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Are Capital Controls and Central Bank Intervention Effective?*

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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. The objective of this paper is to evaluate the effectiveness of these policies for depreciating the exchange rate, reducing its volatility, and moderating the exchange rate vulnerability to external shocks. The paper uses high frequency data from Colombia for the period 1993-2010, 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, but have the side effect of augmenting its volatility. Nonetheless, during the period 2008-2010 when both policies were used simultaneously, they were effective to produce a daily average depreciation of the exchange rate, without increasing its volatility.

Keywords: Capital controls (Tobin tax); central bank intervention; exchange rate return; GARCH model; volatility; effectiveness

JEL Classification: C52, E58, F31, F32

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1. Introduction

During the last few years, countries in Latin America and other emerging economies have been receiving an increasing amount of capital inflows as a result of a combination of push and pull factors that have increased the attractiveness of these economies for foreign investment. The loose monetary policy of advanced economies that has reduced their interest rates to historical lows is the most important push factor. In addition, the loss of investor's confidence on the performance of these economies has acted in the same direction.

On top of that, pull factors in emerging economies such as their relatively high interest rates; the increasing confidence on these economies, as reflected in low EMBI and CDS indicators; their fairly good performance during the economic crisis that demonstrated strong fundamentals; and in general, the opportunities of good returns at a low risk, have attracted capital inflows of all kinds to these economies.

In these conditions, appreciation of emerging country's currencies has been widespread. The impact that an excessive currency appreciation could have on the competitiveness of tradable sectors increased the pressure on governments and central banks to adopt policies to reverse this trend. In addition, these economies face the risk of deterioration of their current account balances, the formation of asset price bubbles, excessive foreign indebtedness and increasing financial fragility.

Facing this scenario, economic authorities in emerging markets 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, for example, developed economies should eventually start to raise interest rates to avoid inflationary pressures, once economic recovery has been achieved.

From a theoretical point of view, intervention in the foreign exchange market can affect the level of the exchange rate in different ways. In the case of a non-sterilized intervention, the level of the exchange rate will be affected by the change in the relative supplies of domestic and foreign money, similarly as with any other open market operation. The effects of a sterilized intervention are less direct, and occur through different channels. First, the *signaling channel*, that operates when intervention conveys information to the market about future fundamentals, and particularly, the likely eventual stance of monetary policy. Whenever these signals are credible, expectations of future fundamentals will be revised, which bring about a change in the current exchange rate (Kenen, 1988; Domínguez, 1998). Secondly, *the portfolio channel*. When domestic and foreign assets are imperfect substitutes, an intervention that changes the relative supply of domestic assets will require a change in expected relative returns, which induce

[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.

variations in the exchange rate (Sarno and Taylor, 2001). And thirdly, the *microstructure channel*. This effect occurs through the net purchasing pressure on the foreign exchange market ('orders flows') that intervention entails (Lyons, 2001; Evans and Lyons, 2002). In addition to these traditional channels, Taylor (1994, 1995), Sarno and Taylor (2001) and Reitz and Taylor (2008) have proposed the *coordination Channel* as a means by which forex intervention may be effective. According to this channel, intervention operations may stabilize the exchange rate by encouraging stabilizing speculators to re-enter the market. This is possible thanks to the sudden rise in confidence of the informed traders in fundamental analysis based on the signal provided by official intervention. Regarding the effect of intervention on the volatility of the exchange rate, it has been noted that if information signaled via intervention is entirely credible and unambiguous, and if the central bank is fully committed to reducing volatility, one may expect interventions to be associated with lower exchange rate variances (Domínguez, 1998).

Colombia has been very active by using intervention and capital controls policies either separately and at times simultaneously. In addition, there have been several efforts in the past for empirically assessing the effectiveness of these policies with differing conclusions. The results that Colombia has achieved on exchange rates by employing these policies is something of interest for other countries that have been subject to the same pressures, and that have followed similar policies. Regarding intervention in the foreign exchange market, the Colombian experience has shown that its effectiveness is at most short-lived and in many cases unable to modify the level of the exchange rate (Appendix A). Furthermore, it has been observed that in some instances, intervention increases 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 B). 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]

With regard to the objective of depreciating the exchange rate that the model will evaluate, it is well known that in the context of the inflation targeting regime and free capital movements, setting a target on the exchange rate creates a conflict with the inflation target. As a result, credibility of the central bank on its commitment for controlling inflation weaken, since markets realize that pursuing an exchange rate target compromises the autonomy of monetary policy. Given this conflict, central banks are often reluctant to recognize in their official communications that the ultimate objective of their foreign exchange intervention is to depreciate the exchange rate. Instead, they prefer to announce as the objective of intervention the accumulation of international reserves. To the extent that the objective of accumulating reserves does not involve hidden objectives on the exchange rate, one must expect that intervention have no effects on the path of the exchange rate. As far as exchange rate volatility, central banks often see it as undesirable given its adverse effects on the stability of the financial system, particularly under the presence of currency or term mismatch between assets and liabilities. In the case of Colombia, the central bank has explicitly recognize that one of the objectives of its forex intervention is to 'moderate' the volatility of the exchange rate. On this basis, our econometric model aim at assessing the effectiveness of foreign exchange intervention for: (i) depreciating

[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 exchange rate –even if the Colombian central bank do not explicitly acknowledge this objective due to the policy conflict mentioned above- and; (ii) reduce the volatility of the exchange rate as in fact the Banco de la República has recognized it as one of its objectives for carrying out intervention in the foreign exchange market.

The effort for assessing the effectiveness of both capital controls and foreign exchange intervention is justified, taking into account that they could cause significant efficiency and economic costs. As mentioned, 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 quasi-fiscal costs which, 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.

The remaining of this paper is organized as follows. The second section 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 four sub-samples (1993:01:04 - 1999:09:30; 1999:10:01 - 2010:07:30; 2004:01:01 - 2010:07:30; 2008:01:01 - 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. 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. Later on, 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.

The liberalization of foreign lending in September 1993 was, however, accompanied by a compulsory unremunerated reserve requirement (URR) on short term loans different from trade financing, which remained on place up to April 2000. This deposit had the effects of a tax (a Tobin type of tax) on short term capital inflows.[3] 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.[4]

Initially, in September 1993, only foreign loans with a shorter term than 18-month maturity were required to make the unremunerated 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 URR was reduced to zero in April 2000, once the peso was let free to float. That decision took place in a context when an inflation targeting regime for monetary policy was adopted; the economy was recovering from the deepest recession in almost one century (GDP plunged -4.2% in 1999); and the country was experiencing a rapid drop in international reserves and strong pressures towards a currency devaluation. 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 URR changed broadly, even, at some point of time short-run foreign indebtedness became prohibitive (Appendix C summarizes the central bank legislation on the reserve requirement since 1993).

More recently, in May 2007, in a context where the country was facing a rapid currency appreciation and a strong surge in capital inflows, the central bank decided to activate capital controls by imposing an URR of 40% on both foreign borrowing and portfolio inflows of all maturities which had to be kept at the central bank during 6 months.[5] The URR 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 April 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 the holder the right to sell (buy) foreign exchange to (from) the central bank. The amount of the

[3] Strictly speaking it is not a Tobin (1978) tax because: i) It is not levied on all foreign exchange transactions, but on inflows, in particular on foreign debt inflows; ii) it depends on the maturity of the loans; (iii) it was not permanent; and iv) it has been applied only for Colombia and some other countries so that it is not a worldwide control.

[4] Ocampo and Tovar (1997) have an excellent discussion on the rational that authorities have at that time for continuing with capital controls.

[5] 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.

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 5% 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 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, 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 originated in a strong surge of capital inflows, the central bank initiated a new round of preannounced interventions which went up to September 2011, accumulating US$ 5,180 million (the Colombian international reserves amounted to 32,439 million at the end of that month).

3. Empirical regularities of the Colombian nominal exchange rate and basic statistics[6]

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 quotes for holidays others than Sundays was kept constant and equal to that of the previous working day.[7] Once these adjustments were made, the total sample size reached 4584 observations (260 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 sustained appreciation trend which by mid-2008 took the exchange rate to levels similar to those

[6] The various tests that were implemented and the estimations were made using the 7.20 version of RATS. Henceforth any result on diagnostic or specification tests not reported may be requested directly from the authors.
[7] In the preliminary estimations we also adjusted the sample for the holidays in the United States, giving them the same treatment as weekends, and the results did not change.

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 (Top-left of 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 below by using a unit root test.

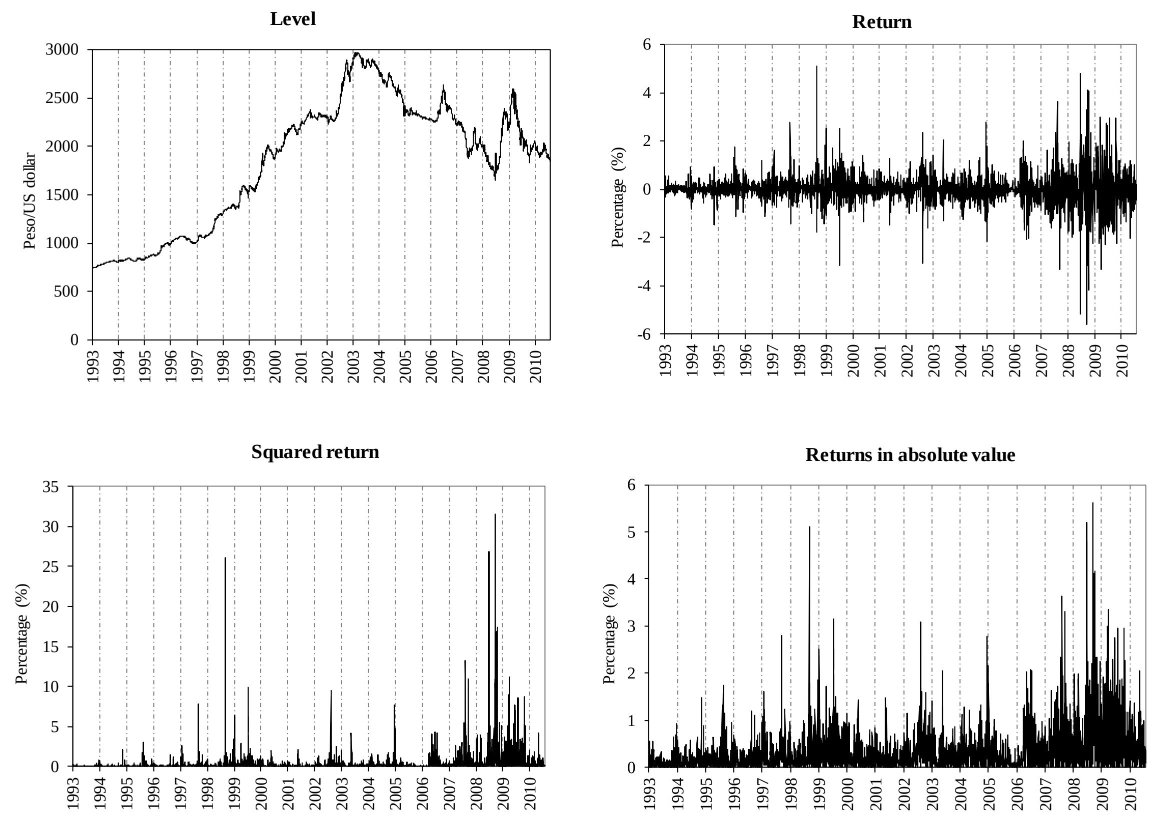
The return, that is the daily percentage variation of the exchange rate (Top-right of Figure 1); the squared return (Bottom-left of Figure 1), and its absolute value (Bottom-right of Figure 1), show a variance (volatility) that changes over time but behaves in a similar way during particular periods of time, thus forming clusters: large/small shocks in the returns tend to be followed by large/small changes in the same variable. 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.[8] 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).[9]

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 indicates that 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 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.

[8] 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.

[9] 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. Therefore, the null hypothesis of a short memory process was not rejected at 1% and 5% level of significance.



Source: Authors' calculations.

Fig. 1. Daily peso/US dollar exchange rate

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 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.

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		
Peŕiod in which the capital control was impossed			
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		
Peŕiod in which forex intervention was used			
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		
Peŕiod in which both the capital control and forex intervention were used			
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 model is an augmented version of the return of the domestic's currency derived from the uncovered interest parity condition for a small open economy under imperfect substituibility between domestic and foreign assets. The regression model is a GARCH model which allows us to simultaneously estimate the mean and variance of the return of the nominal exchange rate. The stylized facts just described, the data frequency used, 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 (Andersen and Bollerslev, 1998; Engle et al., 1990).

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):

$$\Delta e_t = \beta_0 + \underset{(+)}{\beta_1 \Delta e_{t-1}} + \underset{(+)}{\beta_2 \Delta spread_t} + \underset{(+)}{\beta_3 vix_t} + \underset{(-)}{\beta_4 \Delta Dif_t} + \underset{(+)}{\beta_5 TAX_t^j} + \underset{(+)}{\beta_6 I_t} + \underset{(-)}{\beta_7 \Delta pc_t} + \underset{(-)}{\beta_8 Dq_{t-1}}$$

$$+ \underset{(-)}{\beta_9 TAX_t^j * \Delta spread_t} + \underset{(+)}{\beta_{10} TAX_t^j * I_t} + \underset{(+)}{\beta_{11} TAX_t^j * \Delta Dif_t} + u_t \quad (1)$$

[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 initially assumed to be normally distributed *i.i.d.* (identically and independently) with a mean of zero and conditional *h* variance. 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.[11] It is important to mention that we choose to work with time series in first differences because theoretically we are interested in evaluating the effects on the exchange rate return rather than on the level of the exchange rate; and empirically, because the non-stationary nature its level and some of the time series being used.

The explanatory variables of the model are: i) *spread*: Measure the risk in the financial sector of Emerging Markets; ii) *vix*: Measure the volatility (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 URR on capital inflows as a measure of the capital controls. This constitutes our first variable of interest (the index *j* indicates the alternative measurements of the *TAX* variable, as explained below; v) *I*: The forex central bank intervention measure, which is our second variable of interest. Since it cannot be ruled out that intervention be decided by authorities as a reaction to the behavior of the exchange rate, a serious simultaneity problem would be introduced in equation (1) that would bias the estimations.[12] In order to prevent this, we

[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] 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.

[12] The literature on this issue has always recognized the potential problem of a simultaneous bias between intervention and the exchange rate. For instance Kearns and Rigobon (2002, page 3) states that: "the insignificance and incorrectly signed coefficients in many previous studies indicate that an accurate estimation of the impact of

instrument the intervention variable as shown below; vi) *pc*: The commodity prices; vii) *Dq*: The misalignment measure of the real exchange rate; and viii) the interaction variables $TAX^{j}*\Delta spread$, $TAX^{j}*I$, and $TAX^{j}*\Delta Dif$ (in Appendix D we provide a detailed description of the series used). The logarithmic exchange rate series, the logarithm of the *spread*, the interest differential and the logarithm of prices of commodities were differentiated once to obtain stationary 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 Emerging Markets: If the risk increases, the exchange rate return of the domestic currency should increase; *vix*, the effect of the perception of risk in the financial markets of the industrialized countries. According to the flight to quality hypothesis, if this type of risk increases, then capitals leave Emerging Markets and depreciates their currencies; *Dif*, the influence of interest differential on capital movements (the so called carry trade effect): If this differential raises then capital inflows increase, putting pressure on the local currency to appreciate; *TAX*, the effect of the URR on restricting capital inflows and then reducing the appreciation pressures on the peso; *I*, the consequence of the central bank intervention in the forex market; *pc*, the effect of real flows due to variations on commodity prices, since Colombian mainly exports are those type of goods;[13] *Dq* acts as an error correction mechanism for the nominal exchange rate towards its long-run equilibrium level: When *Dq* is positive in the current period the real exchange rate of the peso is undervalued, so that it is expected that the nominal rate appreciates in the next period. On the contrary, if the real exchange rate of the peso is overvalued it is expected that the nominal rate depreciates in the next period. The implicit assumption here is that the nominal and the real exchange rate are cointegrated variables;[14] and finally, the three interaction variables, whose motivation and expected effects are explained below.

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):

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

$$\underset{(-)}{\alpha_7 TAX_t^j * \Delta spread_t} + \underset{(-)}{\alpha_8 TAX_t^j * I_t} + \underset{(-)}{\alpha_9 TAX_t^j * \Delta Dif_t} \qquad (2)$$

intervention on the exchange rate must incorporate the contemporaneous effect, and account for the endogeneity of these variables". See also Rogoff (1984) and Dominguez and Frankel (1993)

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

[14] The existence of a long-run relationship between the nominal and the real exchange rate, or a cointegration relationship from econometrics point of view, can be traced to Krugman and Obstfeld (1991). The assumption behind this is that there are nonmonetary factors that can cause sustained deviations from PPP. From a microstructure approach to exchange rates, Reitz and Taylor (2008) show that the real exchange rate affects the equilibrium spot exchange rate through the dealers expectations about the future path of macroeconomic fundamentals, among them, the real exchange rate. To give empirical support to our view we run simple Engle-Granger cointegration tests for the series of nominal exchange rate, real exchange rate and the estimated "equilibrium" real rate. The results showed evidence that supported our assumption of cointegration.

where α_0 is the constant term,[15] 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 variance. The coefficients we are interested mainly on are α_4 and α_5, which measure, respectively, the effects of the capital controls and forex 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 the volatility of the return. As was argued by Eichengreen et al. (1995), by throwing "sand in the wheels", capital controls constrain speculative inflows helping to stabilize the exchange rate and reducing its short term volatility. As for forex intervention, as said before, Dominguez (1998) argued that if the signal that intervention provides on the future monetary policy stance is credible and unambiguous, and if the foreign exchange market is efficient, then an intervention should not have any influence on the volatility of the exchange rate. On this basis, we will conclude that the central bank intervention is effective if it reduces -or at least do not increase- the daily average volatility of the return.

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 it was shown 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).

Finally, in the estimation of the regression model given by equations (1) and (2), we included three interaction variables, firstly between the TAX^j variable and the *spread* ($TAX^i * \Delta spread$), in order to deduce whether or not the capital control helped to isolate the domestic foreign exchange market from the shocks in Emerging Markets. If the capital control was effective for this purpose, the coefficient of the interaction variable should be negative and significant in the equation of the mean and of the variance; secondly, between the TAX^j variable and the forex intervention variable ($TAX^i * I$), to assess if the combination of the capital control and foreign exchange intervention had an impact on the exchange rate return beyond each policy taken separately. If the interaction of both policies were effective the resulting coefficient must be positive and statistically significant in the equation of the mean and negative and statistically significant in the equation of the variance, and thirdly, between the TAX^j variable and the interest rate differential *Dif* ($TAX^i * \Delta Dif$) to evaluate, in the spirit of Villar and Rincón (2003), whether the URR helped central bank to gain autonomy by allowing it "to increase the domestic interest rates… without simultaneously creating additional pressures towards the appreciation of the… exchange rate" (Ibid., page 375). If the capital control was effective in attaining this task, the coefficient of the interaction variable must be positive and statistically significant in the equation

[15] Notice that α_0 represents also the constant term of the numerator of the unconditional or long term variance of the return. Since the conditional variance will depend on other explanatory variables besides of the ARCH and GARCH components, that is the unconditional variance will be time varying or time dependent, the standard assumption of $\alpha_0 \geq 0$ is not strictly necessary. What is required is that the numerator of the unconditional variance be positive: From equation (2) one can derive the unconditional variance of the unexpected returns u_t as:

$$\sigma_t^2 = \left[\alpha_0 + \alpha_1|\Delta spread_t| + \alpha_2 vix_t + \alpha_3|\Delta Dif_t| + \alpha_4 TAX_t^i + \alpha_5 I_t + \alpha_6|\Delta pc_t| + \alpha_7 TAX_t^j * \Delta spread_t + \alpha_8 TAX_t^j * I_t + \alpha_9 TAX_t^j * \Delta Dif_t\right] \Big/ [1 - a - b]$$

of the mean (and possibly negative in the equation of the variance).

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 has similarities to those estimated by Edwards and Rigobon (2005) for the Chilean case and Clements and Kamil (2008) for Colombia.

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 Emerging Markets Bond Index Plus (EMBI+) is used as the measurement of the *spread*. We tried to capture the external risk shocks excluding Colombia from the aggregate index but abandoned this idea for different reasons. First of all, the EMBI-Colombia was not available for the sample needed. Second, for the sample available the correlation coefficient between the EMBI+ and the EMBI-Colombia is 0.9, which makes unnecessary separate Colombia from the index. Third, we wanted to avoid measurement errors in this explanatory variable by including proxies we built to exclude Colombia from the total index (notice that the countries' weights used to build the aggregate index are unknown).[16]

The Chicago Board Options Exchange Volatility Index (*vix*) is used as the measurement of the risk in the international financial markets.

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 URR on capital inflows is calculated in three alternative ways. The first is simply a dummy variable that takes the value of one when there is capital 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 URR 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 URR. Thus, the tax is simply the excessive relative cost caused by the URR. If there were no control, only the financial cost would exist.

If we assume that *tm* is the time (in months) that an URR on foreign debt had to be kept in the central bank, then the present value of the cost of the URR per dollar borrowed (*PVURR*) is expressed as:

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

[16] The simplest calculation was to build an index with the same base for the individual countries' EMBIs, compute a simple average and then subtract the EMBI-Colombia from the aggregate. The second one was to build weights from the GDP in dollars for each country and applied the steps followed when building the first measurement.

where θ =1, when the URR 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. Notice that the *PVURR* is positively related with the interest rate and negatively related with the devaluation expectations: the higher i the bigger the cost of the URR, and the larger $\Delta E^{\in}$ the smaller the cost of the URR.

Now, if the relevant nominal interest rate over a foreign loan requested by a Colombian agent is defined as the sum of the foreign interest rate i^f plus the spread of the Colombian public bonds, which it is assumed to reflect the country-risk for Colombia, $i^* = i^f$ + *spread-col*, the loan period (in months) is referred to as tc and the percentage of the reserve requirement as ε, then the total cost of a foreign loan (z), including the cost of the URR, can be written as:

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

Observe that the longer the maturity of the loan tc the smaller the cost z, which reflects the purpose of the URR to levy a higher cost on short-run loans than long-run ones.

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

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

Notice that variables θ, i, tm, i*, i^f, tc, and ε in equations 3 to 5 are directly observable. Variables *spread-col* and $\Delta E^{\in}$ are not. The first one was calculated as the implicit difference between the interest rate paid by the Colombian public bonds denominated in US dollars and the US Treasury Bonds of the same maturities.[17] The expectations of the peso/US dollar exchange rate return, $\Delta E^{\in}$, were estimated assuming that agents in the forex market base their expectations on past observations of the exchange rate fundamentals. [18] Thus, we estimate the expectations as 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 *spread-col* and of the daily foreign-domestic interest differential.

Finally, the value of the tax is calculated using the observable and estimated non-observable components and 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 E).

[17] The series was built by researchers of the Banco de la República and it is not public.

[18] The model could be written as $\Delta E^{\epsilon}_{t+s} = f(.)_{t-1} + \mu_{t+s}$, where $f(.)$ is a linear function of the exchange rate fundamentals and μ is the error term. Notice that if μ is *white-noise* agents have rational expectations. Therefore, agents' expectations are estimated as the statistical expected values ($\hat{f}(.)$).

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 used by Cardenas y Barrera (1997) for evaluating the effectiveness of capital controls in the case of Colombia and De Gregorio et al. (2000) and Edwards and Rigobon (2005) for the Chilean case. According to these authors, the equivalent tax of the URR on 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):

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

where i^f is the foreign interest rate, which measures the opportunity cost of the URR. Just as in the previous case, the tax is calculated as an average on the basis of the different values of *tc*, *tm* and ε (Appendix F). Notice that this formulation assumes that the reserve requirement is always in local currency. Under the tax definition given by equation (6), if *tm* is assumed constant and given, $TAX^{E\text{-}R}$ is a decreasing function of *tc* so that the longer the loan term *tc*, the lower the equivalent tax imposed by the control.

Now, the indicator of the central bank's intervention in the forex market (*I*) is constructed as the relation 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 (Appendix G). 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. For this purpose 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 Czech Republic, and Toro and Julio (2005) and Kamil (2008) for Colombia.

The instrument for the forex intervention variable I ($\hat{I}$) was calculated using a generalized instrumental variable procedure. Thus, we estimate it as the fitted value of the following (random) reaction function of the central bank (the expected signs are in parenthesis), which is the foreign exchange authority:

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

Where υ is a stochastic shock to the forex intervention policy which is assumed to behave white noise. The lagged *I* variable in equation (7) captures the possible intervention persistence. The last term in equation (7), 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 annual inflation at each corresponding month and the annual inflation target. Then, the daily *INFS* series are obtained allocating the corresponding monthly difference to each of the days of that month. In order to smooth out the series, we use a moving average of one month window.[19] If the

[19] By construction this method introduces a well-known problem of error of measurement which creates a specification bias (positive or negative). We could have addressed this issue in several ways. For example, we may have used a Kalman Filter or other econometric methodologies such as the disaggregation approach of unobserved time series proposed by Guerrero (2003). However, these techniques are not free from statistical errors due to 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*.

The prices for nineteen *commodities* based on the Bloomberg Commodity Index are used to account for the foreign exchange pressures coming from the current account.

The misalignment of the real exchange rate (*Dq*) was calculated as the difference between the monthly real exchange rate taken from the central bank statistics (when it increases it depreciates) and the estimated monthly equilibrium real exchange rate made by the Real Exchange Rate Team of the Economic Studies Department of the central bank. The latter is a simple average of four estimates of the equilibrium real exchange rate: i) The filtered value of the real exchange rate using the Hodrick and Prescott filter; ii) the fitted value of a structural VEC model of the real exchange rate on real variables such as net foreign assets, terms of trade and an indicator of the Colombian trade openness; iii) the fitted value of a VEC model of the real exchange rate on real variables such as net foreign assets, terms of trade, public expenditures and relative productivity between Colombia and USA; and iv) the estimated of the "fundamental equilibrium exchange rate" according to the methodology developed by the International Monetary Fund. As in the case of the *INFS* series, the daily *Dq* series are obtained assigning the corresponding monthly observation to every of the days of that month, and then smoothing the series out by using a moving average of one month window.

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 present the estimates for the entire sample 1993:01:04 - 2010:07:30. Then, based on the results of the statistical tests we adjust the model and, present the results for four sub-samples (1993:01:04 - 1999:09:30; 1999:10:01 - 2010:07:30; 2004:01:01 - 2010:07:30; 2008:01:01 - 2010:07:30). The first two subsamples were required given the changes of the monetary and foreign exchange regimes by the end of the nineties, which implied a structural change as supported by the statistical tests. The third subsample covers a period of a very active intervention policy when new forex intervention modalities and capital controls were utilized in a context of changing external conditions and mounting appreciation pressures. Finally, the latest 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).

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estimation of unobserved components. Moreover, given the nature of the required time series transformation (from monthly to daily series), the errors may be larger. Therefore, we recognize that a specification bias could be present, but given the frequency of our data the solution may be more expensive than the problem.

6.1 Total sample: 1993:01:04 - 2010:07:30

i.) *Diagnostic and specification tests*

First of all, we test if equation (7) is both well specified and the instruments are valid using the Sargan test. It is obtained that *I* and *INFS* are valid instruments for forex intervention. After choosing them, we carried out the Kleibergen-Paap (2006) *rk* statistics of under-and-weak identification. First, the tests showed that the null hypothesis of under-identification was rejected, which means that the model is identified. Second, the null hypothesis of the equation being weakly identified was also rejected. Then, 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 1. Afterward, we corroborated the presence of at least one ARCH component 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 of the unexpected returns *u* of equation (1) to fulfill normality so that we used the Kolmogorov-Smirnov test to evaluate their distribution. The tests reported that the distribution was neither normal nor *t-student* so that we used a function of *generalized* GED distribution (Generalized Error Distribution).[20] The GED distribution was also used by Toro and Julio (2005), Castaño et al. (2008), and Echavarria et al. (2009b), who also estimated models of the GARCH family for the Colombian peso exchange rate.

Thirdly, we carried out tests for detecting 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 but not at 10%. 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 that the constant term in the variance equation turned out to be negative. Secondly, the estimated coefficients *a* and *b* for equation (2) turned out to be larger than one, which could indicate that the conditional variance *h* is not stationary. Notice that the hypothesis that *h* is a *long memory* process was not completely corroborated by the test that was used. 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

[20] It is said that a random variable (continuous) *X* is *GED* distributed if its probability density function has the following form: $f(X_t) = exp\left[(-|X_t|/\lambda)^{2/\upsilon}/2\right]/\lambda\left(2^{(\upsilon/2)+1}\right)\Gamma(1+\upsilon/2)$, 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.

(1996) and Davidson (2004). In the Colombian case, Castaño et al. (2008) 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, it may be inappropriate for analyzing the data.

Therefore, and based on the statistical findings, we use a AR(1)-IGARCH(1,1) model which imposes the $a + b = 1$ restriction on equation (2).[21] Additionally, we imposed the restriction that the constant term in the conditional variance to be zero ($\alpha_0 = 0$). Notice that 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. [22] This was demonstrated also by Jensen and Rahbek (2004). These authors showed that even under the case of a + b > 1, which is our case, "the likelihood-based estimator for the GARCH parameters is consistent and asymptotically normal in the entire parameter region including both stationary and explosive behavior" (Ibid., pp. 1203).[23] 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.[24]

ii.) *Estimations*

In this section, we show and discuss the results of the simultaneous estimation of the AR(1)-IGARCH(1,1) model for the mean and variance of the exchange rate return given by equations (1) and (2). As will be common throughout the estimations, we estimated a regression for each calculation method of the tax equivalent to the URR, when TAX^d is used, when the implementation of equation (5) ($TAX^{O\text{-}T\text{-}R}$) is used, and when equation (6) ($TAX^{E\text{-}R}$) is employed. In addition, for each definition of the tax, we estimate five alternative specifications. The first regression model includes all the explanatory variables, but excludes the interaction variables; the second incorporates the $TAX^i{*}spread$ interaction variable, the third the $TAX^i{*}\hat{I}$ interaction variable, the fourth the $TAX^i{*}\Delta Dif$ interaction variable, and the fifth the whole set of explanatory variables (the least restricted model). Hence, at the end we will have fifteen estimates of equations (1) and (2) for each sample.

The estimates indicate, in the first place, that the capital control is statistically non-significant in most of the cases and when it is significant, the average return on the exchange rate falls instead

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[21] Under the IGARCH the unconditional variance does not exist (the denominator of equation in footnote 14 equals zero). However, in this paper only the conditional variance is of interest.

[22] We did not find an economic argument to support the two restrictions, besides of avoiding spurious results in the case of the former. Another justification for this restriction, statistically speaking is that we wanted to reduce the "amplitude" (Davidson, 2004) of the GARCH model, that is, to reduce the size of the amplitude of the variations of the conditional variance. This may have been caused by strong outliers in the variance of the returns at times of high international financial turbulence, as shown by the squared returns and returns in absolute values in Figure 1. To evaluate this restriction we compare the in-sample forecasts of model (2) with the square returns of Figure 1. The figures showed almost a perfect fit except for the biggest outliers. As for the second restriction, that is, equation (2) without drift ($\alpha 0=0$), it was indifferent whether we restrict it or not, as shown by the fitted values of the conditional variance (the drift coefficient estimates were close to zero).

[23] Moreover, they stated that "the requirements for existence of moments and stationarity for the GARCH process can be ignored when reporting, e.g., standard deviations and test statistics involving the likelihood-based estimators" (Ibid., pp. 1204). We report only the results under the IGARCH process, though.

[24] 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.

of increasing (Tables 2.1-2.3). As for the variance of the return, the control has no effect on it. The coefficient of the TAX^j**spread* interaction variable turned out to be significant in most of the cases and with the expected sign. This would provide evidence to conclude that the control helped to stem devaluation pressures and reduce the volatility of the exchange rate during episodes of external risk shocks, although regarding volatility its effect is almost nil. The $TAX^i * \hat{I}$ and $TAX^i * \Delta Dif$ interaction variables were non-significant in the mean and variance equations in most cases. When the former is statistically significant in the variance equation it increases the return volatility. The results for mean and variance of the exchange rate return do not coincided with those found by Edwards and Rigobon (2005) for the Chilean case, but they do with those of Clements and Kamil (2008) in the case of Colombia. Our results did coincide with those of the former authors for the TAX^j**spread* interaction variable.

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. The inability of intervention to affect the exchange rate return contradicts most of the findings of the Colombian literature (Appendix A). Nevertheless, this estimation coincides with previous research that also found that intervention increases volatility. As said above, the use of capital control and foreign exchange intervention at the same time has no effect on the mean return but their simultaneous presence does seem to 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.

To highlight how our results differ from the previous literature we run again all regressions (for the current sample and the subsamples explained below) with one policy variable at a time. The results showed non-significant changes in the size of the coefficients or their standard errors in either case, which seems to rule out any specification problem related to omitting a relevant variable. In addition, they provide additional evidence of the robustness of our results against the literature that finds that forex intervention is effective to depreciate the peso (see Appendix A). As for the effects of the capital controls on the mean and variance of the return, our findings generally showed non-significant effects which contrasts with those found by Edwards and Rigobón (2005), who suggest that capital controls depreciate the nominal exchange rate in the Chilean case.

The rest of control variables such as the measure of risk perception in EM, the prices of commodities and the misalignment of the real exchange rate are statistically significant and with the expected signs in the equation for the mean of the return. These show that, together with the lagged self-comportment of the return, those variables are the determinants of the daily average behavior of the exchange rate return of the peso. As for the variance equation, the risk perception in Global Markets and the volatility of the interest rate differential seem to be the key determinants of the return volatility of the peso.

It is interesting to note four 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 turns out to be non-significant in all of the regressions. That is not a surprising result for the current data given the fact that the sum of gross private portfolio flows and private debt (which are mostly dependent on interest rate differentials) are a small portion of total capital flows of the balance of payments.

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
Total sample: 1993:01:04 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.
Equation for the mean of the return															
Constant	0.004	0.48		0.003	0.34		0.004	0.47		0.005	0.51		0.003	0.30	
Δe_{t-1}	0.170	12.83	***	0.168	12.77	***	0.171	12.89	***	0.171	12.95	***	0.168	12.77	***
$\Delta spread_t$	0.003	2.41	**	0.015	6.78	***	0.003	2.51	**	0.003	2.54	**	0.015	6.77	***
vix_t	0.001	2.29	**	0.001	2.45	***	0.001	2.29	**	0.001	2.27	**	0.001	2.44	**
ΔDif_t	-0.000	-0.32		-0.000	-0.54		-0.000	-0.38		-0.000	-0.97		-0.000	-1.19	
TAX^d_t	-0.031	-3.62	***	-0.029	-3.34	***	-0.031	-3.61	***	-0.032	-3.67	***	-0.029	-3.33	***
$\hat{I}_t$	-0.000	-0.87		-0.001	-0.99		-0.000	-0.32		-0.000	-0.80		-0.000	-0.22	
Δpc_t	-0.029	-6.84	***	-0.028	-6.47	***	-0.029	-6.79	***	-0.030	-7.07	***	-0.029	-6.72	***
Dq_{t-1}	-0.003	-5.93	***	-0.003	-5.68	***	-0.003	-5.95	***	-0.003	-6.01	***	-0.003	-5.67	***
$TAX^d_t * \Delta spread_t$	---	---		-0.017	-6.38	***	---	---		---	---		-0.017	-6.27	***
$TAX^d_t * \hat{I}_t$	---	---		---	---		-0.000	-0.04		---	---		-0.000	-0.21	
$TAX^d_t * \Delta Dif_t$	---	---		---	---		---	---		0.002	1.90	*	0.002	2.25	**
Equation for the variance of the return															
a	0.209	15.51	***	0.211	15.42	***	0.209	15.56	***	0.208	15.45	***	0.210	15.35	***
b	0.791	58.82	***	0.789	57.71	***	0.791	58.75	***	0.792	58.89	***	0.790	57.77	***
$\|\Delta spread_t\|$	0.000	0.98		0.000	1.39		0.000	0.95		0.000	1.03		0.000	1.48	
vix_t	0.000	2.25	**	0.000	2.34	**	0.000	2.24	**	0.000	2.24	**	0.000	2.28	**
$\|\Delta Dif_t\|$	0.000	2.50	**	0.000	2.44	**	0.000	2.51	**	0.000	2.35	**	0.000	2.28	**
TAX^d_t	0.001	0.97		0.000	0.34		0.001	0.94		0.000	0.85		0.000	0.15	
$\hat{I}_t$	0.000	2.82	***	0.000	2.77	***	0.000	0.47		0.000	2.55	**	0.000	0.35	
$\|\Delta pc_t\|$	-0.001	-0.94		-0.001	-1.16		-0.001	-0.81		-0.001	-0.89		-0.001	-0.97	
$TAX^d_t * \Delta spread_t$	---	---		-0.001	-1.78	*	---	---		---	---		-0.001	-1.85	*
$TAX^d_t * \hat{I}_t$	---	---		---	---		0.000	0.45		---	---		0.000	0.47	
$TAX^d_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.58		0.000	0.58	
Shape	1.847	48.52	***	1.849	47.55	***	1.840	48.79	***	1.842	48.59	***	1.842	47.53	***
Observations	4583			4583			4583			4583			4583		
Log Likelihood	1670			1653			1671			1669			1652		

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 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; *Dq*, misalignment of the real exchange rate. 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: $TAX^{O\text{-}T\text{-}R}$
Total sample: 1993:01:04 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	t	Sig.	Coeff.	t	Sig.	Coeff.	t	Sig.	Coeff.	t	Sig.	Coeff.	t	Sig.
Equation for the mean of the return															
Constant	0.000	0.01		0.000	0.03		0.000	-0.01		0.000	0.01		-0.001	-0.05	
Δe_{t-1}	0.171	12.86	***	0.171	12.88	***	0.170	12.71	***	0.171	12.89	***	0.170	12.75	***
$\Delta spread_t$	0.003	2.71	***	0.004	2.79	***	0.003	2.71	***	0.003	2.70	***	0.004	2.72	***
vix_t	0.001	1.24		0.001	1.26		0.001	1.26		0.001	1.25		0.001	1.34	
ΔDif_t	-0.000	-0.33		-0.000	-0.33		-0.000	-0.34		-0.000	-0.42		-0.000	-0.40	
$TAX^{O\text{-}T\text{-}R}_t$	0.000	0.69		0.000	0.74		0.000	0.58		0.000	0.67		0.000	0.55	
$\hat{I}_t$	-0.000	-0.45		-0.000	-0.48		-0.000	-0.06		-0.000	-0.40		-0.000	-0.06	
Δpc_t	-0.028	-6.49	***	-0.028	-6.53	***	-0.028	-6.55	***	-0.028	-6.51	***	-0.028	-6.56	***
Dq_{t-1}	-0.001	-4.09	***	-0.001	-4.21	***	-0.001	-4.11	***	-0.001	-4.10	***	-0.001	-4.27	***
$TAX^{O\text{-}T\text{-}R}_t * \Delta spread_t$	---	---		-0.000	-1.37		---	---		---	---		-0.000	-1.41	
$TAX^{O\text{-}T\text{-}R}_t * \hat{I}_t$	---	---		---	---		-0.000	-1.17		---	---		-0.000	-0.94	
$TAX^{O\text{-}T\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.23		0.000	0.29	
Equation for the variance of the return															
a	0.210	15.56	***	0.210	15.56	***	0.211	15.66	***	0.211	15.58	***	0.210	15.66	***
b	0.790	58.40	***	0.790	58.52	***	0.789	58.56	***	0.789	58.43	***	0.790	58.84	***
$\lvert\Delta spread_t\rvert$	0.000	1.13		0.000	1.43		0.000	1.28		0.000	1.28	**	0.000	1.54	
vix_t	0.000	2.49	**	0.000	2.30	**	0.000	2.28	**	0.000	2.36	***	0.000	2.17	**
$\lvert\Delta Dif_t\rvert$	0.000	2.43	**	0.000	2.45	**	0.000	2.42	**	0.000	2.41	**	0.000	2.42	**
$TAX^{O\text{-}T\text{-}R}_t$	0.000	0.41		0.000	0.34		0.000	0.66		0.000	0.21		0.000	0.54	
$\hat{I}_t$	0.000	2.71	***	0.000	2.64	***	0.000	1.24		0.000	2.46	**	0.000	1.29	
$\lvert\Delta pc_t\rvert$	-0.001	-0.82		-0.001	-0.88		-0.001	-0.67		-0.001	-0.79		-0.001	-0.74	
$TAX^{O\text{-}T\text{-}R}_t * \Delta spread_t$	---	---		-0.000	-0.89		---	---		---	---		-0.000	-0.85	
$TAX^{O\text{-}T\text{-}R}_t * \hat{I}_t$	---	---		---	---		0.000	2.12	**	---	---		0.000	2.13	**
$TAX^{O\text{-}T\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.66		0.000	0.22	
Shape	1.839	48.46	***	1.838	48.25	***	1.831	47.98	***	1.837	48.25	***	1.828	47.98	***
Observations	4583			4583			4583			4583			4583		
Log Likelihood	1677			1676			1674			1676			1673		

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: $TAX^{E\text{-}R}$
Total sample: 1993:01:04 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**
Equation for the mean of the return															
Constant	0.002	0.19		0.001	0.06		0.002	0.21		0.002	0.23		0.001	0.06	
Δe_{t-1}	0.171	12.86	***	0.172	12.91	***	0.170	12.71	***	0.171	12.88	***	0.171	12.77	***
$\Delta spread_t$	0.003	2.75	***	0.005	3.16	***	0.004	2.87	***	0.003	2.77	***	0.005	3.23	***
vix_t	0.001	1.14		0.001	1.33		0.001	1.16		0.001	1.10		0.001	1.35	
ΔDif_t	-0.000	-0.33		-0.000	-0.39		-0.000	-0.34		-0.000	-0.35		-0.000	-0.38	
$TAX^{E\text{-}R}_t$	-0.000	-0.02		-0.000	-0.17		-0.000	-0.30		-0.000	-0.03		-0.000	-0.46	
$\hat{I}_t$	-0.000	-0.51		-0.000	-0.35		-0.000	-0.25		-0.000	-0.48		-0.000	-0.37	
Δpc_t	-0.029	-6.66	***	-0.028	-6.59	***	-0.029	-6.74	***	-0.029	-6.64	***	-0.029	-6.61	***
Dq_{t-1}	-0.002	-4.22	***	-0.002	-4.45	***	-0.002	-4.40	***	-0.002	-4.21	***	-0.002	-4.49	***
$TAX^{E\text{-}R}_t * \Delta spread_t$	---	---		-0.000	-1.74	*	---	---		---	---		-0.000	-2.03	**
$TAX^{E\text{-}R}_t * \hat{I}_t$	---	---		---	---		-0.000	-0.46		---	---		-0.000	-0.27	
$TAX^{E\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.04		0.000	0.00	
Equation for the variance of the return															
a	0.210	15.58	***	0.210	15.61	***	0.210	15.75	***	0.210	15.56	***	0.209	15.64	***
b	0.790	58.60	***	0.790	58.56	***	0.790	59.09	***	0.790	58.50	***	0.791	59.15	***
$\lvert\Delta spread_t\rvert$	0.000	1.13		0.000	1.47	**	0.000	1.52		0.000	1.20		0.001	1.71	*
vix_t	0.000	2.52	**	0.000	2.34	**	0.000	2.14	**	0.000	2.43	**	0.000	2.14	**
$\lvert\Delta Dif_t\rvert$	0.000	2.45	**	0.000	2.47	**	0.000	2.46	**	0.000	2.45	**	0.000	2.45	**
$TAX^{E\text{-}R}_t$	0.000	0.30		0.000	0.15		0.000	0.64		0.000	0.23		0.000	0.53	
$\hat{I}_t$	0.000	2.77	***	0.000	2.73	***	0.000	0.98		0.000	2.55	**	0.000	0.95	
$\lvert\Delta pc_t\rvert$	-0.001	-0.88		-0.001	-0.95		-0.001	-0.78		-0.001	-0.87		-0.001	-0.96	
$TAX^{E\text{-}R}_t * \Delta spread_t$	---	---		-0.000	-0.85		---	---		---	---		-0.000	-0.83	
$TAX^{E\text{-}R}_t * \hat{I}_t$	---	---		---	---		0.000	2.30	**	---	---		0.000	2.25	**
$TAX^{E\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.30		0.000	0.03	
Shape	1.839	48.36	***	1.837	48.15	***	1.824	47.94	***	1.839	47.99	***	1.830	47.90	***
Observations	4583			4583			4583			4583			4583		
Log Likelihood	1677			1675			1674			1677			1672		

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.

For instance, for the period 1994-2009, these private flows amounted on average to 30% of the capital account balance (gross private portfolio flows added to only 1%). In contrast, gross foreign direct investment (FDI) and public flows were on average equivalent to 70% of the capital account balance. Since FDI and public flows respond to different incentives, it is easy to understand the reason why the interest rate differential turned out to be non-significant for explaining the mean return of the exchange rate.

The second one, which contrasts to the above result, is that the interest rate differential happened to be a key determinant of the volatility of the exchange rate return. More precisely, variations of the interest rate differential raises without ambiguity the volatility of the exchange rate return. This result might be a consequence of the short term character of private capital flows, both portfolio and debt that instill volatility to the exchange rate.

The third thing to note 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 reduces the exchange rate return, that is, appreciates the peso.

The fourth one is the role played by the error correction mechanism captured by the misalignment of the real exchange rate: According to the size of the coefficient, it seems to take a lot of time to the nominal exchange rate to adjust and come back to the level required by the equilibrium real exchange rate.

Before continuing, it is worth to mention that we evaluated the possible presence of a non-linear effects of the capital control and/or intervention on the exchange rate return; that is whether their size matter or not. To do this, we include in equation (1) second-and-third degree polynomials in the capital control and intervention variables and test their partial and joint statistical significance using χ^2 and F statistics. The tests could not reject the null hypotheses of the absence of non-linear effects of the capital control and/or intervention variables.[25]

Due to the size of the sample analyzed, an additional mandatory test is a stability or perseverance test of the parameters in the model.[26] If there are structural changes, biases may 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 (1989) fluctuations test. The results for both tests reject the null hypothesis of the perseverance of the parameters.[27]

[25] When the polynomial of degree 3 was in place most of the models did not converge. From the economics point of view, in our data a third-degree polynomial on the capital control variable seems at odds with the fact that a tax over 100% became prohibitive, as was the case in the nineties (see figures in appendixes E and F).

[26] The coefficients can change over time because the structure of the economy or the economic policy regime changes, 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. According to the test cited, the first reason seems to explain the behavior of the current data.

[27] In the first case, the *LM* (Lagrange Multiplier) static is equal to 82.47 and the critical value of χ^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 12.84 with a *p-value* of 0.00.

In order to incorporate this result, and to evaluate the effectiveness of the capital control and forex intervention per periods of interest, we use four sub-samples. The criteria for selecting the first two subsamples is based on the structural change that was detected by the end of the 90's as a result of the modification of the monetary and foreign exchange regimes adopted in 1999. The third subsample is chosen to evaluate closely the changes in the nature and size of the forex intervention. 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 to 1999:09:30). The second covers the period with a floating exchange rate and an inflation targeting monetary regime (1999:10:01 to 2010:07:30). 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 one. The third sub-sample (2004:01:01 to 2010:07:30), covers as mentioned, a period of a very active forex intervention policy and also coincides with the consolidation of the inflation targeting regime, once the economy had fully recovered from the economic crisis of the end of the nineties. Finally, the fourth sub-sample includes exclusively the period of preannounced intervention (2008:01:01 to 2010:07:30). It must be noticed that for this latter sub-sample it is not necessary to instrument the intervention variable since, due its preannounced character, 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

In this section, we will show and discuss the results of the simultaneous estimations of the AR(2)-IGARCH(1,1), AR(1)-IGARCH(1,1), AR(1)-IGARCH(1,1), and AR(1)-IGARCH(1,1) models for the mean and variance of the exchange rate return for the four sub-samples, respectively. As before, we carried out the different diagnostic and specification tests, which are not shown here but yield similar results. Just like with the total sample, we estimated a regression for each definition of the tax equivalent to the URR and, at the same time, five specifications of the model according to the explanatory variables included in it. 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,[28] and the specification of the forex reaction function (equation 7).

It is worth noting that we have some reasons to keep the same specification of the reaction function across the samples. First of all, obeying a Constitutional mandate, inflation is the only objective of the Colombian monetary authorities since 1991, which establish a limit to forex intervention even under the former monetary regime (monetary aggregates). Thus, the *INFS* variable (inflationary surprise) captures that mandate across the samples. Second, as shown by the literature on forex intervention in Emerging Markets, intervention has persistence (measured by the lag of the intervention variable), and this behavior is observed under different foreign exchange and monetary regimes. Third, we wanted to have some degree of comparability of the

[28] As before, we evaluated the possible presence of non-linear effects of the capital control and/or intervention on the exchange rate return. The tests could not reject the null hypotheses of non-linear effects.

results across the samples, which would be impossible if we change the specification of the reaction function. Finally, the results of the identification test indicate that we have a well identified equation for the reaction function.

The estimates are summarized in Table 3 and the results of individual regressions are shown in Appendixes H.1 – H.12. 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.[29] Thus, 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 for the total sample and without ambiguity, forex intervention does not 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. This result match the hypothesis put forward by Dominguez (1998), who argues that when the signal of a forex intervention lack credibility, its only effect would be increasing the volatility of the exchange rate, without affecting its level.
The interaction variables delivered interesting results as explain below. A general result is that none of them in any sub-sample affect the volatility of the return, and for the first sub-sample none affect the mean. This indicates that during the first sub-sample the combined policies were ineffective either to reduce the short-run pressures on the forex market when facing external shocks, to modify the daily average return, or to make monetary policy more autonomous.

During the second and third sub-samples the interaction between the capital control and the spread -as a measure of risk in Emerging Markets-, unambiguously increased the return. This result suggests that the capital control was unable to isolate the exchange rate return from external shocks. In contrast, during the fourth sub-sample, it seems that capital controls did play such a role. Now, when the capital control and the forex intervention were used simultaneously a statistically significant positive effect was obtained for the last sub-sample, thus making the return higher as expected.

As shown in tables A.8.10-A.8.12, the interaction between the capital control and the forex intervention variable (TAX^j*I) turned out to be positive and significant for sample 4 (2008:01:01-2010:07:30), but not for the previous ones. The capital control by imposing a URR had been established since May 6 2007, and then in June 24 of 2008, the central bank initiated a preannounced intervention while maintaining the URR. 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$^+$, our measure of risk in Emerging Markets, the Credit Default Swaps (CDS) on 5yr corporate

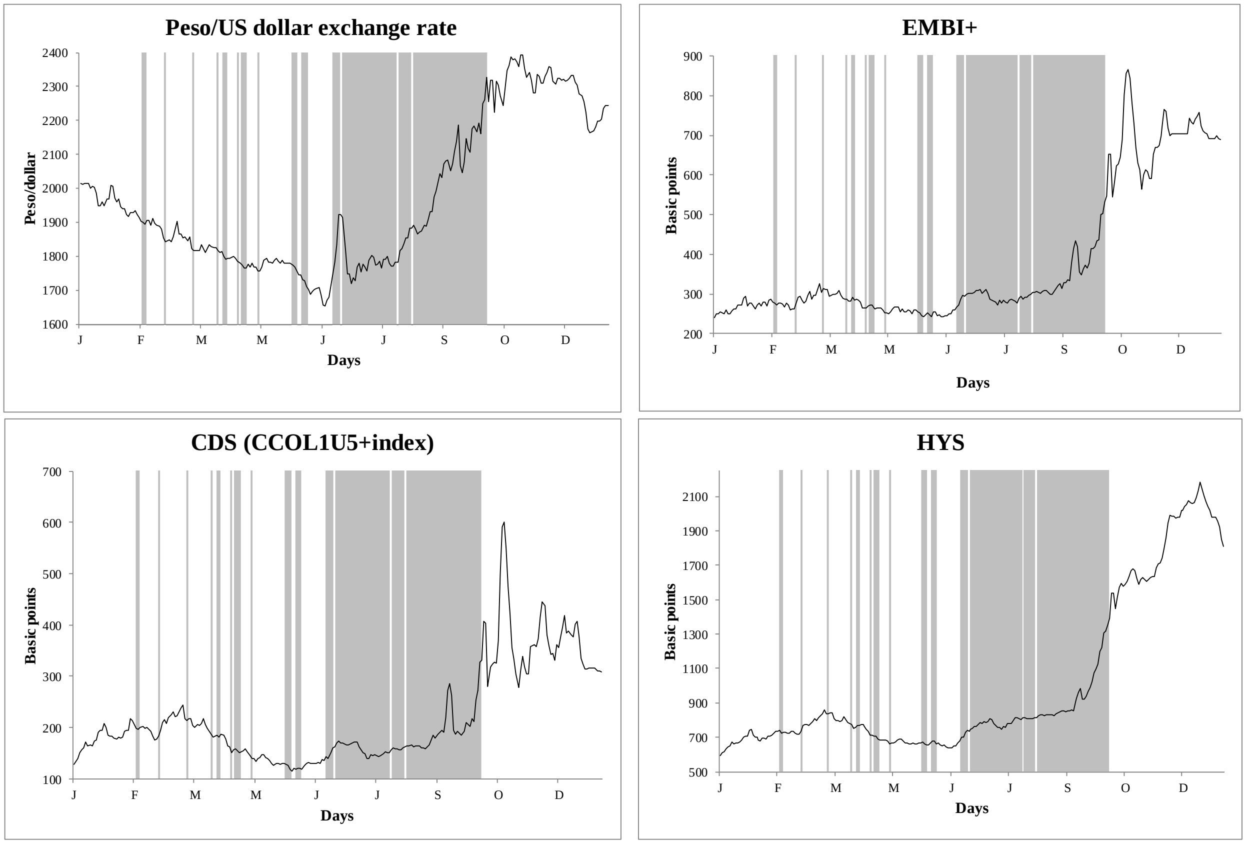
[29] On this regard, Cordella (1998) argues that capital controls could induce instead of restrain capital inflows if they are effective in reducing a country's vulnerability to external shocks. In such a case, capital control would reduce instead of increase a country's currency return.

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}	S but not robust	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
$TAX^{d}_{t}*\Delta Dif_{t}$	NS	NS
Floating exchange rate and inflation targeting monetary regime (1999:10:01 - 2010:07:30)		
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	NS
$TAX^{j}_{t}*\hat{I}_t$	NS	NS
$TAX^{d}_{t}*\Delta Dif_{t}$	S and return increases	NS
Secret and preannounced forex intervention (2004:01:01 - 2010:07:30)		
TAX^{j}_{i}	NS	NS/S and volatlity increases
$\hat{I}_t$	NS	NS
$TAX^{j}_{t}*\Delta spread_{t}$	S and return increases	NS
$TAX^{j}_{t}*\hat{I}_t$	NS	NS
$TAX^{d}_{t}*\Delta Dif_{t}$	S and return increases	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	NS
$TAX^{j}_{t}*\hat{I}_t$	S and return increases	NS
$TAX^{d}_{t}*\Delta Dif_{t}$	NS	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.

Period: 2008:01:01 – 2008:12:31
(*Shadowed area: Interaction TAX*I*)



Source: Banco de la República and Bloomberg. Authors' calculations.

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

Colombian debt; and the High Yield Spread were all increasing.[30] 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).

As stated by Blanchard et.al. (2013), capital controls and foreign exchange intervention are both complements and substitutes: complements because capital controls decrease the elasticity of flows with respect to relative rates of return, thereby making foreign exchange intervention more powerful; substitutes because both can be used to affect the exchange rate. Through the interaction variable between intervention and control, the model try to assess the effectiveness of the complementarity of these two policies to depreciate the exchange rate.

Supporting the complementarity hypothesis, it is found that the interaction of control and intervention since June 24 gave a boost to the ongoing depreciation trend. The exchange rate

[30] Unfortunately, we could not use the latest two measurements as alternative measures of risk in our estimations because they were not available for the total sample. However, when we used the CDS as the measurement of risk in EM instead of the $EMBI^+$ the results did not change much.

even overshoots during the first few days of intervention, and then maintained a depreciation trend all along the interaction period. This is reflected in the statistical significance effect of the interaction of control-intervention for increasing the exchange rate return within this sub-sample. Another fact that may have contributed to this result is that before the interaction period the URR 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.[31] This upgrading of capital controls together with the preannounced intervention at the right moment were key factors that helped to achieve the desired effect of depreciating the exchange rate, without increasing volatility. Therefore, the effectiveness of the interaction of intervention and control in these particular circumstances is related to a situation of 'lean with the wind´ as opposed to 'lean against the wind'. This means that the policy of intervention and control were able to provide an impulse to a depreciation process that was already on its way. Nonetheless, in circumstances where all economic forces were pushing for an appreciation, even the interaction between intervention and control were insufficient for modifying the appreciation trend.

To evaluate the robustness of this important result we carried out joint significance tests for the capital control, intervention and the interaction coefficients. The χ^2 and F statistics showed that the null hypotheses of non-significance could not be rejected except for the joint test for the forex intervention and interaction coefficients in the last subsample, at least at 10% statistical significance level. This means that the capital control does not affect the exchange rate return by itself, as was displayed by the *t*-statistics along outputs of the different samples, but it does when it interacts with forex intervention, which was also supported by the statistical significance of the interaction partial regression coefficient in the last subsample.

Lastly, in two out of the four sub-samples, the interaction variable between the capital control and the interest differential was statistically significant. This means that for particular periods of time the capital control allowed monetary authorities to gain some autonomy since they could increase interest rate without putting additional appreciation pressure on the exchange rate.

The rest of the explanatory variables change their sign and statistical significance depending on the sample that was analyzed (Appendix H). 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. On the other hand, the variable *vix* resulted significant and with the expected positive sign in the equation for the mean of the return in this subsample. 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 sign. Accordingly,

[31] Moreover, as we said above, a ceiling on derivative positions, not captured by our capital control measurements, had been imposed in 2007, and then tightened in 2008. In addition, in May 2007 the URR was extended to portfolio inflows by foreign residents.

a positive variation of the risk in Emerging and Global Markets increases the foreign exchange rate return, making the exchange rate recovering its stabilization role. Notice, however, that when the last two sub-samples are considered, the variable *vix* lose its importance as determinant of the peso return. In the case of the *spread*, its volatility unambiguously increases the foreign exchange rate volatility during the second sub-sample. This does not happen when the last two sub-samples are considered and it loses its importance as determinant of the return volatility.

Contrary to what was expected, the variations in the interest differential did not have any statistically significant effect on the mean of the return except in the last sub-sample when it reduced the return, as expected, while –in the first sub-sample- its volatility unambiguously induced a greater volatility of the return. This result might have to do with the fact that during the first sub-sample, especially during the second part of the sub-sample, 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 different from direct investment to come in despite positive interest rate differentials.

The price of commodities and the misalignment of the real exchange rate play also a fundamental role in determining the exchange rate return of the peso as shown by the size, sign and statistical significance of their coefficients. As before, their importance and robustness is missed during the first sub-sample, which may corroborate the miss-functioning of the different monetary and exchange rate channels during that period. During the last sub-sample, the role of the misalignment of the real exchange rate as an error correction is missed again. As for the volatility of the return, the volatility of the price of commodities plays no role.

Finally, it is important to observe two things: the high persistence of the exchange rate return, independently of the subsample analyzed, which coincides with the findings for the entire sample, and that volatility of the return is mostly determined sub-sample by sub-sample by its own volatility and by the term capturing the clustering property of the return.

7. Conclusions

The policy debate on how to manage the international capital inflows and the resulting appreciation trend is commonly 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, countries intervene in the foreign exchange market, and some of them also impose 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 Colombia for the 1993 to 2010 period and a GARCH model of the peso/US dollar exchange rate return.

The key general finding indicates that neither capital control nor central bank interventions were successful for inducing a currency depreciation. In addition, as a side effect, these policies increased the exchange rate volatility. Nonetheless, and exclusively during the period 2008 - 2010, 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 statistical significant effect on the exchange rate volatility.

Finally, we found that the fundamental determinants of the daily average behavior of the exchange rate return are its own past behavior, the risk in Emerging and Global Markets, the price of commodities and the misalignment of the real exchange rate.

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Appendix A

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	Economtric 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 (2009b)									
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 (2009a)									
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 B

Literature review on the effectiveness of the capital control 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 C

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.

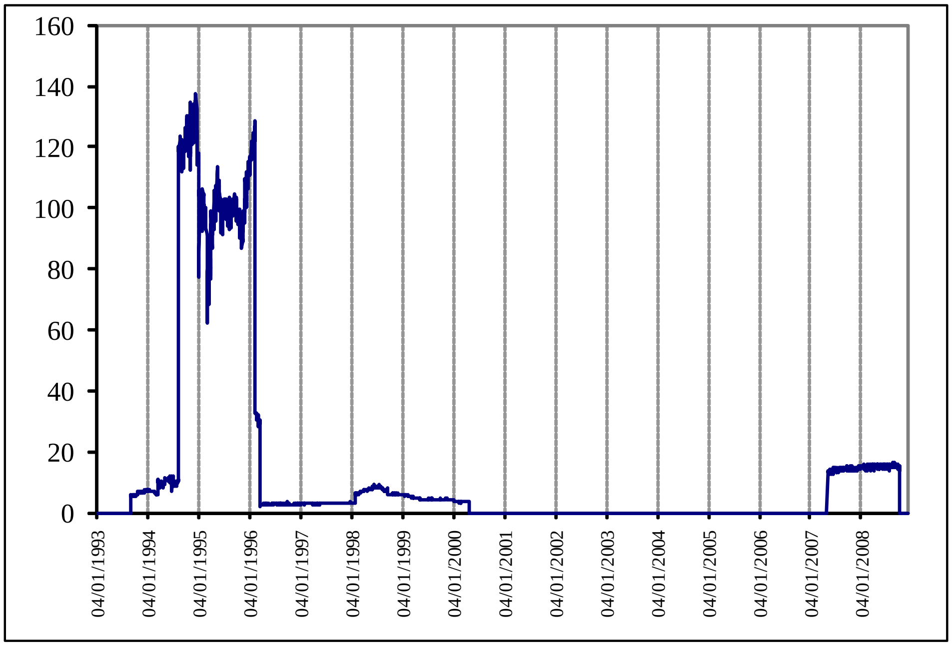
Appendix D

Series and sources

- E: It is the nominal daily exchange rate of the Colombian peso with respect to the US dollar reported by the Banking Superintendence (now Financial Superintendence). Source: Statistics Section, Division of Economic Studies and Monetary and Reserves Division, Banco de la República.
- 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. Source: Statistics Section, Division of Economic Studies, Banco de la República.
- EMBI+: It is "EMBI+ portfolio's spread over the theoretical U.S zero-coupon curve, which equates the total net present value of the sovereign risk cash flow to zero. Unlike Blended Spread calculations, sovereign spread calculations extract principle and interest collateral." (Bond Index, J.P. Morgan Securities Inc., December 2004). The holidays and other days missing from the series had the data from the immediately preceding day. Source: Bloomberg (*Ticker*: *JPEMSOSD Index*).
- 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 República 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. 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. 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. 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. Source: Monetary and Reserves Division, Banco de la República.
- Interbanking rate (TIB in Spanish) or the Banking Superintendence 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 República (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. Source: Statistics Section, Division of Economic Studies, and Monetary and Reserves Division, Banco de la República.
- TAX^i ($i = d$, $O\text{-}T\text{-}R$, $E\text{-}R$): It is the tax equivalent to the reserve requirements on foreign debt. It is calculated as explained above. Source: Authors' calculations.

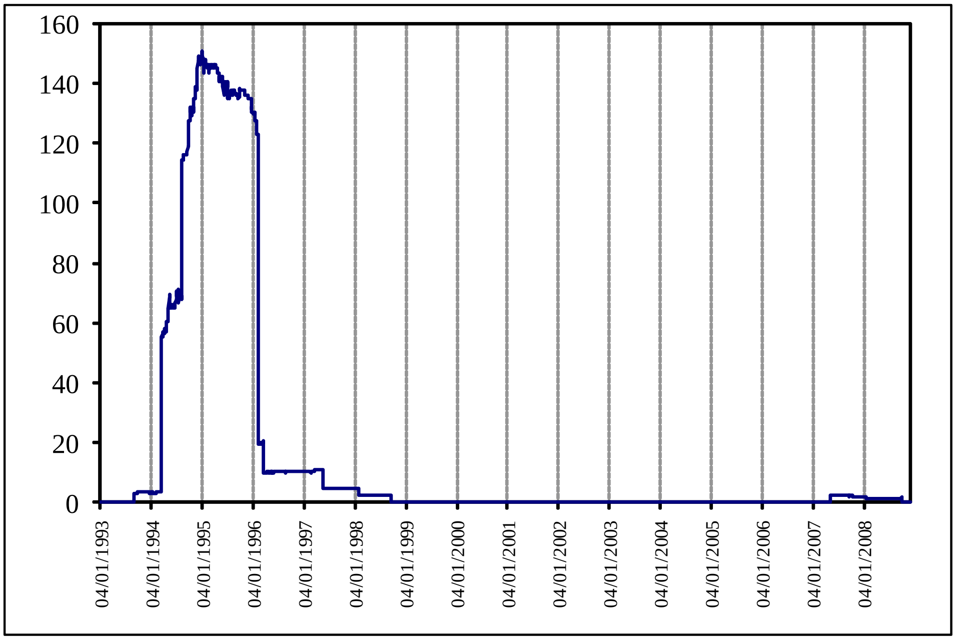
- C*ommodity* price index: It is the arithmetic mean of commodity prices with monthly readjustment. Source: *Bloomberg* (*ticker*: *CRY*).
- CDS: It is a Credit Default Swaps “designed to transfer the credit exposure of fixed income products between parties. The buyer of a credit swap receives credit 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 E
Path of TAX^{O-T-R} (equation (5))



Source: Authors' calculations.

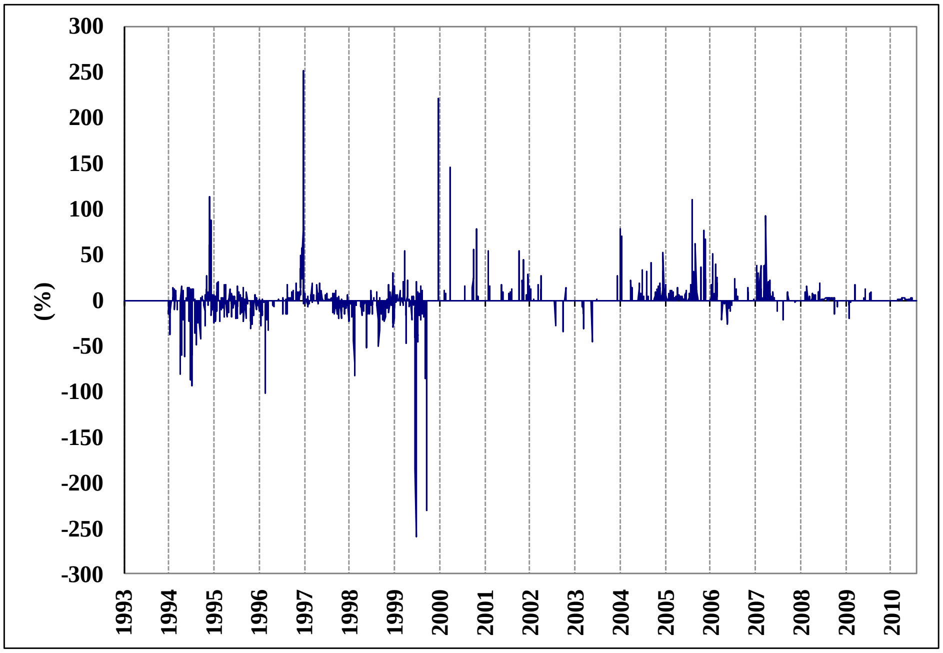
Appendix F
Path of TAX^{E-R} (equation (6))



Source: Authors' calculations.

Appendix G

Indicator of the central bank's intervention in the forex market (*I*)



Source: Authors' calculations.

Appendix H

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

H.1

Definition of the tax: TAX^d

Sample 1: 1993:01:04 - 1999:09:30

Variables	**Model 1**[+]			**Model 2**[+]			**Model 3**[+]			**Model 4**			**Model 5**[+]		
	Coeff.	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**
Equation for the mean of the return															
Constant	0.004	0.31		0.006	0.50		-0.005	-0.26		0.005	0.46		0.001	0.03	
Δe_{t-1}	0.202	9.15	***	0.200	9.07	***	0.204	9.18	***	0.202	9.09	***	0.201	9.02	***
$\Delta spread_t$	-0.003	-2.10	**	0.002	0.41		-0.003	-2.02	**	-0.002	-1.85	*	0.002	0.50	
vix_t	0.002	2.61	***	0.002	2.54	**	0.002	2.65	***	0.002	2.67	***	0.002	2.73	***
ΔDif_t	0.000	0.08		0.000	0.06		0.000	0.06		-0.007	-1.79	*	-0.006	-1.39	
TAX^d_t	-0.019	-2.08	**	-0.020	-2.25	**	-0.012	-0.83		-0.021	-2.37	**	-0.019	-1.36	
$\hat{I}_t$	-0.000	-0.21		-0.000	-0.23		-0.004	-0.67		-0.000	-0.15		-0.004	-0.65	
Δpc_t	-0.006	-0.98		-0.004	-0.69		-0.007	-1.13		-0.008	-1.33		-0.007	-1.11	
Dq_{t-1}	0.000	0.04		-0.005	-1.01		0.000	0.00		0.000	0.21		0.000	0.08	
$TAX^d_t*\Delta spread_t$	---	---		-0.000	-0.03		---	---		---	---		-0.005	-1.06	
$TAX^d_t*\hat{I}_t$	---	---		---	---		0.004	0.65		---	---		0.004	0.63	
$TAX^d_t*\Delta Dif_t$	---	---		---	---		---	---		0.008	1.89	*	0.006	1.51	
Equation for the variance of the return															
a	0.263	11.12	***	0.263	10.99	***	0.271	11.05	***	0.269	11.36	***	0.277	11.02	***
b	0.737	31.20	***	0.736	30.68	***	0.729	29.71	***	0.731	30.87	***	0.723	28.72	***
$\lvert\Delta spread_t\rvert$	0.000	0.23		0.000	0.55		0.000	0.66		0.000	0.24		0.000	1.21	
vix_t	0.000	0.21		0.000	0.27		0.000	1.06		-0.000	-0.06		0.000	0.99	
$\lvert\Delta Dif_t\rvert$	0.001	2.39	**	0.001	2.36	**	0.001	2.32	**	0.001	2.53	**	0.001	2.37	**
TAX^d_t	0.001	1.41		0.001	1.34		-0.001	-0.75		0.001	1.61		-0.001	-0.90	
$\hat{I}_t$	0.000	3.30	***	0.000	3.26	***	0.001	2.25	**	0.000	3.65	***	0.001	2.50	**
$\lvert\Delta pc_t\rvert$	-0.000	-0.13		-0.001	-0.29		0.001	0.60		0.000	0.06		0.002	0.75	
$TAX^d_t*\Delta spread_t$	---	---		-0.001	-1.27		---	---		---	---		-0.001	-1.86	*
$TAX^d_t*\hat{I}_t$	---	---		---	---		-0.001	-1.92	*	---	---		-0.001	-2.12	**
$TAX^d_t*\Delta Dif_t$	---	---		---	---		---	---		-0.001	-1.14		-0.001	-1.01	
Shape	1.959	31.80	***	1.959	31.75	***	1.958	31.31	***	1.950	31.70	***	1.967	31.09	***
Observations	1754			1754			1754			1754			1754		
Log Likelihood	49			47			47			47			43		

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.

[+] Even though this model did not converge, for completeness we show the results. Notice that to be consistent across all estimations we carried them out using the same optimization method (BHHH method), iterations, and convergence criterion. In cases where convergence was not reached, as these cases, we used alternative methods such as the BFGS method (Broyden, Fletcher, Golfarb, Shanno). Although the model converged, most of the estimates became practically zero and their signs were not robust to changes in the especification of the model. These outputs are available upon request from the authors.

H.2

Definition of the tax: $TAX^{O\text{-}T\text{-}R}$

Sample 1: 1993:01:04 - 1999:09:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**
Equation for the mean of the return															
Constant	-0.001	-0.06		0.001	0.09		-0.001	-0.06		0.000	0.04		0.001	0.05	
Δe_{t-1}	0.199	9.04	***	0.202	9.17	***	0.198	8.88	***	0.199	9.05	***	0.200	8.94	***
$\Delta spread_t$	-0.002	-1.87	*	-0.003	-1.81	*	-0.002	-1.97	**	-0.002	-1.85	*	-0.003	-1.90	*
vix_t	0.002	2.46	**	0.002	2.35	**	0.002	2.41	**	0.002	2.42	**	0.002	2.39	**
ΔDif_t	0.001	0.35		0.001	0.44		0.000	0.27		0.001	0.53		0.001	0.55	
TAX^{O-T-R}_t	0.000	1.83	*	0.000	1.78	*	0.000	1.75	*	0.000	1.78	*	0.000	1.56	
$\hat{I}_t$	0.000	0.12		0.000	0.11		0.000	0.11		0.000	0.10		0.000	0.10	
Δpc_t	-0.007	-1.18		-0.008	-1.24		-0.007	-1.18		-0.007	-1.10		-0.007	-1.14	
Dq_{t-1}	0.002	2.26	**	0.002	2.29	**	0.002	2.18	**	0.002	2.35	**	0.002	2.28	**
$TAX^{O-T-R}_t * \Delta spread_t$	---	---		0.000	0.89		---	---		---	---		0.000	0.77	
$TAX^{O-T-R}_t * \hat{I}_t$	---	---		---	---		-0.000	-0.18		---	---		-0.000	-0.09	
$TAX^{O-T-R}_t * \Delta Dif_t$	---	---		---	---		---	---		-0.000	-0.25		-0.000	-0.31	
Equation for the variance of the return															
a	0.268	11.61	***	0.266	11.42	***	0.266	11.65	***	0.267	11.53	***	0.264	11.48	***
b	0.732	31.73	***	0.734	31.55	***	0.734	32.21	***	0.733	31.64	***	0.736	31.96	***
$\lvert\Delta spread_t\rvert$	0.000	0.28	**	0.000	0.45		0.000	0.24		0.000	0.36		0.000	0.28	
vix_t	0.000	0.80		0.000	0.74		0.000	0.87		0.000	0.76		0.000	0.91	
$\lvert\Delta Dif_t\rvert$	0.001	2.52	**	0.001	2.46	**	0.001	2.32	**	0.001	2.49	**	0.001	2.22	**
TAX^{O-T-R}_t	0.000	0.12		0.000	0.14		0.000	0.79		0.000	0.02		0.000	0.81	
$\hat{I}_t$	0.000	3.34	***	0.000	3.22	***	0.000	1.87	*	0.000	3.04	***	0.000	1.82	*
$\lvert\Delta pc_t\rvert$	-0.001	-0.25		-0.001	-0.26		-0.001	-0.27		-0.001	-0.24		-0.001	-0.32	
$TAX^{O-T-R}_t * \Delta spread_t$	---	---		-0.000	-0.48		---	---		---	---		-0.000	-0.25	
$TAX^{O-T-R}_t * \hat{I}_t$	---	---		---	---		0.000	1.69	*	---	---		0.000	1.61	
$TAX^{O-T-R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.26		0.000	-0.04	
Shape	1.954	32.01	***	1.954	31.61	***	1.945	31.50	***	1.957	31.49	***	1.942	31.18	***
Observations	1754			1754			1754			1754			1754		
Log Likelihood	51			50			49			50			49		

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.

H.3

Definition of the tax: $TAX^{E\text{-}R}$

Sample 1: 1993:01:04 - 1999:09:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5[+]		
	Coeff.	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**
Equation for the mean of the return															
Constant	-0.001	-0.05		0.000	-0.01		0.001	0.05		-0.001	-0.07		0.001	0.07	
Δe_{t-1}	0.200	9.13	***	0.201	9.15	***	0.200	8.97	***	0.198	9.06	***	0.201	8.99	***
$\Delta spread_t$	-0.003	-2.35	**	-0.003	-2.08	**	-0.003	-2.25	**	-0.003	-2.35	**	-0.003	-2.02	**
vix_t	0.002	2.41	**	0.002	2.33	**	0.002	2.29	***	0.002	2.44	**	0.002	2.23	**
ΔDif_t	0.001	0.52		0.001	0.44		0.001	0.51		0.001	0.44		0.000	0.15	
$TAX^{E\text{-}R}_t$	0.000	1.48		0.000	1.51		0.000	1.20		0.000	1.47		0.000	1.07	
$\hat{I}_t$	0.000	0.11		0.000	0.15		-0.000	-0.02		0.000	0.11		0.000	0.03	
Δpc_t	-0.004	-0.68		-0.006	-0.95		-0.005	-0.76		-0.004	-0.66	***	-0.006	-1.05	
Dq_{t-1}	0.002	2.26	**	0.002	2.22	**	0.002	2.14	**	0.002	2.27	**	0.002	2.02	**
$TAX^{E\text{-}R}_t * \Delta spread_t$	---	---		0.000	0.73		---	---		---	---		0.000	0.648	
$TAX^{E\text{-}R}_t * \hat{I}_t$	---	---		---	---		0.000	0.13		---	---		0.000	0.121	
$TAX^{E\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	-0.06		0.000	0.221	
Equation for the variance of the return															
a	0.265	11.53	***	0.265	11.44	***	0.264	11.65	***	0.265	11.51	***	0.263	11.43	***
b	0.735	31.96	***	0.735	31.73	***	0.736	32.45	***	0.735	31.95	***	0.737	32.00	***
$\lvert\Delta spread_t\rvert$	0.000	0.36		0.000	0.54		0.000	0.62		0.000	0.43		0.000	0.65	
vix_t	0.000	0.74		0.000	0.65		0.000	0.70		0.000	0.70		0.000	0.76	
$\lvert\Delta Dif_t\rvert$	0.001	2.55	**	0.001	2.54	**	0.001	2.39	**	0.001	2.53	**	0.001	2.29	**
$TAX^{E\text{-}R}_t$	-0.000	-0.04		0.000	0.01		0.000	0.42	*	-0.000	-0.10		0.000	0.68	
$\hat{I}_t$	0.000	3.31	***	0.000	3.27	**	0.000	1.79	*	0.000	3.14	**	0.000	1.75	*
$\lvert\Delta pc_t\rvert$	-0.001	-0.23		-0.000	-0.21		-0.001	-0.27		-0.000	-0.22		-0.001	-0.35	
$TAX^{E\text{-}R}_t * \Delta spread_t$	---	---		0.000	-0.60		---	---		---	---		-0.000	-0.59	
$TAX^{E\text{-}R}_t * \hat{I}_t$	---	---		---	---		0.000	1.40		---	---		0.000	1.49	
$TAX^{E\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.24		0.000	0.07	
Shape	1.967	31.50	***	1.958	31.03	***	1.951	31.34	***	1.968	31.06	***	1.944	30.76	***
Observations	1754			1754			1754			1754			1754		
Log Likelihood	51			51			50			51			50		

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.

[+] Even though this model did not converge, for completeness we showed the results. Notice that to be consistent across all estimations we carried them out using the same optimization method (BHHH method), iterations, and convergence criterion. In cases where convergence was not reached, as this case, we used alternative methods such as the BFGS method (Broyden, Fletcher, Golfarb, Shanno). Although the model converged, most of the estimates became practically zero and their signs were not robust to changes in the especification of the model. These outputs are available upon request from the authors.

H.4

Definition of the tax: TAX^d

Sample 2: 1999:10:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5[+]		
	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.
Equation for the mean of the return															
Constant	-0.005	-0.27		-0.002	-0.09		-0.005	-0.26		-0.004	-0.21		-0.004	-0.20	
Δe_{t-1}	0.147	8.60	***	0.143	8.37	***	0.148	8.62	***	0.147	8.62	***	0.145	8.50	***
$\Delta spread_t$	0.023	8.61	***	0.021	7.43	***	0.024	8.65	***	0.024	8.74	***	0.021	7.47	***
vix_t	0.002	2.41	**	0.002	2.31	**	0.002	2.41	**	0.002	2.45	**	0.002	2.45	***
ΔDif_t	-0.000	-0.20		-0.000	-0.05		-0.000	-0.24		-0.000	-0.84		-0.000	-0.95	
TAX^d_t	-0.035	-1.72	*	-0.033	-1.56		-0.034	-1.31		-0.043	-2.09	**	-0.027	-0.97	
$\hat{I}_t$	0.001	0.24		-0.000	-0.04		0.001	0.18		0.000	0.10		0.001	0.12	
Δpc_t	-0.040	-6.77	***	-0.039	-6.67	***	-0.040	-6.79	***	-0.040	-6.85	***	-0.039	-6.69	***
Dq_{t-1}	-0.003	-3.25	***	-0.003	-3.30	***	-0.003	-3.24	***	-0.003	-3.32	***	-0.003	-3.37	***
$TAX^d_t * \Delta spread_t$	---	---		0.031	3.51	***	---	---		---	---		0.034	3.82	***
$TAX^d_t * \hat{I}_t$	---	---		---	---		-0.000	-0.01		---	---		-0.002	-0.24	
$TAX^d_t * \Delta Dif_t$	---	---		---	---		---	---		0.003	1.75	*	0.003	2.03	**
Equation for the variance of the return															
a	0.187	10.79	***	0.185	10.60	***	0.188	10.80	***	0.187	10.80	***	0.187	10.59	***
b	0.813	46.83	***	0.815	46.66	***	0.812	46.52	***	0.813	47.05	***	0.813	46.07	***
$\|\Delta spread_t\|$	0.004	3.30	***	0.003	3.19	***	0.004	3.30	***	0.004	3.29	***	0.003	3.19	***
vix_t	0.000	-0.24		-0.000	-0.22		-0.000	-0.23		-0.000	-0.24		-0.000	-0.20	
$\|\Delta Dif_t\|$	0.000	1.01		0.000	0.97		0.000	0.97		0.000	0.93		0.000	0.89	
TAX^d_t	0.007	1.68	*	0.009	1.94	*	0.013	1.64		0.006	1.51		0.020	2.33	**
$\hat{I}_t$	-0.000	-1.08		-0.001	-1.17		-0.000	-0.94		-0.000	-0.94		-0.000	-0.93	
$\|\Delta pc_t\|$	-0.001	-1.18		-0.001	-1.02		-0.001	-1.18		-0.001	-1.22		-0.001	-1.15	
$TAX^d_t * \Delta spread_t$	---	---		0.005	0.88		---	---		---	---		0.007	1.11	
$TAX^d_t * \hat{I}_t$	---	---		---	---		-0.003	-1.07		---	---		-0.006	-2.20	**
$TAX^d_t * \Delta Dif_t$	---	---		---	---		---	---		0.001	0.45		0.000	0.09	
Shape	1.756	29.73	***	1.758	29.62	***	1.758	29.69	***	1.756	29.72	***	1.765	29.60	***
Observations	2825			2825			2825			2825			2825		
Log Likelihood	1552			1547			1552			1550			1544		

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.

[+] Even though this model did not converge, for completeness we showed the results. Notice that to be consistent across all estimations we carried them out using the same optimization method (BHHH method), iterations, and convergence criterion. In cases where convergence was not reached, as this case, we used alternative methods such as the BFGS method (Broyden, Fletcher, Golfarb, Shanno). Although the model converged, most of the estimates became practically zero and their signs were not robust to changes in the especification of the model. These outputs are available upon request from the authors.

H.5

Definition of the tax: $TAX^{O\text{-}T\text{-}R}$

Sample 2: 1999:10:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5[+]		
	Coeff.	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**
Equation for the mean of the return															
Constant	-0.005	-0.30		-0.001	-0.04		-0.005	-0.29		-0.005	-0.27		-0.004	-0.23	
Δe_{t-1}	0.146	8.52	***	0.143	8.38	***	0.147	8.52	***	0.149	8.67	***	0.144	8.45	***
$\Delta spread_t$	0.023	8.53	***	0.020	7.01	***	0.023	8.56	***	0.024	8.68	***	0.020	7.09	***
vix_t	0.002	2.22	**	0.002	2.16	**	0.002	2.26	**	0.002	2.33	***	0.002	2.39	***
ΔDif_t	-0.000	-0.24		0.000	0.03		-0.000	-0.22		-0.000	-0.91		-0.000	-0.98	
$TAX^{O\text{-}T\text{-}R}_t$	-0.003	-1.61		-0.003	-1.63		-0.003	-0.67		-0.004	-2.02	**	-0.003	-0.71	
$\hat{I}_t$	0.001	0.22		-0.001	-0.18		0.001	0.15		0.001	0.21		0.000	0.12	
Δpc_t	-0.040	-6.74	***	-0.039	-6.63	***	-0.039	-6.72	***	-0.040	-6.78	***	-0.038	-6.46	***
Dq_{t-1}	-0.003	-3.00	***	-0.003	-3.19	***	-0.003	-3.05	***	-0.003	-3.17	**	-0.003	-3.24	***
$TAX^{O\text{-}T\text{-}R}_t * \Delta spread_t$	---	---		0.005	6.21	***	---	---		---	---		0.005	6.30	***
$TAX^{O\text{-}T\text{-}R}_t * \hat{I}_t$	---	---		---	---		-0.001	-0.22		---	---		-0.001	-0.20	
$TAX^{O\text{-}T\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	2.03	**	0.000	2.08	**
Equation for the variance of the return															
a	0.190	10.72	***	0.190	10.49	***	0.190	10.76	***	0.190	10.72	***	0.189	10.53	***
b	0.810	45.60	***	0.810	44.84	***	0.810	45.89	***	0.810	45.83	***	0.811	45.13	***
$\lvert\Delta spread_t\rvert$	0.003	3.11	***	0.003	2.87	**	0.003	3.16	***	0.003	3.10	***	0.003	2.92	***
vix_t	-0.000	-0.08		-0.000	-0.03	*	-0.000	-0.09		-0.000	-0.10		0.000	0.01	
$\lvert\Delta Dif_t\rvert$	0.000	0.95		0.000	0.90	***	0.000	0.96		0.000	0.90		0.000	0.91	
$TAX^{O\text{-}T\text{-}R}_t$	0.001	2.14	**	0.001	2.30	**	0.001	1.24		0.001	1.76	*	0.002	1.40	
$\hat{I}_t$	-0.000	-0.88		-0.000	-0.88		-0.000	-0.76		-0.000	-0.80		-0.000	-0.82	
$\lvert\Delta pc_t\rvert$	-0.001	-1.26		-0.001	-0.96		-0.002	-1.47		-0.001	-1.29		-0.001	-1.23	
$TAX^{O\text{-}T\text{-}R}_t * \Delta spread_t$	---	---		0.000	0.44	*	---	---		---	---		0.000	0.29	
$TAX^{O\text{-}T\text{-}R}_t * \hat{I}_t$	---	---		---	---		-0.000	-0.23		---	---		-0.000	-0.44	
$TAX^{O\text{-}T\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.29		0.000	-0.27	
Shape	1.756	29.58	***	1.752	29.47	***	1.756	29.62	***	1.755	29.56	***	1.763	29.47	***
Observations	2825			2825			2825			2825			2825		
Log Likelihood	1550			1538			1550			1549			1535		

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.

[+] Even though this model did not converge, for completeness we showed the results. Notice that to be consistent across all estimations we carried them out using the same optimization method (BHHH method), iterations, and convergence criterion. In cases where convergence was not reached, as this case, we used alternative methods such as the BFGS method (Broyden, Fletcher, Golfarb, Shanno). Although the model converged, most of the estimates became practically zero and their signs were not robust to changes in the especification of the model. These outputs are available upon request from the authors.

H.6

Definition of the tax: $TAX^{E\text{-}R}$

Sample 2: 1999:10:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5+		
	Coeff.	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**
Equation for the mean of the return															
Constant	-0.004	-0.24		-0.000	-0.01		-0.005	-0.26		-0.004	-0.24		-0.004	-0.23	
Δe_{t-1}	0.148	8.63	***	0.144	8.39	***	0.148	8.61	***	0.151	8.81	***	0.145	8.50	***
$\Delta spread_t$	0.023	8.60	***	0.019	6.85	***	0.023	8.60	***	0.024	8.69	***	0.019	6.98	***
vix_t	0.002	2.18	**	0.001	2.05	**	0.002	2.20	**	0.002	2.28	**	0.002	2.33	**
ΔDif_t	-0.000	-0.23		-0.000	-0.01		-0.000	-0.24		-0.000	-1.08		-0.000	-1.13	
$TAX^{E\text{-}R}_t$	-0.027	-1.50		-0.023	-1.36		-0.025	-0.76		-0.034	-1.90	*	-0.024	-0.66	
$\hat{I}_t$	0.001	0.14		-0.001	-0.21		0.001	0.14		0.001	0.19		0.000	0.12	
Δpc_t	-0.040	-6.80	***	-0.039	-6.70	***	-0.040	-6.78	***	-0.040	-6.81	***	-0.038	-6.54	***
Dq_{t-1}	-0.003	-3.00	***	-0.003	-3.09	***	-0.003	-3.01	***	-0.003	-3.15	***	-0.003	-3.18	***
$TAX^{E\text{-}R}_t*\Delta spread_t$	---	---		0.040	7.03	***	---	---		---	---		0.042	7.40	***
$TAX^{E\text{-}R}_t*\ \hat{I}_t$	---	---		---	---		-0.002	-0.08		---	---		-0.007	-0.24	
$TAX^{E\text{-}R}_t*\Delta Dif_t$	---	---		---	---		---	---		0.002	2.14	**	0.002	2.31	**
Equation for the variance of the return															
a	0.190	10.76	***	0.191	10.62	***	0.190	10.72	***	0.189	10.71	***	0.191	10.61	***
b	0.810	45.99	***	0.809	45.06	***	0.810	45.70	***	0.811	45.83	***	0.809	44.87	***
$\lvert\Delta spread_t\rvert$	0.003	3.16	***	0.003	2.83	***	0.003	3.12	***	0.003	3.08	***	0.003	2.85	***
vix_t	-0.000	-0.08		0.000	0.03		-0.000	-0.07		-0.000	-0.08		0.000	0.07	
$\lvert\Delta Dif_t\rvert$	0.000	0.93		0.000	0.88		0.000	0.92		0.000	0.88		0.000	0.89	
$TAX^{E\text{-}R}_t$	0.011	2.14	**	0.011	2.23	**	0.012	1.21		0.010	1.77	*	0.015	1.32	
$\hat{I}_t$	-0.000	-0.82		-0.000	-0.83		-0.000	-0.78		-0.000	-0.81		-0.000	-0.86	
$\lvert\Delta pc_t\rvert$	-0.002	-1.38		-0.001	-1.01		-0.002	-1.32		-0.001	-1.26		-0.001	-1.10	
$TAX^{E\text{-}R}_t*\Delta spread_t$	---	---		-0.001	-0.15		---	---		---	---		-0.002	-0.43	
$TAX^{E\text{-}R}_t*\ \hat{I}_t$	---	---		---	---		-0.001	-0.22		---	---		-0.002	-0.32	
$TAX^{E\text{-}R}_t*\Delta Dif_t$	---	---		---	---		---	---		0.000	0.24		0.000	-0.40	
Shape	1.755	29.68	***	1.748	29.48	***	1.755	29.64	***	1.756	29.63	***	1.758	29.46	***
Observations	2825			2825			2825			2825			2825		
Log Likelihood	1551			1534			1551			1548			1531		

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.

+ Even though this model did not converge, for completeness we showed the results. Notice that to be consistent across all estimations we carried them out using the same optimization method (BHHH method), iterations, and convergence criterion. In cases where convergence was not reached, as this case, we used alternative methods such as the BFGS method (Broyden, Fletcher, Golfarb, Shanno). Although the model converged, most of the estimates became practically zero and their signs were not robust to changes in the especification of the model. These outputs are available upon request from the authors.

H.7

Definition of the tax: TAX^d

Sample 3: 2004:01:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.
Equation for the mean of the return															
Constant	0.010	0.40		0.011	0.42		0.009	0.37		0.009	0.35		0.010	0.41	
Δe_{t-1}	0.123	5.62	***	0.128	5.90	***	0.125	5.67	***	0.126	5.78	***	0.129	5.96	***
$\Delta spread_t$	0.048	12.25	***	0.038	9.33	***	0.048	12.29	***	0.048	12.34	***	0.038	9.46	***
vix_t	0.000	0.29		0.000	0.31		0.000	0.29		0.000	0.36		0.000	0.27	
ΔDif_t	0.000	-0.43		-0.000	-0.32		-0.000	-0.41		-0.000	-0.84		-0.000	-0.95	
TAX^d_t	-0.017	-0.50		-0.022	-0.64		-0.052	-0.62		-0.035	-1.02		-0.077	-0.91	
$\hat{I}_t$	0.002	0.82		0.003	0.90		0.002	0.78		0.002	0.83		0.003	0.91	
Δpc_t	-0.051	-6.86	***	-0.049	-6.65	***	-0.051	-6.86	***	-0.051	-6.90	***	-0.047	-6.52	***
Dq_{t-1}	-0.004	-1.97	**	-0.004	-2.11	**	-0.004	-1.90	*	-0.004	-1.95	*	-0.004	-1.97	**
$TAX^d_t * \Delta spread_t$	---	---		0.060	5.27	***	---	---		---	---		0.062	5.44	***
$TAX^d_t * \hat{I}_t$	---	---		---	---		0.025	0.43		---	---		0.026	0.45	
$TAX^d_t * \Delta Dif_t$	---	---		---	---		---	---		0.003	1.65	*	0.003	1.81	*
Equation for the variance of the return															
a	0.179	7.98	***	0.175	8.00	***	0.177	7.93	***	0.178	7.93	***	0.173	8.02	***
b	0.821	36.48	***	0.825	37.82	***	0.823	36.85	***	0.822	36.66	***	0.827	38.42	***
$\|\Delta spread_t\|$	0.002	1.09		0.001	0.70		0.002	1.13		0.002	1.08		0.001	0.80	
vix_t	0.000	0.95		0.000	0.95		0.000	0.93		0.000	0.93		0.000	0.96	
$\|\Delta Dif_t\|$	0.000	0.72		0.000	0.86		0.000	0.70		0.000	0.70		0.000	0.87	
TAX^d_t	0.017	1.77	*	0.019	1.98	**	-0.030	-0.46		0.015	1.39		-0.011	-0.17	
$\hat{I}_t$	0.000	-0.83		-0.000	-0.57		-0.000	-0.85		-0.000	-0.82		-0.000	-0.58	
$\|\Delta pc_t\|$	-0.002	-0.84		-0.002	-0.73		-0.002	-0.85		-0.002	-0.80		-0.002	-0.91	
$TAX^d_t * \Delta spread_t$	---	---		0.000	0.01		---	---		---	---		-0.000	-0.01	
$TAX^d_t * \hat{I}_t$	---	---		---	---		0.033	0.68		---	---		0.022	0.46	
$TAX^d_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.17		-0.001	-0.26	
Shape	1.702	20.56	***	1.687	20.59	***	1.704	20.55	***	1.708	20.48	***	1.705	20.45	***
Observations	1717			1717			1717			1717			1717		
Log Likelihood	1237			1229			1236			1235			1226		

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.

H.8

Definition of the tax: $TAX^{O\text{-}T\text{-}R}$

Sample 3: 2004:01:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	t	Sig.	Coeff.	t	Sig.	Coeff.	t	Sig.	Coeff.	t	Sig.	Coeff.	t	Sig.
Equation for the mean of the return															
Constant	0.010	0.41		0.010	0.41	*	0.009	0.36		0.009	0.36		0.010	0.41	
Δe_{t-1}	0.123	5.63	***	0.127	5.84	***	0.124	5.67	***	0.126	5.76	***	0.129	5.98	***
$\Delta spread_t$	0.048	12.25	***	0.038	9.40	***	0.048	12.26	***	0.048	12.33	***	0.038	9.50	***
vix_t	0.000	0.26		0.000	0.33		0.000	0.29		0.000	0.35		0.000	0.25	
ΔDif_t	-0.000	-0.43		-0.000	-0.27		-0.000	-0.42		-0.000	-0.84		-0.000	-0.95	
$TAX^{O\text{-}T\text{-}R}_t$	-0.001	-0.43		-0.002	-0.67		-0.004	-0.62		-0.002	-0.98		-0.006	-0.96	
$\hat{I}_t$	0.002	0.83		0.003	0.92		0.002	0.82		0.002	0.83		0.003	0.91	
Δpc_t	-0.051	-6.86	***	-0.049	-6.65	***	-0.050	-6.85	***	-0.051	-6.90	***	-0.047	-6.49	***
Dq_{t-1}	-0.004	-1.97	**	-0.004	-2.11	**	-0.004	-1.91	*	-0.004	-1.97	**	-0.004	-1.97	**
$TAX^{O\text{-}T\text{-}R}_t * \Delta spread_t$	---	---		0.004	5.25	***	---	---		---	---		0.004	5.30	***
$TAX^{O\text{-}T\text{-}R}_t * \hat{I}_t$	---	---		---	---		0.002	0.47		---	---		0.002	0.53	
$TAX^{O\text{-}T\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	1.70	*	0.000	1.75	*
Equation for the variance of the return															
a	0.179	7.97	***	0.175	7.98	***	0.177	7.97	***	0.178	7.92	***	0.172	7.99	***
b	0.821	36.48	***	0.825	37.75	***	0.823	37.16	***	0.822	36.62	***	0.828	38.38	***
$\lvert\Delta spread_t\rvert$	0.002	1.09		0.001	0.71		0.002	1.14		0.002	1.09		0.001	0.81	
vix_t	0.000	0.95		0.000	0.95		0.000	0.95		0.000	0.93		0.000	0.95	
$\lvert\Delta Dif_t\rvert$	0.000	0.73		0.000	0.86		0.000	0.72		0.000	0.70		0.000	0.87	
$TAX^{O\text{-}T\text{-}R}_t$	0.001	1.77	*	0.001	1.97	**	-0.002	-0.46		0.001	1.37		-0.001	-0.21	
$\hat{I}_t$	-0.000	-0.83		-0.000	-0.58		-0.000	-0.84		-0.000	-0.81		-0.000	-0.57	
$\lvert\Delta pc_t\rvert$	-0.002	-0.84		-0.002	-0.74		-0.002	-0.91		-0.002	-0.82		-0.002	-0.92	
$TAX^{O\text{-}T\text{-}R}_t * \Delta spread_t$	---	---		0.000	0.08		---	---		---	---		0.000	0.10	
$TAX^{O\text{-}T\text{-}R}_t * \hat{I}_t$	---	---		---	---		0.002	0.68		---	---		0.002	0.50	
$TAX^{O\text{-}T\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.10		0.000	-0.32	
Shape	1.702	20.57	***	1.687	20.59	***	1.705	20.59	***	1.708	20.48	***	1.703	20.44	***
Observations	1717			1717			1717			1717			1717		
Log Likelihood	1237			1229			1236			1235			1227		

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.

H.9

Definition of the tax: $TAX^{E\text{-}R}$

Sample 3: 2004:01:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**
Equation for the mean of the return															
Constant	0.011	0.42		0.013	0.52		0.010	0.40		0.011	0.44		0.012	0.48	
Δe_{t-1}	0.124	5.65	***	0.128	5.91	***	0.126	5.73	***	0.128	5.86	***	0.130	6.04	***
$\Delta spread_t$	0.048	12.24	***	0.036	9.00	***	0.048	12.27	***	0.048	12.28	***	0.037	9.22	***
vix_t	0.000	0.23		0.000	0.12		0.000	0.23		0.000	0.28		0.000	0.20	
ΔDif_t	-0.000	-0.43		-0.000	-0.29		-0.000	-0.41		-0.000	-0.90		-0.000	-1.05	
$TAX^{E\text{-}R}_t$	-0.007	-0.39		-0.006	-0.29		-0.036	-0.82		-0.019	-1.01		-0.032	-0.74	
$\hat{I}_t$	0.002	0.83		0.003	0.92		0.002	0.78		0.002	0.81		0.003	0.93	
Δpc_t	-0.051	-6.88	***	-0.048	-6.67	***	-0.051	-6.89	***	-0.051	-6.92	***	-0.048	-6.59	***
Dq_{t-1}	-0.004	-1.96	**	-0.004	-2.10	**	-0.004	-1.90	*	-0.004	-2.00	**	-0.004	-2.03	**
$TAX^{E\text{-}R}_t * \Delta spread_t$	---	---		0.037	6.17	***	---	---		---	---		0.037	6.22	***
$TAX^{E\text{-}R}_t * \hat{I}_t$	---	---		---	---		0.020	0.65		---	---		0.009	0.29	
$TAX^{E\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.002	1.99	**	0.002	2.09	**
Equation for the variance of the return															
a	0.180	7.99	***	0.177	8.14	***	0.178	7.94	***	0.178	7.94	***	0.179	8.11	***
b	0.820	36.53	***	0.823	37.80	***	0.822	36.71	***	0.822	36.68	***	0.821	37.30	***
$\lvert\Delta spread_t\rvert$	0.002	1.07		0.001	0.64		0.002	1.10	**	0.002	1.06		0.001	0.69	
vix_t	0.000	0.96		0.000	1.00		0.000	0.94		0.000	0.93		0.000	1.02	
$\lvert\Delta Dif_t\rvert$	0.000	0.70		0.000	0.89		0.000	0.69	***	0.000	0.68		0.000	0.88	
$TAX^{E\text{-}R}_t$	0.009	1.77	*	0.011	1.94	*	-0.015	-0.44	*	0.009	1.41		0.006	0.18	
$\hat{I}_t$	-0.000	-0.84		-0.000	-0.56		-0.000	-0.85		-0.000	-0.82		-0.000	-0.57	
$\lvert\Delta pc_t\rvert$	-0.002	-0.80		-0.002	-0.74		-0.002	-0.81		-0.002	-0.78		-0.002	-0.81	
$TAX^{E\text{-}R}_t * \Delta spread_t$	---	---		-0.002	-0.55		---	---		---	---		-0.004	-0.70	
$TAX^{E\text{-}R}_t * \hat{I}_t$	---	---		---	---		0.018	0.69		---	---		0.005	0.18	
$TAX^{E\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		0.000	0.07		-0.001	-0.52	
Shape	1.700	20.57	***	1.683	20.64	***	1.702	20.55	***	1.704	20.44	***	1.867	46.48	***
Observations	1717			1717			1717			1717			1717		
Log Likelihood	1237			1225			1236			1234			1222		

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.

H.10

Definition of the tax: TAX^d

Sample 4: 2008:01:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**
Equation for the mean of the return															
Constant	0.062	0.76		0.052	0.65		0.071	0.85		0.074	0.90		0.071	0.88	
Δe_{t-1}	0.140	3.91	***	0.127	3.60	***	0.131	3.61	***	0.145	4.11	***	0.125	3.54	***
$\Delta spread_t$	0.075	7.70	***	0.086	7.43	***	0.076	7.87	***	0.074	7.69	***	0.090	7.71	***
vix_t	-0.004	-1.11		-0.003	-1.07		-0.003	-0.80		-0.004	-1.24		-0.003	-0.84	
ΔDif_t	-0.005	-1.67	*	-0.006	-1.90	*	-0.004	-1.41		-0.001	-0.13		0.000	0.08	
TAX^d_t	-0.015	-0.25		-0.015	-0.26		-0.055	-0.87		-0.014	-0.24		-0.054	-0.88	
I_t	0.036	1.12		0.035	1.10		-0.003	-0.09		0.031	0.97		-0.009	-0.24	
Δpc_t	-0.158	-8.69	***	-0.145	-7.97	***	-0.150	-8.32	***	-0.164	-9.12	***	-0.142	-7.97	***
Dq_{t-1}	-0.000	-0.02		0.001	0.10		-0.004	-0.54		0.000	0.05		-0.004	-0.46	
$TAX^d_t * \Delta spread_t$	---	---		-0.037	-1.79	*	---	---		---	---		-0.046	-2.22	**
$TAX^d_t * I_t$	---	---		---	---		0.155	2.03	**	---	---		0.160	2.13	**
$TAX^d_t * \Delta Dif_t$	---	---		---	---		---	---		-0.008	-1.21		-0.008	-1.28	
Equation for the variance of the return															
a	0.185	3.97	***	0.185	3.83	***	0.197	3.89	***	0.185	3.93	***	0.203	3.73	***
b	0.815	17.50	***	0.815	16.82	***	0.803	15.81	***	0.815	17.25	***	0.797	14.64	***
$\|\Delta spread_t\|$	0.005	0.57		0.005	0.53		0.007	0.68		0.005	0.57		0.007	0.67	
vix_t	-0.000	-0.23		-0.000	-0.26	*	-0.000	-0.12		-0.000	-0.01		-0.000	-0.03	
$\|\Delta Dif_t\|$	-0.001	-0.21		-0.001	-0.22		-0.000	-0.11		-0.000	-0.06		0.000	0.00	
TAX^d_t	0.007	0.26		0.010	0.36		0.002	0.07		0.014	0.51		0.008	0.27	
I_t	-0.000	-0.06		-0.000	-0.01		-0.003	-0.30		-0.002	-0.21		-0.003	-0.35	
$\|\Delta pc_t\|$	0.021	0.67		0.022	0.72		0.017	0.53		0.012	0.41		0.014	0.43	
$TAX^d_t * \Delta spread_t$	---	---		0.013	0.55		---	---		---	---		0.007	0.30	
$TAX^d_t * I_t$	---	---		---	---		0.022	0.52		---	---		0.022	0.48	
$TAX^d_t * \Delta Dif_t$	---	---		---	---		---	---		-0.009	-1.16		-0.007	-0.90	
Shape	1.659	11.37	***	1.706	11.41	***	1.666	11.50	***	1.656	11.24	***	1.727	11.72	***
Observations	674			674			674			674			674		
Log Likelihood	765			763			762			764			759		

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.

H.11

Definition of the tax: $TAX^{O\text{-}T\text{-}R}$

Sample 4: 2008:01:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.	Coeff.	*t*	Sig.
Equation for the mean of the return															
Constant	0.062	0.77		0.051	0.65		0.072	0.86		0.074	0.90		0.073	0.90	
Δe_{t-1}	0.140	3.92	***	0.127	3.61	***	0.131	3.61	***	0.145	4.11	***	0.126	3.57	***
$\Delta spread_t$	0.075	7.70	***	0.087	7.41	***	0.076	7.88	***	0.074	7.71	***	0.090	7.73	***
vix_t	-0.004	-1.12		-0.003	-1.07		-0.003	-0.80		-0.004	-1.23		-0.003	-0.86	
ΔDif_t	-0.005	-1.67	*	-0.006	-1.90	*	-0.004	-1.38		0.000	-0.08		0.001	0.11	
$TAX^{O\text{-}T\text{-}R}_t$	-0.001	-0.26		-0.001	-0.27		-0.004	-0.87		-0.001	-0.20		-0.003	-0.84	
I_t	0.036	1.13		0.035	1.10		-0.003	-0.09		0.031	0.95		-0.009	-0.25	
Δpc_t	-0.158	-8.71	***	-0.145	-7.98	***	-0.150	-8.32	***	-0.164	-9.08	***	-0.141	-7.97	***
Dq_{t-1}	0.000	-0.02		0.001	0.09		-0.004	-0.54		0.000	0.05		-0.004	-0.46	
$TAX^{O\text{-}T\text{-}R}_t * \Delta spread_t$	---	---		-0.002	-1.82	*	---	---		---	---		-0.003	-2.27	**
$TAX^{O\text{-}T\text{-}R}_t * I_t$	---	---		---	---		0.010	1.97	**	---	---		0.010	2.13	**
$TAX^{O\text{-}T\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		-0.001	-1.24		-0.001	-1.37	
Equation for the variance of the return															
a	0.185	3.96	***	0.185	3.81	***	0.197	3.88	***	0.185	3.94	***	0.201	3.72	***
b	0.815	17.49	***	0.815	16.85	***	0.803	15.83	***	0.815	17.36	***	0.799	14.80	***
$\|\Delta spread_t\|$	0.005	0.57		0.005	0.53		0.007	0.67		0.005	0.54		0.007	0.63	
vix_t	0.000	-0.23		0.000	-0.26		0.000	-0.13		0.000	-0.05		0.000	-0.04	
$\|\Delta Dif_t\|$	-0.001	-0.21		-0.001	-0.23		0.000	-0.10		0.000	0.07		0.000	0.11	
$TAX^{O\text{-}T\text{-}R}_t$	0.000	0.25		0.001	0.38		0.000	0.06		0.001	0.51		0.001	0.32	
I_t	0.000	-0.06		0.000	-0.01		-0.003	-0.30		-0.002	-0.21		-0.003	-0.34	
$\|\Delta pc_t\|$	0.020	0.66		0.022	0.71		0.017	0.53		0.012	0.41		0.013	0.41	
$TAX^{O\text{-}T\text{-}R}_t * \Delta spread_t$	---	---		0.001	0.58		---	---		---	---		0.001	0.38	
$TAX^{O\text{-}T\text{-}R}_t * I_t$	---	---		---	---		0.001	0.52		---	---		0.001	0.45	
$TAX^{O\text{-}T\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		-0.001	-1.23		-0.001	-1.05	
Shape	1.660	11.36	***	1.706	11.41	***	1.666	11.49	***	1.651	11.22	***	1.728	11.72	***
Observations	674			674			674			674			674		
Log Likelihood	765			763			762			764			759		

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.

H.12

Definition of the tax: $TAX^{E\text{-}R}$

Sample 4: 2008:01:01 - 2010:07:30

Variables	Model 1			Model 2			Model 3			Model 4			Model 5		
	Coeff.	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**	**Coeff.**	***t***	**Sig.**
Equation for the mean of the return															
Constant	0.065	0.80		0.056	0.70		0.071	0.86		0.075	0.92		0.076	0.94	
Δe_{t-1}	0.140	3.94	***	0.127	3.60	***	0.131	3.61	***	0.142	4.03	***	0.128	3.60	***
$\Delta spread_t$	0.075	7.67	***	0.085	7.34	***	0.076	7.85	***	0.074	7.68	***	0.086	7.48	***
vix_t	-0.004	-1.14		-0.004	-1.12		-0.003	-0.84		-0.004	-1.26		-0.003	-0.89	
ΔDif_t	-0.005	-1.68	*	-0.006	-1.99	**	-0.005	-1.47		-0.002	-0.37		-0.001	-0.20	
$TAX^{E\text{-}R}_t$	-0.015	-0.32		-0.013	-0.29		-0.042	-0.82		-0.012	-0.25		-0.041	-0.83	
I_t	0.037	1.15		0.037	1.14		0.000	0.00		0.032	1.01		-0.006	-0.16	
Δpc_t	-0.159	-8.76	***	-0.145	-8.04	***	-0.151	-8.37	***	-0.164	-9.14	***	-0.145	-8.14	***
Dq_{t-1}	0.000	-0.01		0.001	0.11		-0.004	-0.49		0.001	0.07		-0.004	-0.47	
$TAX^{E\text{-}R}_t * \Delta spread_t$	---	---		-0.028	-1.76	*	---	---		---	---		-0.029	-1.83	*
$TAX^{E\text{-}R}_t * I_t$	---	---		---	---		0.124	2.00	**	---	---		0.127	2.06	**
$TAX^{E\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		-0.005	-1.01		-0.005	-1.11	
Equation for the variance of the return															
a	0.185	3.93	***	0.187	3.84	***	0.197	3.86	***	0.186	3.88	***	0.200	3.72	***
b	0.815	17.34	***	0.813	16.69	***	0.803	15.71	***	0.814	16.99	***	0.800	14.89	***
$\|\Delta spread_t\|$	0.006	0.60		0.005	0.57		0.007	0.71		0.006	0.63		0.007	0.68	
vix_t	0.000	-0.15		0.000	-0.23		0.000	-0.02		0.000	0.13		0.000	0.15	
$\|\Delta Dif_t\|$	-0.001	-0.37		-0.001	-0.32		-0.001	-0.29		-0.001	-0.36		-0.001	-0.26	
$TAX^{E\text{-}R}_t$	0.009	0.42		0.010	0.42		0.006	0.26		0.017	0.78		0.012	0.52	
I_t	0.000	-0.05		0.000	0.00		-0.003	-0.30		-0.001	-0.19		-0.003	-0.32	
$\|\Delta pc_t\|$	0.019	0.63		0.022	0.71		0.014	0.47		0.010	0.34		0.010	0.31	
$TAX^{E\text{-}R}_t * \Delta spread_t$	---	---		0.009	0.48		---	---		---	---		0.005	0.28	
$TAX^{E\text{-}R}_t * I_t$	---	---		---	---		0.019	0.54		---	---		0.018	0.50	
$TAX^{E\text{-}R}_t * \Delta Dif_t$	---	---		---	---		---	---		-0.006	-1.04		-0.005	-0.83	
Shape	1.663	11.37	***	1.702	11.41	***	1.668	11.49	***	1.662	11.23	***	1.712	11.60	***
Observations	674			674			674			674			674		
Log Likelihood	765			763			762			764			760		

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.