t * \Delta spread_t$	---	---		0,001	0,63		---	---	
$TAX^{O\text{-}T\text{-}R}{}_t * I_t$	---	---		---	---		0,001	0,54	
Shape	1,630	11,43	***	1,674	11,41	***	1,636	11,51	***
Observations	674			674			674		
Log Likelihood	765			763			763		

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.

A.7-9
Definition of the tax: TAX^{E-R}
Sample: 2008:01:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3		
	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.	Coefficients	*Stat.-t*	Sign.
Equation for the mean of the return									
Constante	-0,038	-1,22		-0,039	-1,28		-0,023	-0,73	
Δe_{t-1}	0,136	3,79	***	0,128	3,59	***	0,130	3,58	***
$\Delta spread_t$	0,069	6,36	***	0,078	6,26	***	0,067	6,27	***
Δvix_t	0,004	0,84		0,003	0,66		0,005	1,21	
ΔDif_t	-0,005	-1,66	*	-0,006	-1,99	**	-0,005	-1,44	
TAX^{E-R}_t	0,002	0,03		0,001	0,02		-0,033	-0,69	
I_t	0,043	1,49		0,040	1,36		0,015	0,49	
Δpc_t	-0,157	-8,47	***	-0,145	-7,82	***	-0,147	-7,97	***
$TAX^{E-R}_t * \Delta spread_t$	---	---		-0,025	-1,58		---	---	
$TAX^{E-R}_t * I_t$	---	---		---	---		0,114	1,89	*
Equation for the variance of the return									
a	0,182	3,98	***	0,182	3,86	***	0,194	3,86	***
b	0,818	17,86	***	0,818	17,41	***	0,806	16,05	***
$\lvert\Delta spread_t\rvert$	0,002	0,24		0,002	0,16		0,004	0,39	
$\lvert\Delta vix_t\rvert$	0,002	0,62		0,002	0,59		0,002	0,52	
$\lvert\Delta Dif_t\rvert$	-0,002	-0,79		-0,002	-0,76		-0,002	-0,54	
TAX^{E-R}_t	0,017	0,80		0,017	0,82		0,010	0,48	
I_t	-0,002	-0,20		-0,001	-0,12		-0,004	-0,40	
$\lvert\Delta pc_t\rvert$	0,013	0,73		0,014	0,80		0,012	0,66	
$TAX^{E-R}_t * \Delta spread_t$	---	---		0,008	0,46		---	---	
$TAX^{E-R}_t * I_t$	---	---		---	---		0,018	0,55	
Shape	1,629	11,43	***	1,657	11,39	***	1,640	11,56	***
Observations	674			674			674		
Log Likelihood	765			763			763		

Source: Authors' calculations.
The symbols ***, **, * indicate a statistical significance of 1%, 5% and 10%, respectively. The mean equation only reports one lag of the dependent variable.