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Explaining Exchange Rate Movements Using Yield Curves in Emerging Countries

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Abstract

Economic agents and policymakers need to understand the factors that determine the exchange rates in order to make decisions to maximize individual and collective wealth respectively. This paper attempts to explain the movements of major emerging country exchange rates adopting a theory based approach. This approach is based on two major concepts of financial economics, the Uncovered Interest Parity condition and the yield curve. Instead of estimating a UIP regression using some interest rate differential at a specific maturity, we use information from the whole term structure. Using Nelson-Siegel parameters extracted from the yield curve differentials as explanatory variables, we estimate GARCH(1,1) models to predict exchange rate movements of 7 major emerging countries. Our findings indicate that yield curves are useful in explaining exchange rate movements. Rising local interest rates lead to local currency appreciation contrary to the UIP condition. Steeper yield curve causes local currency appreciation in some emerging countries and depreciation in others. Effects of the yield curve parameters are generally stronger at longer horizons implying that UIP does not become valid even in the long run. Finally several robustness checks indicate that these results are robust to data frequency, sample period and yield curve characterization methodology.

Keywords: Uncovered interest parity, term structure of interest rates, exchange rates.

JEL Classification: E43, F37, F31

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Non-technical Summary

Exchange rates are among the most important financial prices for economic agents and policymakers. They need to understand the factors that determine the exchange rates in order to make decisions to maximize their individual wealth and the collective wealth in the economy.

In the related literature there are many different approaches to predict exchange rates. One class of methods is solely based on the time series characteristics of the data while others are based on economic theories. Another approach to exchange rate prediction makes use of evaluating the economic data and professional judgement together. The approach adopted in this study is based on two major concepts of financial economics, namely the Uncovered Interest Parity (UIP) condition and the yield curve. The UIP condition states that the domestic interest rate should equal the foreign country interest rate plus the expected exchange rate depreciation (or appreciation). Thus, the UIP condition links the exchange rates with domestic and global interest rates. On the other hand, the yield curve is the representation of the interest rates at different maturities. Hence it links the interest rates at different maturities to each other.

The standard form of the UIP condition makes use of the information carried by the interest rates at the selected maturity and ignores all the information from the interest rates at other maturities. In this study, instead of estimating a UIP regression using the difference between domestic and foreign interest rates at a specific maturity, we use information from the whole term structure of interest rates by summarizing the yield curve with a group of parameters. In order to do so, we use the parameters extracted from the mathematical form for the yield curve proposed by Nelson and Siegel (1987) as explanatory variables. Then we estimate GARCH(1,1) models to predict exchange rate movements of 7 major emerging countries. Our findings indicate that yield curves are useful in explaining exchange rate movements. Rising local interest rates lead to local currency appreciation contrary to the UIP condition. Steeper yield curve causes local currency appreciation in some emerging countries and depreciation in others. Effects of the yield curve parameters are generally stronger at longer horizons implying that UIP does not become valid even in the long run. Finally several robustness checks indicate that these results are robust to data frequency, sample period and yield curve characterization methodology.

1. Introduction

Exchange rates are among the most important financial prices in any economy. Understanding and predicting the movements in exchange rates is crucial for economic agents since exchange rates affect the wealth, investment decisions and consumption decisions of each person and firm in an economy. Moreover, policymakers need to analyze and understand the movements in exchange rates in order to formulate economic policies that maximize the economic welfare of all the people and firms in the economy. In this sense, policymakers are more interested in the future values of exchange rates than the current exchange rates. Wieland and Wolters (2011) demonstrate that central banks in the U.S. and the Eurozone formulate their policies based on interest rate rules where interest rates respond to the forecasts of inflation and economic activity instead of actual values. Since exchange rates are closely related with the economy and the financial markets, predicting exchange rate movements is of prime importance to central banks. In this study, we adopt an economic theory based approach, and study whether the information content of yield curve differentials help predict exchange rate movements.

In the related literature, there are many theories on exchange rate determination and methodologies that are used to predict the movements in exchange rates. In exchange rate prediction, time series techniques such as ARIMA and VAR models are widely used along with judgmental methods that take several micro and macro variables into account. In their pioneering study in this field, Meese and Rogoff (1983) compare the out-of-sample forecasting accuracy of many structural and time series exchange rate methods and find that none of these methods can beat a simple random walk model. Since then, many studies attempt to beat the random walk with different data and different methodologies for different sample periods. Cheung et al. (2005) assess the forecasting performance of five structural models and conclude that none of the models is successful but some models do well for some exchange rates at some horizons.

In an attempt to enhance the performance of conventional exchange rate prediction models Molodtsova and Papell (2009) incorporate Taylor rule fundamentals to conventional models. They provide evidence that short term exchange rate predictability is much stronger when interest rate smoothing is incorporated in the models. Reviewing the recent literature on exchange rate prediction, Rossi (2013) supports these findings and conclude that some models can predict exchange rate movements at some horizons, in some sample periods but there is no universally successful model. She adds that Taylor rule and net foreign assets are among the best predictors and linear parsimonious models have more success than others. Finally, Bailliu and King (2005) note that parameter instability and non-linearities in exchange rate models, along with strong simplifying assumptions and excess volatility in exchange rate markets are the main reasons behind the failure of exchange rate prediction models in the literature. They point to the importance of market microstructure in exchange rate prediction and introduce the micro based exchange rate model used in the Bank of Canada.

When it comes to understanding the movements in exchange rates, the most common practices are based on international parity conditions such as the purchasing power parity theory and the uncovered interest rate parity theory. Although the fit of these theories on data is generally found to be dismal in the related literature, there are empirical studies that support these theories especially at longer horizons. Chinn and Meredith (2004) estimate UIP regressions and find that short term interest rates fail to forecast short horizon changes in exchange rates but long term interest rates correctly predict subsequent long horizon exchange rate changes. Chinn and Zhang (2015) support these findings and show that the countries where UIP condition does not hold in the long run, have experienced extended periods of low interest rates. Thus, unless there is a long period of low interest rates, long term interest rate differentials are useful in predicting the long horizon exchange rate movements.

Adopting a UIP-based approach, Chen and Tsang (2013) use information from the whole term structure of interest rates instead of using a single maturity and attempt to predict exchange rate movements using cross country yield curve differences. Their results support the asset pricing approach to exchange rate determination which claims that currencies behave like assets and anything that leads to higher payoffs in the future result in the appreciation of the currency. In this sense, higher interest rates and flatter yield curve slope cause local currency appreciation. On the other hand, MacDonald and Marsh (1997), focuses on the PPP condition and document a long run relationship between the exchange rates, price levels and interest rates using cointegration analysis and simultaneous equation models. According to their out-of-sample tests, their PPP-based predictions outperform the random walk model. Moreover, Ca' Zorzi et al. (2016) show that theory based models can outperform the random walk model. Their results document that assuming and imposing slow convergence in the PPP hypothesis dramatically improves the PPP-based real exchange rate forecasts. These forecasts can beat the random walk even at short horizons.

Other than the UIP and PPP-based studies, there are also studies that attempt to predict exchange rate movements using economic fundamentals. Amano and Norden (1995) document a long term relationship between USD/CAD real exchange rate and terms of trade and find that causality runs from terms of trade to the exchange rate. According to their results, an error-correction type exchange rate prediction model outperforms the random walk model. Clark and MacDonald (1998) suggest a behavioral approach to predicting the exchange rate movements by linking the real exchange rates to current and long run values of economic fundamentals such as government debt, real interest rates, terms of trade, net foreign assets and relative prices. Using these variables they estimate a VEC model and identify misalignments in real exchange rates. They illustrate that these misalignments are sustainable as long as the values of economic fundamentals are also sustainable.

In this study, we adopt an economic theory based approach. Using data from seven major emerging countries[2] we analyze 1-month, 3-month, 6-month and 1-year movements of exchange rates

[2] These major emerging countries are Hungary, India, Indonesia, Mexico, Poland, South Africa and Turkey. The sample is fairly representative of the emerging world since Latin America, Asia-Pacific, Eastern Europe and Africa are all represented in this set of countries.

employing the approach suggested by Chen and Tsang (2013) for advanced economies. To the best of our knowledge, this is the first cross-country study that uses yield curves to analyze the emerging country exchange rate movements. This approach is based on the uncovered interest rate parity (UIP) and the liquidity premium theory which explains the term structure of interest rates. In short, we find that relative yield curve approach improves the exchange rate forecasting performance of the standard UIP framework.

The remainder of this paper is organized as follows. We discuss or data and methodology in Section 2 and report our results in Section 3. Section 4 contains robustness checks and Section 5 concludes.

2. Data and Methodology

As it is well known, the UIP condition assumes that the expected return of a local currency bond should not be different than the exchange rate adjusted expected return of a foreign currency bond with an identical maturity and riskiness. Otherwise, the investors demand the bond with higher expected return more and the bond with the lower expected return less until the expected returns become equal. The UIP condition can expressed in general terms as follows:

$$i_{m,t} = i^f_{m,t} + \Delta s^e_{m,t} \tag{1.1}$$

Here i_m stands for the yield of a local currency bond with a maturity of “m” years, i_m^f stands for the yield of a foreign currency bond with the same maturity and Δs_m^e stands for the expected change in the exchange rate in the following “m” years. In practice, the differences in riskiness and the uncertainties in exchange rates distort this relationship. Hence, researchers adjust this condition in empirical studies to somewhat tackle this kind of problems as follows:

$$i_{m,t} = i^f_{m,t} + \Delta s^e_{m,t} + \theta_{m,t} \tag{1.2}$$

Here θ is a premium that contains the riskiness differential between the bonds and the uncertainty regarding the exchange rate. This premium also expresses the structural differences between the two countries. Using this condition, Chen and Tsang (2013) attempt to predict exchange rates using treasury yields of two countries and the structural differences between the countries.[3] However, instead of picking a maturity, they opt for using the whole spectrum of the yields and used the yield curves to predict exchange rates. As it is well known, the liquidity premium theory states that any long term interest rate is comprised of the average of the short term interest rates that are expected to be realized until the maturity date plus a liquidity premium. In other words, the theory claims that in absence of a liquidity premium, investing in a long term bond or investing in a short term bond and rolling it until the maturity date of the long term bond should yield the same amount of money. In mathematical terms, this theory can be expressed as follows:

[3] Prediction in this sense can be considered as an analysis of the mechanics regarding the interest rate-exchange rate relationship rather than a forecast.

$$i_{m,t} = \left(i_{1,t} + i_{1,t+1}{}^{e} + i_{1,t+2}{}^{e} + \cdots + i_{1,t+m-1}{}^{e}\right)/m + \lambda_{m,t} \quad (1.3)$$

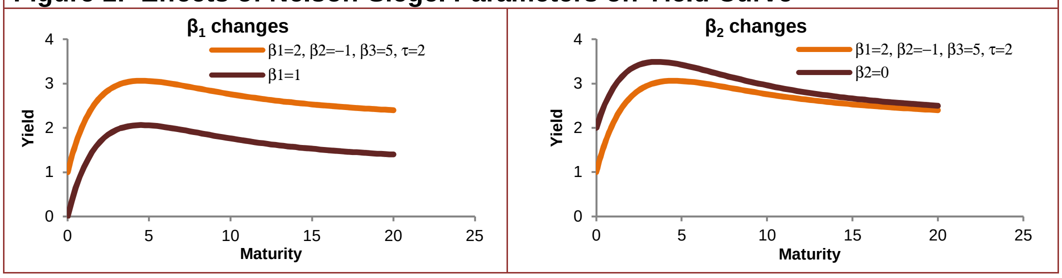
here, i_m stands for "m"-period interest rate, i_1 stands for the 1-period interest rate, superscript "e" expresses expectation and λ represents liquidity premium. According to the research on term structure of interest rates, the yield curve contains information regarding the current state and the future expectations of the economy since the future path of short term interest rates are closely related with the expectations of many macroeconomic variables such as monetary policy, inflation and economic activity. Mishkin (1990) shows the strong linkage between the yield curve and expected inflation. On the economic activity front, studies by Estrella and Mishkin (1998), Hamilton and Kim (2002) and Ang, Piazzesi, and Wei (2006) demonstrate the ability of yield curve characteristics, especially the slope, to predict GDP growth. Thus, using yield curves instead of picking a single maturity in exchange rate prediction captures both the interest rate differential and the premium θ stated in Expression 1.2.

In order to use the yield curve instead of a single maturity, we need to summarize the characteristics of the yield curve such as the location, slope and the shape. Otherwise, we have to use each one of all yields as explanatory variables. This is impossible in practice and problematic in econometric sense.[4] The yield curve modelling approach proposed by Nelson and Siegel (1987) is quite useful in this respect. Nelson and Siegel (1987) model any yield at time t as follows:

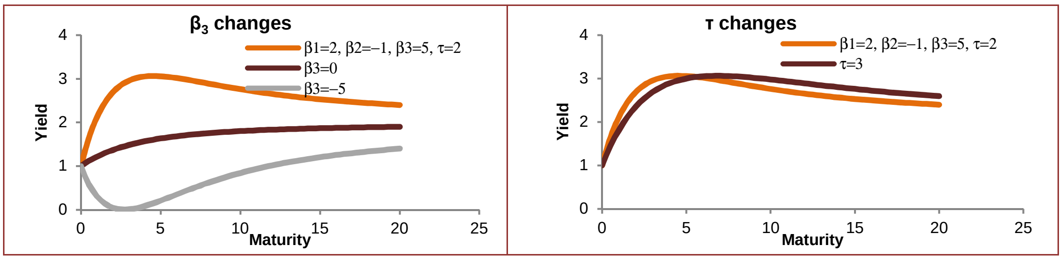
$$i_t(m) = \beta_{1,t} + \beta_{2,t}\left(\left(1 - e^{-\tau m}\right)/\tau m\right) + \beta_{3,t}\left(\left(1 - e^{-\tau m}\right)/\tau m - e^{-\tau m}\right) + \varepsilon_t \quad (2.1)$$

Here i stands for the yield, β_1, β_2, β_3 and τ are parameters and m represents the maturity. This functional form imposes the yield curve to intercept the y-axis at $\beta_1 + \beta_2$, make a "u" or "n" shaped hump depending on the sign of β_3 at maturity "τ" and converge to β_1 asymptotically. Note that if β_1 increases, both the starting point $\beta_1 + \beta_2$ and the ending point β_1 shifts upwards by the amount of the change in β_1. If β_2 increases, the long end of the curve (β_1) stays the same but the short end ($\beta_1 + \beta_2$) shifts upwards resulting in an identical decrease in the slope of the curve (difference between the long end and the short end of the curve). If β_3 increases, the hump becomes sharper whereas a decrease in β_3 makes the hump flatter. Finally if τ increases, the hump shifts to the right by the amount of change in τ. Hence, this parameterization determines the location of the curve by β_1, slope of the curve by the inverse of β_2 and the curvature of the curve by β_3. Figure 1 summarizes the effects of the parameters on the yield curve.

Figure 1: Effects of Nelson-Siegel Parameters on Yield Curve



[4] Using numerous explanatory variables both reduces the degree of freedom and causes the multicollinearity problem.



In all four panels of Figure 1, the orange curve which starts at 1 percent, bends upwards at year 2 and converges to 2 percent in the long run, is constructed using the parameters β_1=2, β_2=-1, β_3=5 and τ=2. In the first panel, β_1 falls to 1 and each point on the orange curve shifts downwards by 1 point. In the second panel, β_1 rises to 0 from -1, resulting in a 1 point decrease in the slope. In the third panel, β_1 falls to 0 from 5 and the hump on the orange curve disappears. Afterwards, β_3 falls further to -5, resulting in a “u” shaped hump this time. But neither of the curves starts at a different point nor converge to a different yield. In the fourth panel, 1-point increase in τ shifts position of the hump on the orange curve to the right.

Based on these characteristics of NS modelling, Chen and Tsang (2013) predict the US dollar exchange rates of several advanced economies using the level, slope and curvature parameters of the yield curves of those countries and the U.S. For instance, to predict the CAD/USD exchange rate, the authors obtain US treasury yields and Canadian yields at several different maturities and then at each maturity subtract the US yield from the corresponding Canadian yield to get the “relative yields”. At the next step, they fit a NS curve to these relative yields and get the β_1, β_2, β_3 and τ parameters. At the final step, using these parameters as explanatory variables, they estimate OLS regressions to predict 1, 3, 6, 12, 18 and 24-month changes in CAD/USD exchange rate. These three parameters reflect information both regarding the differences between interest rates and the differences between the riskiness and economic structures of Canada and the US.

Using this approach, we attempt to analyze the movements of the exchange rates of Hungary, India, Indonesia, Mexico, Poland, South Africa and Turkey. Note that the bond markets in these emerging market countries are less liquid compared to those investigated by Chen and Tsang (2013). Especially, Hund and Lesmond (2008) point that liquidity premium is a significant factor in explaining the cross-sectional yield level and variation in yields of bonds. Hence, this issue has the potential to limit the findings of this study. However, if the liquidity premiums do not exhibit non-stationarity, the harm caused by liquidity issues regarding the emerging bond markets will be limited. Moreover, since sovereign bonds are widely known to be more liquid than corporate bonds, liquidity issues are expected to be even less of a concern.

Looking at the import and export figures of these countries we see that the major foreign currency for Hungary and Poland is Euro and the major currency for India, Indonesia and Mexico is US dollar (Table 1). However, in Turkey and South Africa, both euro and US dollar are widely used foreign currencies. Hence, we analyze EUR/HUF, EUR/PLN, USD/INR, USD/IDR, USD/MXN exchange rates along with the values of Turkish lira and South African rand against an equally weighted basket of US dollar and Euro.

Table 1. Average Annual Trade Volume of Selected Emerging Countries (billion USD)

Country	Average Annual Trade (Imp.+Exp.) Volume	Average Annual Trade Volume vs. European Countries	Euro Trade Percentage
Hungary	186.33	157.65	84.61%
Poland	338.36	276.85	81.82%
Turkey	317.12	176.78	55.75%
S. Africa	160.34	47.85	29.85%
India	563.04	112.83	20.04%
Indonesia	281.99	28.73	10.19%
Mexico	630.49	56.34	8.94%

Source: UNCTAD

We obtain treasury yields of the US, Eurozone, Hungary, Poland, Turkey, South Africa, India, Indonesia and Mexico at 3, 6, 12-month; 2, 3, 4, 5, 7, 10 and 20-year maturities from the Bloomberg terminal.[5] Using these yields we compute the relative yields for the seven emerging countries by substracting the corresponding developed country yields from the emerging country yields of the same maturity. At the next step, we fit yield curves to these relative yields using the NS specification. However, since we investigate the effects of the level, slope and curvature of the relative yield curve on exchange rates, parameter "τ" has to be kept constant. Otherwise, small changes in the slope and the curvature will be reflected by both τ, β_2 and β_3 collectively. Hence, changes in the slope and curvature will no longer be captured solely by β_2 and β_3. Furthermore, β_2 and β_3 may react excessively to small amount of changes in the slope or the curvature if τ is not fixed. Thus, we decide to fix τ for each emerging country. However, we do not impose a specific value to τ. We determine the value of τ endogenously by minimizing the deviations of observed relative yields from the fitted yield curves for each country. In all cases, τ values that optimize the yield curve fit are found to be slightly greater than 1-year maturity. Hence, changes in the curvature parameter can be interpreted as changes in the yields of the emerging country relative to the yields of the corresponding advanced country around 1-year maturity.

Besides the yield curve data, we obtain the exchange rate data from the Bloomberg terminal as well and calculate the rates of change in these exchange rates at 30, 91, 182 and 365-day horizons.[6] The data covers the period between January 2010 and February 2017 to focus on the post-crisis period since the financial structure and the monetary policy implementations have significantly changed after the Global Financial Crisis of 2008.

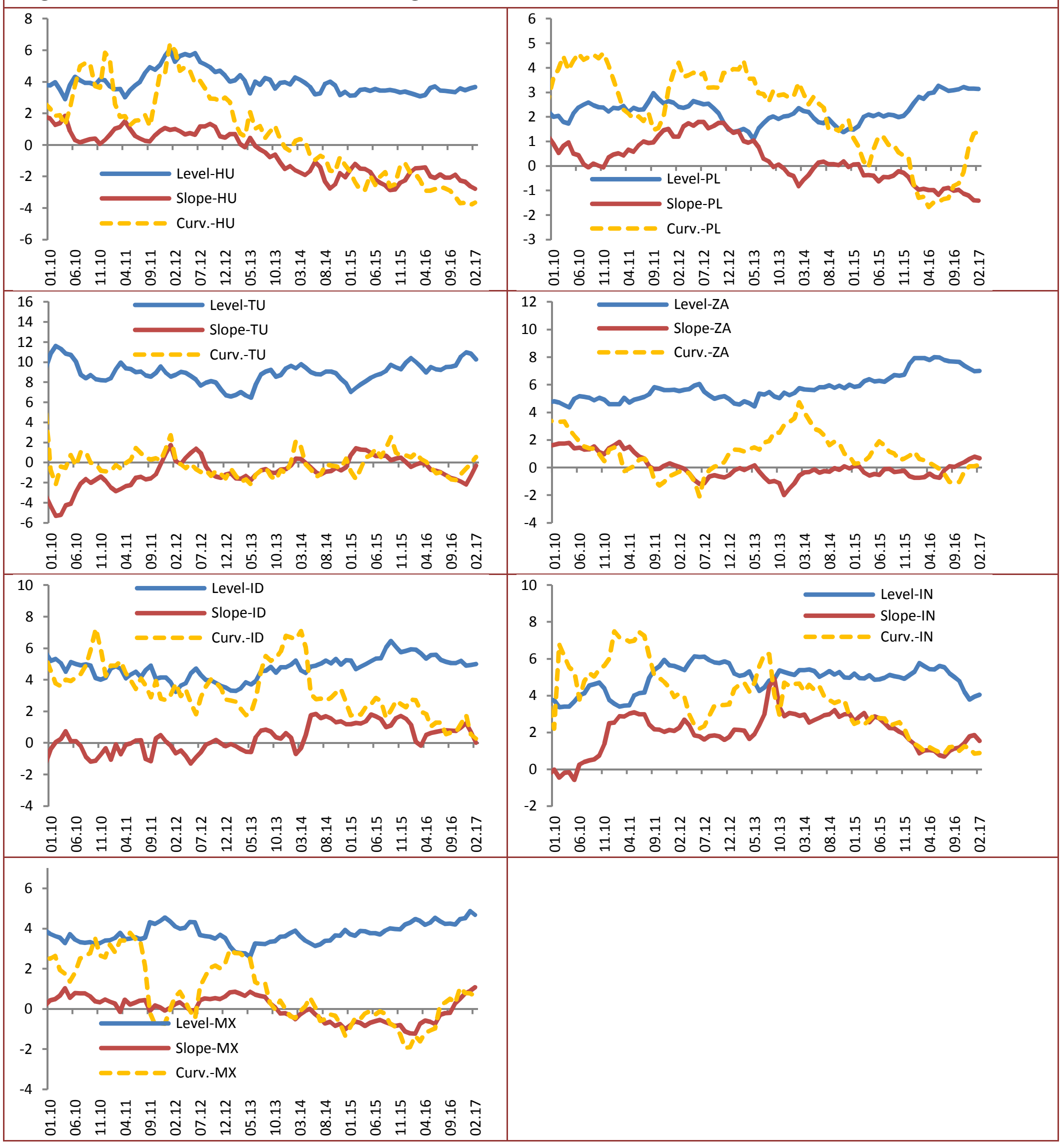
Estimated relative yield curve parameters of the 7 emerging countries are plotted in Figure 2. In each panel, blue lines represent the long term interest rate differentials of the countries. Hungarian long term yields are around 350-400 basis points above the Eurozone long term interest rates and the difference is pretty stable in the last 3 years. Polish and Turkish long term interest rates are on an increasing trend since 2015. Similarly, Mexican long term interest rates are also rising since 2014. In

[5] All of these fixed-maturity yield data are taken from the BVAL Curves calculated by Bloomberg. These yields are zero-coupon yields.

[6] Forward looking logarithmic changes in exchange rates are taken as the changes in exchange rates. For instance, the EUR/HUF exchange rate as of October 10 2016 is 304.08 and 30 days after that day, on November 9, 2016, this rate becomes 305.95. Thus, 1-month change in EUR/HUF exchange rate for October 10, 2016 is Ln(305.95)-Ln(304.08) = 0.6131 percent. Due to sample size concerns, we allow the 3, 6 and 12-month changes in exchange rates to overlap.

South Africa, the long term interest rates have constantly risen until the end of 2015 and began to decline in 2016. Indonesian and Indian long term interest rates have displayed a similar movement in 2016 as well. When it comes to the red lines, we see that Hungarian, Polish and Mexican yield curves got steeper since the Fed tapering in 2013. However, Mexican yield curve has become flat again since the first Quarter of 2016 which coincides with Donald Trump's rise to the US presidency. Turkish yield curve has also become steeper since 2014 but the monetary policy stance tightened significantly since the last quarter of 2016 and the yield curve became flat again. Similar to Mexico, South African yield curve has had positive slope for a long time but the curve became flatter with the increasing political instability and worsened economic outlook. On the other hand, Indian yield curve has always been flatter compared to the US yield curve in our sample period implying slow economic activity and tighter monetary policy stance. Indonesian yield curve also stayed flat since 2014.

Figure 2: Effects of Nelson-Siegel Parameters on Yield Curve



In order to examine the effects of relative yields on emerging country exchange rates, we use a regression model following the approach suggested by Chen and Tsang (2013):

$$\Delta s_{m,t} = \lambda_0 + \lambda_1 L_t + \lambda_2 S_t + \lambda_3 C_t + u_t \tag{2.2}$$

In this representation, Δs_m stands for the rate of change in the exchange rate in the following "m" periods (positive change means depreciation of the local currency), L, S, C are the level, slope and the curvature parameters of the relative yield curve. An increase in the level parameter means that yield curve of the emerging country shifts upwards in all maturities relative to the developed country yield curves. The slope parameter is the inverse of the relative yield curve slope. In other words, an increase in the slope parameter implies a flatter relative yield curve. Moreover, since the parameter τ is fixed around 1, the curvature parameter captures the changes in the yields around 1-year maturity. Positive estimates for the parameters L and C support the UIP condition, while negative estimates would also make sense since higher yield attracts the investor demand to the local currency bonds. Furthermore, negative estimates for parameter S indicate that a steeper yield curve will result in currency depreciation. This is sensible since loose monetary stance is generally associated with steep yield curves. However, if the steepness of the curve stems from improving economic outlook rather than the monetary policy, a currency depreciation probably will not occur. Accordingly, Dewachter and Lyrio (2006) demonstrate that level parameter is related with long-run inflation expectation or the inflation target, the slope parameter is associated with the economic outlook and the curvature parameter reflects monetary policy. On the other hand, according to Rudebusch and Wu (2008), the slope parameter is mainly driven by the central bank's policy stance.

Unlike Chen and Tsang (2013), we opt to estimate the models using GARCH models developed by Engle (1982) to account for the volatility in the emerging financial markets which fluctuates much more compared to that in the developed financial markets. Many academic studies and financial market practitioners model and estimate the volatility in the financial markets such as bond markets and foreign exchange markets, by GARCH models. Since GARCH models are widely used in the literature, we do not discuss the details of the model in this paper and we pick the most popular version of GARCH models which is the GARCH(1,1) model proposed by Bollerslev (1986).

Finally, in all of our models, we add the global risk appetite (VIX) to absorb the effects of all other global events and developments.

3. Empirical Findings

We start with the monthly data to remain comparable with most of the existing studies on the UIP condition. However, given that the GARCH effects are expected to be more prevalent at higher frequencies and offer a much larger sample size, we later estimate the same models using daily data. GARCH(1,1) estimation results for Hungary, Poland, Indonesia, India, Mexico, South Africa and Turkey using monthly data are presented in Tables 2 to 8.

Along with the GARCH regression parameter estimates and the R-squared statistics, we also report the root mean squared error (RMSE) statistics of the one step ahead forecasts. In order to evaluate the forecasting performances of the models, we also report the RMSE of the simple UIP regressions which will act as a benchmark (using the interest rate differential instead of the three NS coefficients as regressors) and the Diebold-Mariano (1995) test statistics. Although this paper does not focus on the predictability of exchange rates, still the indicators regarding the predictability of exchange rates could prove useful in complementing and supporting the main findings.

According to the results in Table 2, an overall increase in Hungarian yields by 1 point leads to the appreciation of Hungarian forint by 1.25 percent in 6 months. The appreciation in forint is immaterial at other horizons. Similar to an overall increase in the yields, an increase in 1-year yield leads to a significant appreciation in forint even at very short horizons. If the Hungarian yield curve becomes steeper, forint appreciates at 1, 3, 6 and 12-month horizons as well probably due to improving economic outlook instead of monetary easing. In all cases the largest reactions take place at 6-month horizon. The RMSE statistics are smaller for the relative yield curve approach and the Diebold-Mariano (DM) statistics are insignificant but always positive. This indicates that the relative yield curve approach weakly improves the forint exchange rate forecasting performance of the model over the UIP approach. Especially the DM statistics of 1, 3 and 6-month horizon forecasts fall just short of the 0.10 significance levels.

Table 2. GARCH Estimation Results for Hungarian Forint

	EURHUF 1M Change	EURHUF 3M Change	EURHUF 6M Change	EURHUF 1Y Change
Intercept	0.8704	5.5819**	9.3579***	6.6228***
	[0.9745]	[2.3517]	[1.8599]	[2.1294]
Level	-0.2775	-0.7059	-1.2472**	0.4231
	[0.2138]	[0.5413]	[0.5001]	[0.5055]
Slope	0.394**	1.7083***	1.9668***	1.7401***
	[0.1753]	[0.2877]	[0.3144]	[0.3354]
Curvature	-0.1558**	-0.7039***	-1.0263***	-0.4465**
	[0.0691]	[0.2204]	[0.2225]	[0.2081]
VIX	0.0393*	-0.048	-0.1369***	-0.2886***
	[0.0212]	[0.0598]	[0.0462]	[0.0414]
# of Obs.:	85	83	80	74
R-squared:	0.1022	0.1334	0.268	0.3196
RMSE	1.5556	2.9510	3.4811	3.4320
RMSE (UIP)	1.6275	3.3531	4.1453	4.0390
DM Statistic	1.5675	1.4729	1.4306	1.0704

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

We see slightly different results for Poland in Table 3. The reaction of Polish zloty to an upward shift in the Polish yield curve is substantial at 1, 3 and 6-month horizons, the latter being the largest but the slope has no significant effect on the EUR/PLN exchange rate. Moreover, the effect of an increase in 1-year Polish yield on the exchange rate is substantial only at 1-year horizon. When it comes to the forecasting performance, the relative yield curve approach and the UIP approach are very close with the former performing slightly better at 1-month horizon and the latter performing surprisingly better at 6-month horizon.

Table 3. GARCH Estimation Results for Polish Zloty

	EURPLN 1M Change	EURPLN 3M Change	EURPLN 6M Change	EURPLN 1Y Change
Intercept	1.3263**	5.258***	8.3896***	5.9089***
	[0.5546]	[1.4068]	[1.5418]	[1.5643]
Level	-0.479***	-1.0708*	-1.8077**	0.2102
	[0.0064]	[0.5491]	[0.7216]	[0.8622]
Slope	0.1951	0.1396	-0.3109	-0.1275
	[0.2607]	[0.4730]	[0.5138]	[0.3740]
Curvature	-0.2379*	-0.2966	-0.2384	-0.5285***
	[0.1392]	[0.2066]	[0.2218]	[0.1977]
VIX	0.0134	-0.1241*	-0.208***	-0.2145***
	[0.0234]	[0.0670]	[0.0295]	[0.0566]
# of Obs.:	85	83	80	74
R-squared:	0.0554	0.0071	0.0165	0.0879
RMSE	1.5321	2.9252	3.4420	4.0536
RMSE (UIP)	1.5551	2.9583	3.4029	4.1027
DM Statistic	1.2024	0.7298	-1.0763	0.3328

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

In Table 4, we see that Indonesian rupiah reacts to the Indonesian yields in the expected direction. If the Indonesian yields on each maturity increase by 1 point, Indonesian rupiah appreciates by 1.33 percent in 3 months, 5.17 percent in 6 months and 8.66 percent in 1 year. Yield curve slope has limited effects on the USD/IDR exchange rate while an increase in 1-year yield has a positive impact on the value of rupiah at relatively longer horizons such as 6 months and 1 year. So, none of the relative yield curve parameters has statistically significant effects on rupiah at short horizons. Nevertheless, the rupiah exchange rate forecasting performance of the relative yield curve parameters appear to be significantly better than that of the UIP approach at 1 and 3-month horizons.

Table 4. GARCH Estimation Results for Indonesian Rupiah

	USDIDR 1M Change	USDIDR 3M Change	USDIDR 6M Change	USDIDR 1Y Change
Intercept	2.1015*	8.9471***	32.319***	54.4625***
	[1.2454]	[1.9899]	[2.8682]	[5.1050]
Level	-0.4822	-1.3269***	-5.166***	-8.6557***
	[0.3105]	[0.4541]	[0.6808]	[0.9705]
Slope	0.4357	0.1848	1.0836*	0.9861
	[0.2945]	[0.4112]	[0.6369]	[0.8927]
Curvature	-0.0421	-0.1515	-1.0176***	-1.0586*
	[0.1060]	[0.1876]	[0.1585]	[0.5790]
VIX	0.0248	-0.0901	-0.13*	-0.285***
	[0.0328]	[0.0596]	[0.0743]	[0.0530]
# of Obs.:	85	83	80	74
R-squared:	0.084	0.0989	0.394	0.5112
RMSE	1.6677	3.3437	4.3357	5.5096
RMSE (UIP)	1.7452	3.4132	5.1653	5.8825
DM Statistic	2.0837**	1.7922*	1.4500	1.1157

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

The findings for India, reported in Table 5, indicate that the value of Indian rupee is positively affected by a steeper yield curve. Especially the reaction of rupee to the yield curve slope is substantially larger at 1-year horizon. When it comes to the level of the yield curve, rupee appreciates in 3 months following an upward shift in the yield curve or in 1-year yield, but the reaction of rupee becomes negative at longer horizons. Hence, an increase in the Indian yields supports the value of rupee temporarily. At longer horizons the findings support the UIP condition. We see negative R-squared values for majority of the estimation results for India. Since this is a GARCH estimation, R-squared values may take negative values, and this indicates that the goodness of fit is somehow weak for Indian data. Moreover, many coefficient estimates have inverse signs. Hence, we should conclude that the predictability of Indian rupee using relative yield curves is rather limited. The RMSE and the DM statistics also support this argument.

Table 5. GARCH Estimation Results for Indian Rupee

	USDINR 1M Change	USDINR 3M Change	USDINR 6M Change	USDINR 1Y Change
Intercept	-0.4359	9.8657***	1.9298	-3.3261*
	[1.4469]	[2.7312]	[2.4283]	[1.9099]
Level	0.0072	-1.3444***	0.2434	-0.1414
	[0.3208]	[0.4572]	[0.3131]	[0.3473]
Slope	0.1169	0.7852***	0.5305**	3.1008***
	[0.1975]	[0.2419]	[0.2431]	[0.2788]
Curvature	0.0619	-0.2554*	0.2991**	0.6348***
	[0.1256]	[0.1497]	[0.1321]	[0.1783]
VIX	0.016	-0.182***	-0.2093***	-0.0249
	[0.0369]	[0.0632]	[0.0487]	[0.0514]
# of Obs.:	85	83	80	74
R-squared:	0.0177	-0.1952	-0.029	-0.0024
RMSE	1.8425	4.1596	5.0444	6.3374
RMSE (UIP)	1.8450	4.0217	5.2868	6.5200
DM Statistic	0.1946	-1.4486	1.0223	0.1229

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

According to the results for Mexico reported in Table 6, relative yield curve affects the value of Mexican peso only at longer horizons while it has limited effects in 1 or 3 months. Consequently, a steeper yield curve in Mexico leads to local currency depreciation. Although the coefficient estimate for curvature parameter at 1-year horizon appears to be in contrast with the coefficient estimate for the level parameter, it is still possible to say that an increase in Mexican yields supports peso since the coefficient estimate for the level parameter is much larger than the estimate for the curvature parameter. But these estimates indicate that peso is positively affected particularly by medium and longer term yields. Furthermore, the reaction of peso to relative yield curve gets stronger with the horizon. When it comes to the predictability of peso, the relative yield curve approach performs better at longer horizons. At 12-month horizon, the relative yield curve parameters substantially improve the forecasts over the UIP approach.

Table 6. GARCH Estimation Results for Mexican Peso

	USDMXN 1M Change	USDMXN 3M Change	USDMXN 6M Change	USDMXN 1Y Change
Intercept	4.6608*	10.4687***	17.3828***	59.0691***
	[2.6333]	[3.5504]	[4.2720]	[4.8678]
Level	-0.9641	-0.892	-2.0169*	-13.0619***
	[0.7065]	[0.9545]	[1.2015]	[1.3593]
Slope	0.0762	-1.2707	-5.3812***	-17.9511***
	[0.7353]	[1.3968]	[1.0454]	[1.0445]
Curvature	-0.528	-0.9143	-0.1879	1.0401***
	[0.3403]	[0.5745]	[0.2233]	[0.3907]
VIX	-0.012	-0.3184***	-0.323***	-0.3087***
	[0.0725]	[0.1076]	[0.0890]	[0.0844]
# of Obs.:	85	83	80	74
R-squared:	0.0506	-0.0379	0.3486	0.8207
RMSE	2.3698	4.8205	5.1088	4.0016
RMSE (UIP)	2.3808	4.8719	7.4261	5.8285
DM Statistic	0.1699	0.3526	1.4510	2.6436***

Sample Period: Jan 2010 – Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

The results for Turkey are reported in Table 7, and the findings indicate that in response to an increase in all Turkish yields by 1-point, Turkish lira appreciates by 0.46 percent in 1 month, 1.66 percent in 3 months and 1.57 percent in 6 months against the equally weighted basket of USD and EUR. If the increase takes place only in 1-year Turkish yield, the reaction of lira becomes even stronger at longer horizons such as 6 months and 1 year. These two findings together imply that rising short term yields in Turkey supports the value of lira while longer term yields have smaller effects on the exchange rate. Moreover, the yield curve slope is effective on the value of Turkish lira only at 1-year horizon. When it comes to the forecasting performance, the relative yield curve approach appears marginally better than the UIP approach but the differences are insignificant.

Table 7. GARCH Estimation Results for Turkish Lira

	TRY 1M Change	TRY 3M Change	TRY 6M Change	TRY 1Y Change
Intercept	5.4686***	21.7348***	29.1069***	37.2357***
	[1.6413]	[2.6321]	[4.2186]	[3.0292]
Level	-0.462**	-1.6572***	-1.5747***	-0.7348
	[0.2111]	[0.3504]	[0.5283]	[0.4862]
Slope	0.1771	-0.1219	-0.1052	-1.7976***
	[0.1976]	[0.3288]	[0.4685]	[0.2216]
Curvature	-0.4377***	-1.4459***	-2.313***	-1.9766***
	[0.1608]	[0.2815]	[0.3308]	[0.2340]
VIX	-0.0276	-0.2184***	-0.3368***	-0.7598***
	[0.0484]	[0.0617]	[0.0945]	[0.0520]
# of Obs.:	85	83	80	74
R-squared:	0.0436	0.2311	0.4073	0.2934
RMSE	2.3397	4.2845	5.0994	6.8907
RMSE (UIP)	2.3707	4.4940	5.4003	7.0046
DM Statistic	0.4741	0.6851	0.2378	0.0544

Sample Period: Jan 2010 – Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Finally, Table 8 reports the results for South Africa. All three parameters are effective on the value of South African rand at almost all horizons. If the South African yield curve gets steeper rand depreciates at 1, 3, 6 and 12-month horizons whereas an upward shift in the South African yield curve leads to appreciation of rand at the same horizons. Following an increase in 1-year South African yield, rand appreciates as well. The RMSE and DM statistics indicate that the improvement in the rand exchange rate predictability caused by the relative yield curve approach is notable.

Table 8. GARCH Estimation Results for South African Rand

	ZAR 1M Change	ZAR 3M Change	ZAR 6M Change	ZAR 1Y Change
Intercept	7.7608***	26.0337***	53.7811***	78.987***
	[2.4144]	[2.2475]	[2.9007]	[3.9984]
Level	-1.037***	-3.5894***	-7.0302***	-10.285***
	[0.3886]	[0.2991]	[0.4133]	[0.8130]
Slope	-0.8074*	-2.2462***	-3.4632***	-5.1657***
	[0.4420]	[0.4186]	[0.3943]	[0.7959]
Curvature	-0.3063	-1.1689***	-2.2086***	-4.1695***
	[0.2460]	[0.2612]	[0.3659]	[0.2823]
VIX	-0.065	-0.2319***	-0.5404***	-0.5339***
	[0.0646]	[0.0734]	[0.0773]	[0.0867]
# of Obs.:	85	83	80	74
R-squared:	0.0756	0.1248	0.2716	0.4733
RMSE	2.6406	5.0582	6.8554	7.7301
RMSE (UIP)	2.7225	5.4866	7.4569	9.1108
DM Statistic	1.3169	2.2433**	3.7428***	3.3510***

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

All these findings indicate that at horizons up to 1 year, UIP holds only in India and the results for rest of the countries exhibit a phenomenon portrayed as the forward premium puzzle. In other words, after an increase in the interest rates, investor demand to that country surges. This leads to local currency appreciation but the bond prices do not react to increased demand so that the interest rates does not fall. This phenomenon is in line with the asset pricing approach to exchange rate determination as noted by Chen and Tsang (2013).

Another interesting finding is that the contrasting reaction of exchange rates to changes in yield curve slope. Changes in the yield curve slope are mainly driven by monetary policy stance and the economic outlook. In Mexico and South Africa, monetary policy stance appears to be the dominant factor; hence steeper yield curve is caused by lower short term interest rates and this leads to local currency depreciation. In contrast, Hungarian and Indian currencies appreciate when the local yield curves get steeper due to higher long term interest rates possibly due to growth prospects. Finally, in Indonesia, Mexico and South Africa, we observe that the effects of yield curves on exchange rates get stronger with the horizon while in Hungary and Turkey; the effects are strongest at 6-month horizon. This finding contradicts with the findings of Chen and Tsang (2013) which indicates that the effect becomes weaker with the horizon. Chen and Tsang (2013) state that the stronger findings at shorter horizons that support the asset pricing approach to exchange rate determination get weaker with the horizon as the UIP condition becomes valid. However, those findings are obtained using developed countries' data. In emerging countries, it is harder to observe that the UIP condition holds. Hence, it is not surprising that in most of the cases our estimates are stronger at longer horizons.

4. Robustness Checks

In this section we re-estimate the Model 2.2 for seven emerging countries first by using daily data, second by extending the start of the sample period to year 2005, and third, by using observed yields instead of the NS parameters.

4.1. Estimation Using Daily Data

The selection of data frequency may have substantial effects on our results. As we note earlier in the paper, the GARCH methodology is usually more preferable when using high frequency data. However, we opt for monthly data for comparability issues with the existing studies. Thus, in this section of the robustness checks, we test the robustness of our results to a change in the data frequency which also brings along a dramatic increase in the number of observations.

Tables A1 to A7 report the results when daily data is used instead of monthly data. Due to the huge increase in the sample size, standard errors shrink dramatically and most of the coefficient estimates become statistically significant at 1 percent level. Thus, instead of focusing on the statistical significance of these estimates we compare the point estimates and signs in Tables 2-8 and Tables A1-A7. Results for Hungary in Table A1 are broadly in line with those in Table 2 except for the ones at 1-month horizon and the point estimates of the coefficients are usually close to each other. In Poland, signs of all estimates in Table 3 are identical to the ones in Table A2, only exception being the 12-month horizon estimates of the slope parameter. Point estimates are similar as well. This is also the case in Indonesia (Table 4 and Table A3), in Mexico (Table 6 and Table A5) and in South Africa (Table 8 and Table A7). The results for India in Table 5 and Table A4 are also similar at 3-month, 6-month and 12-month horizons but surprisingly the coefficient estimate in Table A4 for the curvature parameter at 6-month horizon is statistically insignificant unlike the corresponding estimate in Table 5. We see this pattern also in Turkey. Coefficient estimates at 1-month horizon are not completely in line with each other but the estimates at 3-month, 6-month and 12-month horizons have the same signs and magnitudes (Table 7 and Table A6). All these findings indicate that the original estimations are robust to data frequency.

4.2. Estimation with an Extended Sample Period

In another robustness check we take a longer sample period which begins in January 2005 and ends in February 2017. This extended sample contains the Global Financial Crisis of 2008 which transformed the global financial structure for good; hence we add a dummy variable that takes the value of 1 during the 2-year period between June 2008 and May 2010. Using this dummy variable we estimate a model that modifies the Model (2.2) as follows:

$$\Delta s_{m,t} = \lambda_0 + \lambda_1 L_t + \lambda_2 S_t + \lambda_3 C_t + \lambda_4 \theta_t + \lambda_5 d_t + \lambda_6 d_t L_t + \lambda_7 d_t S_t + \lambda_8 d_t C_t + u_t \qquad (2.3)$$

In this model we allow the intercept and the coefficients of level, slope and curvature to change during the crisis period. Tables A8-A14 report the estimation results for Model (2.3), but the coefficient estimates of the dummy variable and the interaction variables are excluded from the tables to keep the tables short. Results for Hungary in Table A8 are broadly in line with the results in Table 2. Some statistically significant coefficients become insignificant with the longer sample and signs of some insignificant coefficients change but the significant estimates are similar in size and sign in both tables. We see similar results for Indonesia, India and South Africa. In contrast to this, there are major changes in the estimations for Poland. The extended sample estimation results indicate that higher yields in Poland lead to weaker zloty contrary to the results in Table 3. Moreover, statistically insignificant coefficient estimates of the slope parameter become significant in this case. If the Polish yields become much less responsive to exchange rates after the crisis, this dramatic change would be sensible. Hence, a transformation in the economic and financial conditions in Poland could be the most likely reason. Similarly, in Mexico, the coefficient estimates of the slope parameter become inverted. Probably, economic outlook was the dominant factor in Mexico before 2010, but monetary policy stance becomes the primary determinant of the yield curve slope after 2010. Finally, in Turkey, the extended sample estimates are broadly in line with the original sample estimates such as the ones for Hungary, Indonesia, India and South Africa. However, in contrast to the results for these countries, in Turkey, some statistically insignificant estimates become significant when the sample size is extended. In conclusion, the extended sample period results for five of the seven countries support the original results. Results for Mexico and Poland diverge from the original results to an extent but there are possible reasons for these divergences. Thus, the original results seem to be fairly robust in this sense.

4.3. Estimation Using Observed Yields

The Nelson-Siegel Approach to characterize the yield curve may have certain drawbacks, especially for the emerging countries as we note earlier. Therefore we study the robustness of our results by using the observed 5-year yields to represent the level of the yield curve and the spread between the observed 5-year and 6-month yields as the slope of the yield curve. We pick 5-year maturity since the bonds of many emerging countries have liquidity problems in longer maturities such as 7 or 10 or 20 years. Although 5 years can be identified as a medium maturity when dealing with advanced countries, 5-year maturity is adequately long and liquid for many emerging countries. On the other hand, we pick 6-month maturity to represent the short end of the yield curve due to liquidity and data availability issues. The results are reported in Tables A15-A21. Using observed yields to summarize the yield curve to analyze the movements of EUR/HUF exchange rate does not prove useful since the coefficient estimates are all statistically insignificant, the only exception being the coefficient of the slope variable at 6-month horizon which is statistically significant at 10% level (Table A15). In Poland and Indonesia, only the level variable has significant effects on the exchange rate similar to the original NS estimation results (Table A16 and Table A17). India's results in Table A18 are also similar to the ones in Table 5. Steeper yield curve slope supports the value of Indian rupee. Higher yields in India lead to appreciation of rupee in 3 months but the effect is reversed in 12 months. Results for Mexico also confirm the findings in Table 6, higher yields support Mexican peso and steeper yield curve slope leads to depreciation. But in this version, coefficient estimates at shorter horizons become statistically significant as well (Table A19). Finally, the results for Turkey and South

Africa are similar to the results for Mexico and both are in line with the findings in Table 7 and Table 8. Thus, there is no substantial change in the findings when observed yields are used instead of NS parameters. This also indicates that NS parameterization is fairly accurate and adequate in summarizing the yield curve.

5. Conclusion

We show that relative yield curves can explain future exchange rate movements in emerging countries. In most of the countries, rising local interest rates lead to local currency appreciation supporting the asset pricing approach to exchange rate determination. Conversely, Indian rupee reacts to increases in Indian yields by depreciating. Thus, India is the only country in our sample that UIP is found to be valid at short horizons. When it comes to the effects of relative yield curve slope on exchange rates, there are contrasting results. In Mexico and South Africa, if yield curve slope increases relative to the U.S. and/or European yield curve slope, local currency depreciates, probably due to monetary policy stance being the primary determinant of the slope. On the other hand, steeper relative yield curve supports the value of Hungarian and Indian currencies most likely due to improving economic outlook. Turkish, Polish and Indonesian currencies seem not to be affected by the relative yield curve slope. However, this does not mean that yield curve slopes are insignificant factors in exchange rate determination in these countries since changes in the yield curve slope are mainly driven by monetary policy stance and the economic outlook. Possibly, neither of these factors is dominant over the other in these countries so that the estimated effects are statistically insignificant.

In all of the estimations we observe a pattern that the effects of yield curves on exchange rates are generally stronger at longer horizons such as 6 months and 1 year contrary to the findings of Chen and Tsang for the advanced countries. In their study, they interpret this as the indicator of UIP getting stronger in the long run. However, our results imply that the UIP condition for emerging countries may not get stronger even in the long run.

In addition to these findings, although this paper is not focused on the predictability of exchange rates, we analyze the exchange rate forecasting performance of relative yield curves to complement and support our results. We find that relative yield curve approach improves the exchange rate forecasting performance of the standard UIP framework.

Finally, the robustness checks performed in the study indicate that the results are robust to data frequency, sample period and yield curve characterization methodology.

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Appendix

Table A1. GARCH Estimation Results for Hungarian Forint - Daily

	EURHUF 1M Change	EURHUF 3M Change	EURHUF 6M Change	EURHUF 1Y Change
Intercept	4.6425***	5.1535***	7.1124***	8.9575***
	[0.1753]	[0.2109]	[0.1921]	[0.2359]
Level	-1.061***	-0.9735***	-0.8803***	-0.2703***
	[0.0407]	[0.0524]	[0.0479]	[0.0633]
Slope	-0.0498*	0.9206***	2.1108***	2.1986***
	[0.0298]	[0.0333]	[0.0368]	[0.0453]
Curvature	0.1546***	-0.4177***	-1.1725***	-0.6536***
	[0.0168]	[0.0196]	[0.0169]	[0.0304]
VIX	-0.04***	-0.0466***	-0.0687***	-0.2544***
	[0.0058]	[0.0040]	[0.0040]	[0.0070]
# of Obs.:	1831	1789	1723	1593
R-squared:	-0.0288	0.0337	0.3023	0.3036

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A2. GARCH Estimation Results for Polish Zloty - Daily

	EURPLN 1M Change	EURPLN 3M Change	EURPLN 6M Change	EURPLN 1Y Change
Intercept	2.4447***	4.4311***	4.7652***	5.0263***
	[0.1252]	[0.1609]	[0.1696]	[0.1458]
Level	-0.7165***	-0.3943***	-0.9113***	0.2643***
	[0.0569]	[0.0694]	[0.0745]	[0.0818]
Slope	0.49***	0.2939***	-0.2137***	1.0706***
	[0.0349]	[0.0412]	[0.0379]	[0.0440]
Curvature	-0.3323***	-0.4452***	-0.1351***	-0.9173***
	[0.0153]	[0.0206]	[0.0192]	[0.0277]
VIX	-0.0104**	-0.1363***	-0.1372***	-0.1732***
	[0.0042]	[0.0055]	[0.0050]	[0.0044]
# of Obs.:	1831	1789	1723	1593
R-squared:	0.0409	0.023	0.0612	-0.0574

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A3. GARCH Estimation Results for Indonesian Rupiah - Daily

	USDIDR 1M Change	USDIDR 3M Change	USDIDR 6M Change	USDIDR 1Y Change
Intercept	2.3527***	11.9168***	19.7693***	50.0747***
	[0.1217]	[0.1772]	[0.2956]	[0.4653]
Level	-0.4692***	-1.6692***	-2.6682***	-8.041***
	[0.0282]	[0.0352]	[0.0564]	[0.0934]
Slope	0.3144***	-0.1791***	0.9432***	0.2945***
	[0.0254]	[0.0322]	[0.0424]	[0.0790]
Curvature	-0.0076	-0.6981***	-1.0119***	-1.0041***
	[0.0113]	[0.0157]	[0.0220]	[0.0396]
VIX	-0.0031	-0.0765***	-0.0909***	-0.242***
	[0.0024]	[0.0041]	[0.0054]	[0.0117]
# of Obs.:	1831	1789	1723	1593
R-squared:	0.063	0.006	0.3122	0.419

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A4. GARCH Estimation Results for Indian Rupee - Daily

	USDINR 1M Change	USDINR 3M Change	USDINR 6M Change	USDINR 1Y Change
Intercept	-1.6003***	11.178***	3.7105***	-14.5285***
	[0.1873]	[0.2679]	[0.2986]	[0.3750]
Level	0.2421***	-1.6058***	-0.5947***	2.245***
	[0.0345]	[0.0520]	[0.0445]	[0.0744]
Slope	0.4714***	0.4103***	1.1814***	2.1767***
	[0.0229]	[0.0252]	[0.0300]	[0.0512]
Curvature	-0.1551***	-0.2782***	-0.0078	1.3637***
	[0.0152]	[0.0182]	[0.0214]	[0.0330]
VIX	0.0091**	-0.1281***	-0.0826***	-0.0704***
	[0.0037]	[0.0047]	[0.0060]	[0.0073]
# of Obs.:	1831	1789	1723	1593
R-squared:	-0.0649	-0.1257	-0.0235	0.1118

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A5. GARCH Estimation Results for Mexican Peso - Daily

	USDMXN 1M Change	USDMXN 3M Change	USDMXN 6M Change	USDMXN 1Y Change
Intercept	4.8509***	6.8418***	30.1692***	52.8504***
	[0.3175]	[0.3345]	[0.4892]	[0.5942]
Level	-0.8689***	-0.9394***	-5.5142***	-11.507***
	[0.0828]	[0.0877]	[0.1437]	[0.1869]
Slope	-0.1792**	-2.5165***	-5.3328***	-15.5741***
	[0.0839]	[0.1111]	[0.1342]	[0.1429]
Curvature	-0.2278***	-0.5411***	-0.9699***	0.174***
	[0.0364]	[0.0387]	[0.0629]	[0.0618]
VIX	-0.0963***	-0.1668***	-0.2762***	-0.2561***
	[0.0050]	[0.0073]	[0.0076]	[0.0102]
# of Obs.:	1831	1789	1723	1593
R-squared:	-0.0553	-0.0726	0.2772	0.7548

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A6. GARCH Estimation Results for Turkish Lira - Daily

	TRY 1M Change	TRY 3M Change	TRY 6M Change	TRY 1Y Change
Intercept	2.6419***	19.6781***	27.8236***	49.4412***
	[0.2325]	[0.2554]	[0.2835]	[0.3326]
Level	-0.0283	-1.8742***	-1.604***	-3.5743***
	[0.0293]	[0.0334]	[0.0390]	[0.0502]
Slope	-0.492***	-0.1003***	-1.4057***	-0.8789***
	[0.0258]	[0.0288]	[0.0424]	[0.0426]
Curvature	0.0707***	-1.1647***	-1.8782***	-1.6517***
	[0.0193]	[0.0192]	[0.0265]	[0.0234]
VIX	-0.1173***	-0.1113***	-0.3017***	-0.6392***
	[0.0045]	[0.0062]	[0.0051]	[0.0072]
# of Obs.:	1832	1790	1724	1594
R-squared:	-0.0319	0.1583	0.2725	0.2411

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A7. GARCH Estimation Results for South African Rand - Daily

	ZAR 1M Change	ZAR 3M Change	ZAR 6M Change	ZAR 1Y Change
Intercept	8.3057***	27.5444***	46.7897***	68.2915***
	[0.3101]	[0.3710]	[0.3860]	[0.7605]
Level	-1.1615***	-3.8937***	-6.7843***	-7.8351***
	[0.0419]	[0.0515]	[0.0570]	[0.1387]
Slope	-0.7198***	-3.1971***	-3.5045***	-2.662***
	[0.0518]	[0.0528]	[0.0626]	[0.0953]
Curvature	-0.259***	-1.2905***	-2.1345***	-4.8371***
	[0.0323]	[0.0353]	[0.0393]	[0.0486]
VIX	-0.0858***	-0.1577***	-0.2439***	-0.6587***
	[0.0071]	[0.0077]	[0.0090]	[0.0127]
# of Obs.:	1832	1790	1724	1594
R-squared:	0.028	0.1755	0.2275	0.4683

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A8. GARCH Estimation Results for Hungarian Forint - Extended Sample

	EURHUF 1M Change	EURHUF 3M Change	EURHUF 6M Change	EURHUF 1Y Change
Intercept	-0.1122	-0.3977	3.1181***	6.4773***
	[0.7244]	[1.3015]	[1.0912]	[0.9329]
Level	-0.0575	0.2503	0.377	0.3216
	[0.2239]	[0.3847]	[0.2616]	[0.2715]
Slope	0.4205**	1.0999***	1.192***	0.7955***
	[0.2106]	[0.3577]	[0.2699]	[0.2647]
Curvature	-0.2712**	-0.8094***	-0.9423***	0.2224
	[0.1319]	[0.2168]	[0.1806]	[0.1685]
VIX	0.043*	0.0402	-0.1793***	-0.296***
	[0.0255]	[0.0401]	[0.0406]	[0.0288]
# of Obs.:	144	142	139	133
R-squared:	0.2728	0.3907	0.3841	0.0495

Sample Period: Feb 2005 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A9. GARCH Estimation Results for Polish Zloty - Extended Sample

	EURPLN 1M Change	EURPLN 3M Change	EURPLN 6M Change	EURPLN 1Y Change
Intercept	0.6039	2.8635***	-1.5952*	-6.611***
	[0.5695]	[0.8625]	[0.8545]	[1.4059]
Level	0.0828	1.0794***	1.7251***	-0.5385
	[0.2272]	[0.2820]	[0.4213]	[0.6690]
Slope	0.5478***	1.2715***	0.3952	-0.415
	[0.1851]	[0.2765]	[0.2607]	[0.4539]
Curvature	-0.2361**	-0.2633*	0.2899**	1.2505***
	[0.0996]	[0.1413]	[0.1165]	[0.2601]
VIX	-0.028	-0.2735***	-0.1853***	0.3141***
	[0.0252]	[0.0377]	[0.0323]	[0.0581]
# of Obs.:	144	142	139	133
R-squared:	0.0135	-0.0748	0.3547	0.4242

Sample Period: Feb 2005 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A10. GARCH Estimation Results for Indonesian Rupiah - Extended Sample

	USDIDR 1M Change	USDIDR 3M Change	USDIDR 6M Change	USDIDR 1Y Change
Intercept	1.33	8.7831***	20.6533***	24.029***
	[0.8620]	[1.0694]	[1.6450]	[1.7821]
Level	-0.1533	-1.149***	-2.5188***	-3.3892***
	[0.1314]	[0.1575]	[0.2521]	[0.2149]
Slope	0.1201	0.0302	0.6245***	1.3604***
	[0.1151]	[0.1588]	[0.2163]	[0.1991]
Curvature	-0.0288	-0.1292	-0.4173***	-0.3161***
	[0.0864]	[0.1208]	[0.1402]	[0.0852]
VIX	-0.0107	-0.113***	-0.3009***	-0.0845*
	[0.0238]	[0.0382]	[0.0499]	[0.0474]
# of Obs.:	144	142	139	133
R-squared:	0.2556	-0.0972	0.1905	0.3963

Sample Period: Feb 2005 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A11. GARCH Estimation Results for Indian Rupee - Extended Sample

	USDINR 1M Change	USDINR 3M Change	USDINR 6M Change	USDINR 1Y Change
Intercept	0.3492	3.4307***	9.8252***	7.4525***
	[0.8754]	[1.2773]	[0.7967]	[1.1099]
Level	-0.057	-0.2573	-1.1255***	-0.0833
	[0.2324]	[0.2810]	[0.1814]	[0.2890]
Slope	0.1473	0.8002***	0.1224	-0.5891**
	[0.1887]	[0.2659]	[0.2275]	[0.2750]
Curvature	0.0366	0.0145	0.7376***	2.0255***
	[0.1092]	[0.1477]	[0.1228]	[0.1596]
VIX	-0.0102	-0.1659***	-0.2524***	-0.3854***
	[0.0270]	[0.0425]	[0.0317]	[0.0555]
# of Obs.:	144	142	139	133
R-squared:	0.0946	0.156	0.1826	0.3116

Sample Period: Feb 2005 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A12. GARCH Estimation Results for Mexican Peso - Extended Sample

	USDMXN 1M Change	USDMXN 3M Change	USDMXN 6M Change	USDMXN 1Y Change
Intercept	2.8542*	9.6029***	9.534***	9.382***
	[1.6712]	[1.7004]	[2.1499]	[3.4215]
Level	-0.7117	-2.0304***	-2.0684***	-0.3022
	[0.4326]	[0.4594]	[0.6049]	[0.8343]
Slope	0.1062	0.483**	0.7681***	0.4721
	[0.2953]	[0.2215]	[0.2518]	[0.6223]
Curvature	-0.3109	-0.6274***	0.0313	0.991***
	[0.1963]	[0.1616]	[0.2496]	[0.3580]
VIX	0.0091	-0.1632***	-0.1042*	-0.3794***
	[0.0444]	[0.0540]	[0.0564]	[0.0719]
# of Obs.:	144	142	139	133
R-squared:	0.1683	-0.0019	-0.1424	-0.033

Sample Period: Feb 2005 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A13. GARCH Estimation Results for Turkish Lira - Extended Sample

	TRY 1M Change	TRY 3M Change	TRY 6M Change	TRY 1Y Change
Intercept	4.0096***	16.9144***	29.9895***	39.7112***
	[1.2200]	[1.9560]	[2.0704]	[1.8882]
Level	-0.1523	-0.9961***	-1.9907***	-2.3046***
	[0.1174]	[0.2044]	[0.1821]	[0.1840]
Slope	-0.0234	-0.4168	-0.5514**	-1.2527***
	[0.2212]	[0.3340]	[0.2750]	[0.3810]
Curvature	-0.1553***	-0.4113***	-0.6496***	-0.3521***
	[0.0460]	[0.0802]	[0.0802]	[0.0561]
VIX	-0.0906***	-0.333***	-0.4945***	-0.6934***
	[0.0336]	[0.0486]	[0.0580]	[0.0556]
# of Obs.:	144	142	139	133
R-squared:	0.0922	0.3843	0.4362	0.2068

Sample Period: Feb 2005 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A14. GARCH Estimation Results for South African Rand - Extended Sample

	ZAR 1M Change	ZAR 3M Change	ZAR 6M Change	ZAR 1Y Change
Intercept	3.2689**	13.479***	27.9442***	36.3912***
	[1.4523]	[1.9877]	[1.7704]	[3.1982]
Level	-0.4898*	-2.0197***	-4.056***	-3.8266***
	[0.2732]	[0.3863]	[0.2507]	[0.6194]
Slope	-0.4667	-1.9984***	-0.0722	-0.2896
	[0.4896]	[0.6481]	[0.3176]	[0.6807]
Curvature	0.0466	-0.4614*	-0.4662***	-2.334***
	[0.1616]	[0.2713]	[0.1506]	[0.3480]
VIX	-0.0029	-0.0769	-0.2583***	-0.3145***
	[0.0548]	[0.0633]	[0.0595]	[0.0620]
# of Obs.:	144	142	139	133
R-squared:	0.0889	0.1134	0.1131	0.4511

Sample Period: Feb 2005 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A15. GARCH Estimation Results for Hungarian Forint - Observed Yields

	EURHUF 1M Change	EURHUF 3M Change	EURHUF 6M Change	EURHUF 1Y Change
Intercept	-0.2373	2.3457**	2.8279***	8.6819***
	[0.1450]	[1.1319]	[0.5786]	[1.1741]
Level (5Y)	-0.0008	0.0015	-0.0021	-0.0009
	[0.0036]	[0.0123]	[0.0024]	[0.0051]
Slope (5Y-6M)	-0.0005	0.0007	0.0011*	0
	[0.0006]	[0.0004]	[0.0007]	[0.0009]
VIX	0.0192***	-0.1325**	-0.1509***	-0.439***
	[0.0004]	[0.0636]	[0.0323]	[0.0634]
# of Obs.:	85	83	80	74
R-squared:	0.0291	-0.1306	-0.008	0.0581

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A16. GARCH Estimation Results for Polish Zloty - Observed Yields

	EURPLN 1M Change	EURPLN 3M Change	EURPLN 6M Change	EURPLN 1Y Change
Intercept	1.3343***	5.5724***	8.8943***	6.4248***
	[0.3900]	[1.4637]	[0.9697]	[1.3375]
Level	-0.5236***	-1.1349**	-1.8787***	-0.5782
	[0.1076]	[0.5162]	[0.4547]	[0.5749]
Slope	-0.216	-0.5305	-0.4824	0.2498
	[0.2670]	[0.5473]	[0.6324]	[0.6587]
VIX	0.0138***	-0.1228*	-0.1861***	-0.217***
	[0.0000]	[0.0675]	[0.0571]	[0.0769]
# of Obs.:	85	83	80	74
R-squared:	0.0386	0.0049	0.0343	0.0913

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A17. GARCH Estimation Results for Indonesian Rupiah - Observed Yields

	USDIDR 1M Change	USDIDR 3M Change	USDIDR 6M Change	USDIDR 1Y Change
Intercept	1.2745	7.8727***	18.0304***	49.7116***
	[0.9617]	[1.8462]	[1.8661]	[5.1969]
Level	-0.2056	-0.8968**	-2.7649***	-6.2132***
	[0.1941]	[0.3591]	[0.2569]	[0.9133]
Slope	-0.0914	0.0552	-0.0368	-1.2234
	[0.3677]	[0.3778]	[0.6277]	[1.4603]
VIX	0.0058	-0.1176**	-0.0777	-0.4791***
	[0.0302]	[0.0505]	[0.0565]	[0.1214]
# of Obs.:	85	83	80	74
R-squared:	0.0063	0.0596	0.1427	0.4866

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A18. GARCH Estimation Results for Indian Rupee - Observed Yields

	USDINR 1M Change	USDINR 3M Change	USDINR 6M Change	USDINR 1Y Change
Intercept	-0.6738	7.8948***	1.8781	-10.4235*
	[1.3880]	[3.0261]	[2.7963]	[5.4329]
Level	0.0547	-0.9436**	0.2974	2.6627***
	[0.2776]	[0.4326]	[0.2706]	[0.6270]
Slope	-0.2005	-1.383***	-0.8981**	-0.8405
	[0.3030]	[0.3534]	[0.4401]	[0.9008]
VIX	0.0246	-0.136**	-0.1755**	-0.1752
	[0.0331]	[0.0607]	[0.0890]	[0.1150]
# of Obs.:	85	83	80	74
R-squared:	0.0206	-0.191	-0.0833	0.009

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A19. GARCH Estimation Results for Mexican Peso - Observed Yields

	USDMXN 1M Change	USDMXN 3M Change	USDMXN 6M Change	USDMXN 1Y Change
Intercept	5.361**	14.5488***	23.9259***	59.9489***
	[2.6415]	[3.8127]	[2.9432]	[4.3352]
Level	-1.2783*	-2.1972**	-4.0662***	-12.6293***
	[0.6868]	[1.0787]	[0.8132]	[1.2328]
Slope	0.2089	3.1214*	8.3384***	15.126***
	[0.8258]	[1.6471]	[0.9793]	[1.2668]
VIX	0.0161	-0.3001**	-0.27***	-0.3582***
	[0.0590]	[0.1246]	[0.0640]	[0.0983]
# of Obs.:	85	83	80	74
R-squared:	0.0419	-0.0117	0.3399	0.6408

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A20. GARCH Estimation Results for Turkish Lira - Observed Yields

	TRY 1M Change	TRY 3M Change	TRY 6M Change	TRY 1Y Change
Intercept	4.3308***	17.2124***	28.9762***	38.6989***
	[1.6342]	[2.0739]	[3.9067]	[2.9394]
Level	-0.418**	-1.2052***	-1.7839***	-1.6872***
	[0.1987]	[0.3045]	[0.4802]	[0.3561]
Slope	-0.2348	-0.4267	1.435**	1.9096***
	[0.2790]	[0.4878]	[0.7251]	[0.6198]
VIX	-0.0128	-0.3611***	-0.4912***	-0.8638***
	[0.0280]	[0.0403]	[0.0740]	[0.0502]
# of Obs.:	85	83	80	74
R-squared:	-0.0077	0.1126	0.3243	0.2306

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

Table A21. GARCH Estimation Results for South African Rand - Observed Yields

	ZAR 1M Change	ZAR 3M Change	ZAR 6M Change	ZAR 1Y Change
Intercept	6.9465***	24.5914***	51.8894***	74.0556***
	[2.4582]	[2.2662]	[3.8413]	[5.6665]
Level	-0.927**	-3.4004***	-6.8692***	-9.8326***
	[0.3648]	[0.3049]	[0.4987]	[0.9956]
Slope	0.948*	2.2899***	3.7366***	7.1555***
	[0.5666]	[0.6004]	[0.6747]	[1.2673]
VIX	-0.0541	-0.2107**	-0.4484***	-0.3578***
	[0.0608]	[0.0826]	[0.0967]	[0.1287]
# of Obs.:	85	83	80	74
R-squared:	0.079	0.0918	0.2173	0.3378

Sample Period: Jan 2010 - Feb 2017.
Standard errors are given in brackets.
*, ** and *** denote statistical significance in 10%, 5% and 1% levels respectively.

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