Box 2: The Higher Sensitivity of Peso-denominated TES Compared to UVR in Scenarios of Higher International Risk

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Introduction

The government bonds market in Colombia incorporates relevant information for the analysis of expectations regarding inflation, MPR, and economic growth. Therefore, the dynamics of these interest rates are an essential input for monetary policy decisions. Studying the factors that explain interest rates in the government bonds market is crucial for monetary policy for several reasons: *i*) Government bonds rates are a reference for other interest rates in the economy and are a key channel for the transmission of monetary policy, and *ii*) market agents value these instruments by incorporating information about their expectations regarding the MPR and inflation, with these expectations serving as an essential input for monetary policy decision-making.

In the government bonds market, bonds are traded in both pesos and real value units (UVR in Spanish). The rates of these bonds may respond differently to changes in certain economic and financial variables. Specifically, it is observed that peso-denominated TES rates tend to be more sensitive than UVR-denominated TES rates in scenarios of higher international risk. Differential liquidity conditions and the participation of several types of investors in both markets may explain the different reactions of TES rates to different international events.

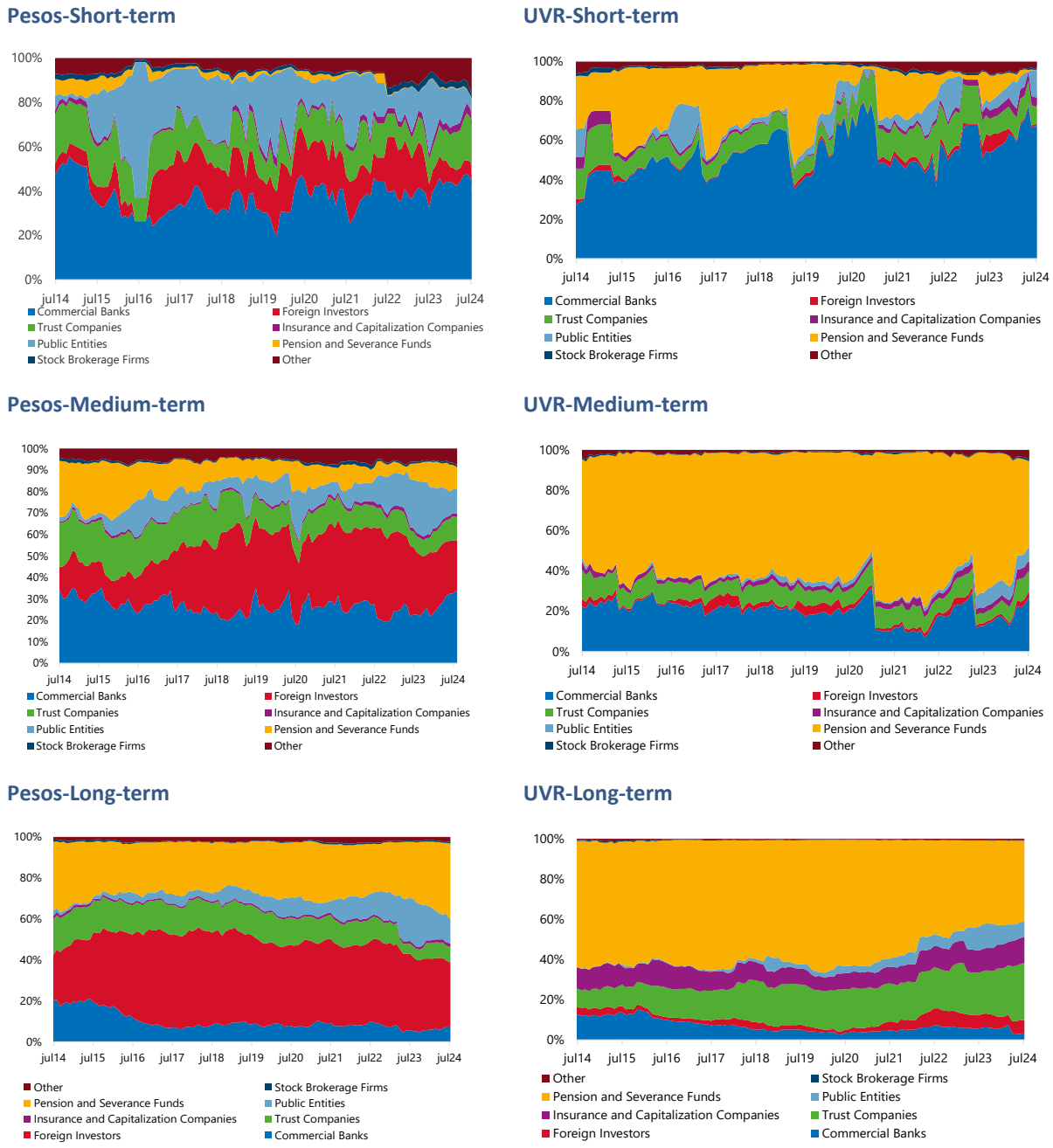
This box exhibits an empirical approach that shows statistical evidence supporting the greater sensitivity of peso-denominated TES rates compared to UVR-denominated TES rates in scenarios of higher international risk. Through an econometric exercise, it is observed that peso-denominated TES rates and their volatility show a greater reaction to scenarios of higher international risk than UVR-denominated TES rates.

Stylized Facts

The TES market is characterized by a differential composition of the investor base across maturities and markets (*Graph B2. 1*). The relative absence of foreign investors in the UVR TES market is notable, whereas they have a significant share in the peso-denominated TES market. The greater share of foreign investors in the peso-denominated TES market may make this market more susceptible to external events. On the other hand, local pension funds have a higher relative share in the UVR-denominated market compared to their share in the peso-denominated TES market.

[1] The opinions expressed in this document do not reflect or represent the views of *Banco de la República* or its Board of Directors. Any errors or omissions are and will be the sole responsibility of the authors.

Graph B2. 1. Share by Type of Investor in the TES Market at Different Maturities

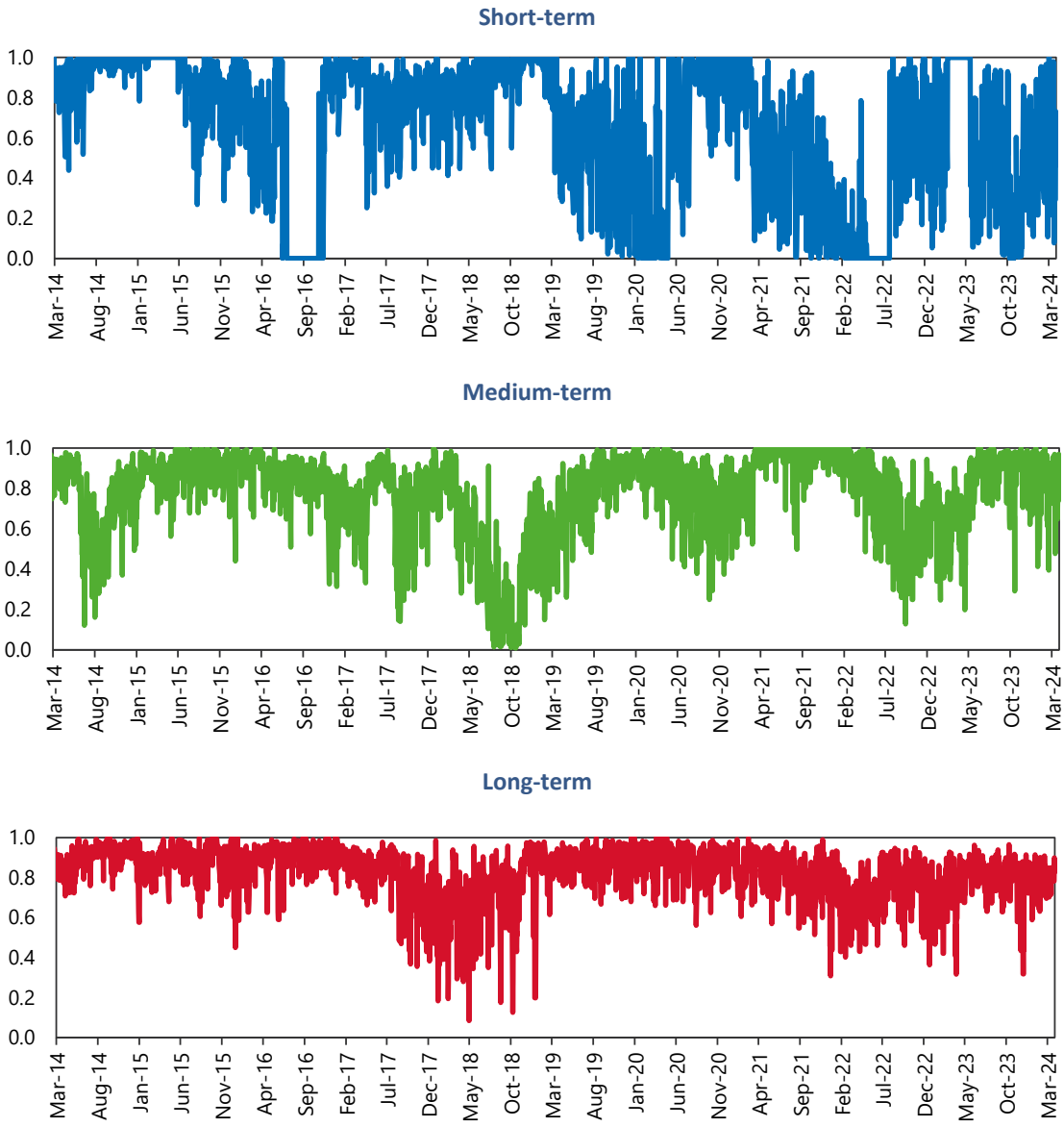


Source: *Banrep*. **Notes:** Short-term refers to bonds with maturities of less than 2 years, medium-term refers to bonds with maturities between 2 and 5 years, and long-term refers to bonds with maturities of more than 10 years.

Differential liquidity conditions are also observed across markets at different maturities. In the short term, there are several episodes where the trading volume of UVR-denominated bonds exceeds that of peso-denominated TES. On average, peso-denominated TES are traded more in the medium and long term (*Graph B2. 2*). Seasonal strategies may also affect the

demand for UVR-denominated bonds. During the first months of each year, UVR TES tend to experience higher appreciation due to high monthly inflation rates.

Graph B2. 2 Trading Volume of Peso-denominated TES / Total Trading Volume



Source: *Banrep*. **Notes:** The total trading volume is calculated as the sum of transactions in the peso- and UVR-denominated TES market. Values above 0.5 indicate that peso-denominated TES are traded more than UVR-denominated TES. Short-term refers to bonds with maturities of less than 2 years, medium-term refers to bonds with maturities between 2 and 5 years, and long-term refers to bonds with maturities of more than 10 years

Methodological Approach

To test the hypothesis, a two-step exercise is proposed. First, an EGARCH(1,1)[2] model is estimated to calculate the implied volatility of peso- and UVR-denominated TES rates. Then, using the calculated volatilities, a generalized linear model is estimated to model the volatility ratio. The EGARCH model quantifies the sensitivity of rates, while the generalized model allows to observe the greater sensitivity in terms of volatility.

The EGARCH(1,1) model estimation uses several financial variables to model the mean and variance of the rates. Including these variables also allows to capture some important relationships within the TES market. Specifically, the following model is proposed:

$$\mathrm{r}_{\mathrm{t}}^{\mathrm{i,j}} = \mu^{i,j} + \sum_{l=1}^{p} \theta_{l}^{\mathrm{i,j}} \mathrm{r}_{\mathrm{t}-l}^{\mathrm{i,j}} + \sum_{n=1}^{k} \varphi_{\mathrm{n}}^{\mathrm{i,j}} X_{n,j} + \varepsilon_{\mathrm{t}}^{\mathrm{i,j}} \; ; \; i \in \{pesos,\, uvr\} \; and \; j \in \{short,\, medium, and \; long - term\}$$

$$where \quad \varepsilon_{\mathrm{t}}^{\mathrm{i,j}} = \sigma_{\mathrm{t}}^{\mathrm{i,j}} z_{\mathrm{t}}^{\mathrm{i,j}} \qquad z_{\mathrm{t}}^{i,j} \big| I_{t-1} \sim IID(0,1)$$

$$\ln(\sigma_{\mathrm{t},i,j}^{2}) = \omega^{i,j} + \alpha^{i,j}\left(z_{\mathrm{t}-1}^{\mathrm{i,j}} - E\left[\left|z_{\mathrm{t}-1}^{\mathrm{i,j}}\right|\right]\right) + \beta^{i,j} \ln(\sigma_{\mathrm{t}-1,i,j}^{2}) + \gamma^{i,j} z_{\mathrm{t}-1}^{\mathrm{i,j}} + \sum_{n=1}^{r} \delta_{\mathrm{n}}^{\mathrm{i,j}} Y_{n,j}$$

Where $r_t^{i,j}$ represents the daily variations of peso- and UVR-denominated TES rates at different maturities. $X_{n,j}$ is a set of variables that explain rate variations, particularly including the following indicators:

- Seasonal dummies. D_2, D_3, and D_4 take the value of 1 for the second, third, and fourth quarters, respectively.
- Inflation surprises and local MPR. These indicators are calculated as the difference a
- Changes in international risk (ΔRI_{t-1}). The RI is derived from the first principal component of the MOVE, VIX, and the 3-month implied volatility of Euro/Dollar options.
- Changes in the 3-month Treasury rates (with a 1-day lag).
- Changes in the international commodity price index (with a 1-day lag).
- Changes in the risk perception index of emerging countries (with a 1-day lag).
- Net purchases by FPCs ($CNFPC$), foreign investors ($CNEXT$), the Ministry of Finance and Public Credit ($CNMHCP$), and *Banco de la República* ($CNBR$) by market and maturity (these purchases were divided by the total trading volume per market and maturity and the one-day lag was used);
- Turnover by market and maturity (with a 1-day lag). It is calculated as the total trading volume divided by the total securities issued.

[2] EGARCH models have two advantages over the GARCH model. First, by using the exponential formulation, positive constraints on the estimated coefficients in the variance equation are no longer necessary. Second, a limitation of the GARCH model is that conditional variance depends on the magnitude of the disturbance term but not its sign, making it unable to capture the negative asymmetry commonly observed in many financial time series.

- Includes a variable relating foreign investor purchases to international risk ($CNEXT * RI$).

In turn, $Y_{n,j}$ represents variables that explain rate volatilities. Particularly, the variables $X_{n,j}$ in levels were used.

Using the estimated conditional volatilities, a gamma regression is proposed to test the greater sensitivity of peso-denominated TES rates compared to UVR-denominated TES rates in scenarios of greater international risk aversion. This regression is appropriate to model the volatility ratio $\left(\frac{\hat{\sigma}_{t,pesos,j}}{\hat{\sigma}_{t,UVR,j}}\right)$ as this variable is positive and biased towards high[3] values. Thus, the estimated regression is:

$$\ln\left(\mathrm{E}\left(\frac{\hat{\sigma}_{t,pesos,j}}{\hat{\sigma}_{t,UVR,j}}\right)\right) = \omega^j + \beta^j \ln\left(\frac{\hat{\sigma}_{t-1,pesos,j}}{\hat{\sigma}_{t-1,UVR,j}}\right) + \sum_{n=1}^{r} \gamma_{n,i} Y_{n,j}\,;\; y \quad \frac{\sigma_{t,pesos,j}}{\sigma_{t,UVR,j}} \sim Gamma\left(\mu_t^i, \alpha\right)$$

Where $Y_{n,j}$is a set of variables that explain rate volatilities. Specifically, the same explanatory variables used to estimate the variance equation in the EGARCH(1,1) models are employed. If the previous regression shows that the coefficient associated with international risk is positive, it would indicate that the volatility of the peso-denominated TES market is higher than the volatility of the UVR-denominated TES market.

Results

The EGARCH(1,1) model estimation shows that the coefficient associated with variations in international risk is positive for both markets and maturities. Additionally, the coefficient for the peso-denominated TES market is always higher than that for the UVR-denominated TES market, indicating that these rates respond in a greater magnitude to changes in international risk (*Table B2. 1*). Other results from the model include: *i*) a surprise in inflation expectations in Colombia may lead to increases in the BEI at different maturities[4]; *ii*) an upward surprise in the MPR in Colombia results in higher increases in short-term peso-denominated TES rates[5]; *iii*) foreign investor purchases lead to an appreciation in peso-denominated TES rates in the medium and long terms, and *iv*) greater local and international liquidity[6] reduces market volatility.

[3] The estimated volatility ratio by maturity of the peso- and UVR-denominated TES market using a GARCH(1,1) model suggests that the volatility of the peso-denominated TES market tends to show significant jumps at certain points in time.
[4] The Breakeven Inflation (BEI) is a measure calculated as the difference between the rates of peso- and UVR-denominated bonds. This indicator can be used to approximate inflation expectations in the Colombian government bonds market.
[5] The central bank information effect hypothesis considers that when agents face a contractionary surprise, they anticipate that the central bank has privileged information about future price developments, leading to an increase in inflation expectations. See: *i*) Romer, C.D., Romer, D.H., 2000. *Federal Reserve information and the behavior of interest rates*. Am. Econ. Rev. 90(3), 429–457; *ii*) Campbell, J.R., Evans, C.L., Fisher, J.D.M., Justinian, A., 2012. *Macroeconomic Effects of Federal Reserve Forward Guidance. Brookings* Pap. Econ. Act, Spring, pp. 1–80; and Nakamura, E., Steinsson, J., 2018. *High-frequency identification of monetary non-neutrality: the information effect*. Q. J. Econ. 133(3), 1283–1330.
[6] The treasury rate is aligned with international liquidity conditions. Specifically, there is a negative relationship between the Fed's balance sheet (%GDP) and the 3-month treasury rate.

Table B2.1 Estimation Result of the EGARCH(1,1) Model for Different Maturities and Markets

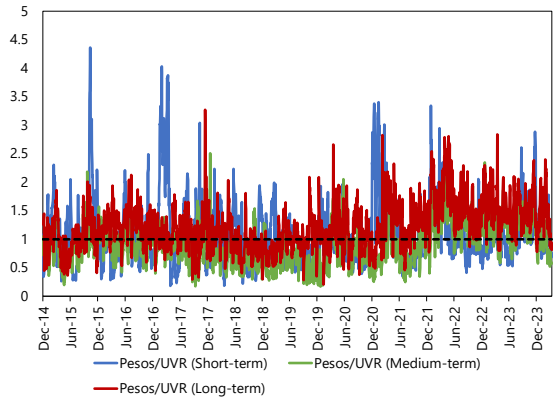
		Dependent Variable											
		Short-term				Medium-term				Long-term			
		PESOS		UVR		PESOS		UVR		PESOS		UVR	
Mean	μ	-1.0806	(1.5929)	0.355***	(0.0466)	-0.5431	(0.6034)	-0.2812***	(0.3681)	-0.2972	(0.9573)	0.2496***	(0.0273)
	D_2	-0.1506	(0.4085)	0.6282***	(0.0606)	-0.2588	(0.4636)	-0.2095**	(0.5766)	-0.1205	(3.0507)	-0.5087***	(0.1748)
	D_3	0.2797	(0.325)	-0.5677	(0.4097)	0.0961	(0,578)	-0.7338***	(0.8679)	-0.0698	(2.5929)	-0.5292***	(0.1077)
	D_4	0.4844	(0.3347)	-0.578***	(0.0404)	0.1033	(0.3465)	-0.6655**	(0.7657)	-0.1197	(2.2453)	-1.0416***	(0.0787)
	Inflation Shock	2.3017***	(0.5415)	-2.5998***	(0.1901)	2.5802***	(0.3671)	-0.9587***	(0)	1.5631***	(0.4684)	-0.4939*	(0.2862)
	MPR Shock	0.4283***	(0.0958)	0.0312	(0.0444)	1555 0	(0.1046)	0.1067***	(0.137)	0.1635***	(0.0361)	0.0258	(0.0348)
	ΔRI_{t-1}	2,313***	(0,768)	1.6525***	(0.2891)	5.9643***	(0.6698)	3.8037***	(0)	6.4079***	(0,719)	3.4987***	(0.6674)
	3-Month Treasures	0.1345**	(0.0584)	0.0876***	(0.0151)	0.2436***	(0,057)	0.1584***	(0)	0.2185	(0.1454)	0.0946*	(0.0495)
	Commodities	-0.3327*	(0.1792)	-0.3318***	(0.038)	-0.4892***	(0.1745)	-0.3229**	(0,005)	-0.3779**	(0.159)	-0.3541***	(0.0774)
	EM risk	1.5837	(2.6766)	0.0753	(0.0532)	2.3911***	(0.8502)	1.1745***	(0.0049)	1.8874***	(0.6831)	0.9099***	(0.0763)
	$CNEXT$*RI	0.3579	(0.4208)	0.3105	(13.0387)	-0.2827	(0.7941)	-0.7076	(0.7218)	-24.9871**	(10.0365)	5.4943	(3.5524)
	$CNEXT$	-0.0509***	(0.0067)	0.1686	(0.7988)	-0.9912***	(0.3059)	-0.0659	(0.0012)	-6.7125***	(2.2246)	0.0104	(0.8807)
	$CNFPC$	3.1389*	(1.7137)	-0.0233	(0.0175)	-1.1765***	(0.3424)	-0,023	(0.0006)	4,7507	(3.3829)	0.0501***	(0.0022)
	$CNBR$	-0.0793	(0.0744)	0.3308	(0.3939)	-0.2775	(0.345)	-0.9749	(0.4213)	-0.5051*	(0.2866)	-0.1919	(0.5777)
	$CNMHCP$	-0.0029***	(0.0007)	-0.009**	(0,004)	0.0133	(0.1935)	-0.2359***	(0.9451)	-0.0579	(0.2953)	-0.0504	(0.2473)
	Turnover	1.2857	(1.4412)	-9.0524**	(3.7458)	-21.7444***	(5.4456)	0.2394	(0.0001)	-27.0939	(86,478)	-16.7164**	(7.9327)

		Dependent Variable											
		Short-term				**Medium-term**				**Long-term**			
		PESOS		**UVR**		**PESOS**		**UVR**		**PESOS**		**UVR**	
Variance	ω	0.137***	(0.0149)	0.3252***	(0.1092)	0.1764***	(0.012)	0.8299***	(0.299)	0.1954***	(0.0102)	0.949***	(0.2861)
	α	0.045*	(0.0236)	0.0171	(0.0298)	0.0507***	(0.0174)	-0,025	(0.0286)	0.0343*	(0.0185)	0.0223	(0.03)
	β	0.9556***	(0.0014)	0.9024***	(0.0313)	0.9552***	(0.0007)	0.8**	(0.0707)	0.9521***	(0.0004)	0.7443***	(0.0776)
	γ	0.34***	(0.0386)	0.4496***	(0.0705)	0.188***	(0.0317)	0.5948***	(0.0834)	0.21***	(0.0168)	0.4066***	(0.0556)
	Inflation Shock	0.0611	(0.0587)	0.3315***	(0.0909)	0.0953**	(0.0455)	-0.0473	(0.0714)	0.0518	(0.0509)	-0.0197	(0.1162)
	MPR Shock	0.0277***	(0,009)	0.0095	(0.0077)	0.0137**	(0,006)	0.0098	(0.0085)	0.0144**	(0.0067)	0.0217*	(0.0128)
	RI	0.018***	(0.0048)	0.0368**	(0.0156)	0.0259***	(0.0045)	0.0455**	(0.0225)	0.0308***	(0.0042)	0.0793***	(0.0281)
	3-Month Treasures	0.0092**	(0.0037)	0.0006	(0,006)	0.0054**	(0.0022)	0.0145	(0.0095)	0.0047**	(0.0024)	0.0251**	(0.0127)
	$\boldsymbol{CNEXT}$*RI	-0.010791	(0.0294)	0.0225	(0.0232)	-0.029004	(0.0428)	0.4826	(0.3602)	-0.141778**	(0.0557)	-0.0498	(0.4703)
	$\boldsymbol{CNEXT}$	-0.0012	(0,001)	-0.0253*	(0.0153)	-0.036883	(0.032)	-0.0036	(0.0125)	-0.0476	(0.1349)	-0.1082	(0.1947)
	$\boldsymbol{CNFPC}$	0.2525***	(0.0565)	-0,002	(0.0046)	0.009437	(0.0924)	-0.0009	(0.0047)	-0.1515	(0.1219)	-0.0304	(0.0794)
	$\boldsymbol{CNBR}$	0.0841**	(0.0367)	-0.0717	(0.0603)	-0.072632	(0.0502)	-0.4136*	(0.2216)	-0.118696	(0.0827)	-0.2072	(0.2789)
	$\boldsymbol{CNMHCP}$	0.0003*	(0.0001)	0.0025	(0.0036)	0.010368	(0.0452)	-0.1172**	(0.0471)	-0.012493	(0.0572)	0.0346	(0.0277)
	Turnover	-0.181789	(0.1816)	1.3822	(1.8528)	-1.503654***	(0.4615)	-1.0648**	(0.4541)	-1.416076***	(0.4628)	-13.4617***	(5.1783)
	Observations	2261		2261		2261		2261		2261		2261	
	Log Likelihood	-6982,568		-6916,717%		-7353,742%		-7722,275%		-7508,172		-7196,986	

Note: *i*) The following significance conventions apply *** *p-value<0.01, *** p-value<0.05, and * p-value<0.1*. The values in parentheses represent the standard errors estimated with robust errors. *ii)* The Commodities and Emerging Risk variables were not included in the variance equation since their coefficients were not significant for any market or maturity. *iii*) A t-student distribution was used for the maximum likelihood estimation, and the shape parameter was positive and significant for all markets and maturities. *iv*) In the variance equation, the inflation and MPR shock variables were used as absolute values; the variables in levels were not significant. *v*) The estimations of the coefficients associated with the autoregressive orders were omitted, which in the case of the peso-denominated TES are AR(1), AR(1), and AR(2) for the short, medium, and long-term, respectively; and for the UVR-denominated TES are AR(6), AR(3), and AR(2) for the short, medium, and long-term, respectively.

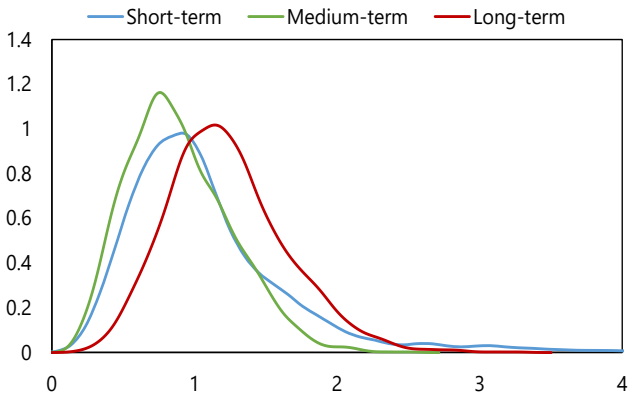
The probability distribution of the volatility ratio of peso-denominated TES rates with respect to the volatility of UVR-denominated TES rates suggests similar values[7]. However, it is observed that in certain periods, the volatility of peso-denominated TES rates may be higher than that of UVR-denominated TES rates (*Graph B2. 3* and *Graph B2. 4*). Notably, since 2021, it has been observed that peso-denominated TES rates have been more volatile than UVR-denominated TES rates, in line with the greater uncertainty at the international level.

Graph B2. 3 Estimated Relative Volatilities (Vol pesos/Vol UVR) by Maturity



Source: Bloomberg

Graph B2. 4 Probability Distribution of Relative Volatilities at Different Maturities



Note: The probability distribution is calculated using non-parametric techniques.

In addition, the results of the gamma models indicate that higher international risk leads to greater volatility in peso-denominated TES rates compared to UVR-denominated TES rates (*Table B2. 2*). On the other hand, the regressions reveal other interesting relationships, such as: *i)* in the long term, higher relative liquidity, measured by turnover, tends to reduce the relative volatility between markets, and *ii)* seasonal strategies reduce the relative volatility of UVR-denominated bonds in the short term.

Table B2. 2 Estimation Result of the EGARCH(1,1) Model for Different Markets

	Short-term		Medium-term		Long-term	
Constant	0.7735***	(0.0167)	-1.0792***	(0.0176)	-0.6799***	(0.0144)
D_2	-0.0243*	(0.0132)	0.0126	(0.0129)	-0,005	(0.0094)
D_3	-0.0623***	(0.0134)	0.018	(0.0128)	0.0042	(0.0094)
D_4	-0.0246*	(0.0131)	0.016	(0.0131)	0,008	(0.0095)
$Lag\ (t-1)$	0.724***	(0.0092)	0.9952***	(0.0145)	0.6939***	(0.0095)
RI	0.0115***	(0.0039)	0.0289***	(0.0042)	0.0107***	(0.0031)
3-Month Treasures	0.0118***	(0.0027)	-0.0025	(0.0027)	-0.0015	(0.0021)
Inflation Shock	0.0034	(0.013)	0.0038	(0.0127)	0.0165*	(0.0093)

[7] The distributions are centered around the value of zero.

	Short-term		Medium-term		Long-term	
MPR Shock	0.0008	(0.0015)	0.0038**	(0.0015)	0.0017	(0.0011)
$CNEXT_{pesos}$	-0.0013	(0.0014)	-0.0131	(0.0114)	-0.0147	(0,051)
$CNEXT_{pesos}$	-0.0158	(0.0267)	-0.0031	(0.0328)	-0.0022	(0.0315)
$CNBR_{pesos}$	-0.0119	(0.0143)	-0.0216	(0.0268)	-0.0107	(0.0376)
$CNMHCP_{pesos}$	0	(0.0001)	-0.0016	(0.0154)	-0.0008	(0.014)
$CNEXT_{UVR}$	0.0244	(0.0315)	-0.0004	(0.0032)	-0.0231	(0.0158)
$CNEXT_{UVR}$	-0.0001	(0.0008)	0,001	(0.0009)	0.0007	(0.0057)
$CNBR_{UVR}$	-0.0035	(0,007)	-0.1632**	(0.0707)	-0.0201	(0.0682)
$CNMHCP_{UVR}$	-0.0005	(0.0006)	-0.0013	(0.0087)	0.0016	(0.0046)
$Turnover_{pesos}$	0.0708	(0.0564)	0.0974	(0.4039)	-0.9939***	(0.2116)
$Turnover_{UVR}$	0.7342	(0.4773)	1525	(0.0963)	1.2253**	(0.5893)
$CNEXT_{pesos} * RI$	-0.0016	(0.0021)	-0.0032	(0.0097)	0.0103	(0.0194)
$CNEXT_{UVR} * RI$	-0.0205	(0.0314)	-0.0027	(0.0028)	-0.0485**	(0.0199)
Observations	2261		2261		2261	
Akaike Information Criterion (AIC)	-235.43%		-1268		-1070.8	
Pseudo-R^2	0.7613		0.7213		0.7651	

Note: i) The following significance conventions apply *** p-value<0.01, *** p-value<0.05, and * p-value<0.1

Conclusions

There is statistical evidence supporting the hypothesis that, when international uncertainty increases, the variations and volatility of peso-denominated TES rates are higher than those of UVR-denominated TES rates. This differential performance could be associated with the greater share of foreign investors in the peso-denominated TES market.

Additionally, various estimations reveal other significant relationships between some economic variables and variations in TES rates at different maturities. Specifically, *(i)* a surprise in inflation expectations in Colombia may lead to increases in the BEI at different maturities; (*ii*) an upward surprise in the MPR in Colombia results in higher increases in short-term peso-denominated TES rates; *iii*) foreign investor purchases lead to an appreciation in peso-denominated TES rates in the medium and long terms, and *iv*) greater local and international liquidity reduces market volatility.