The information content of risk reversals in emerging market currencies

(O conteúdo informacional dos “risk reversals” em moedas de países emergentes)

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Abstract

This paper analyzes the information content of risk reversals for ten emerging market currencies. In contrast to the findings for major developed currencies, it is found that in some cases risk reversals (RR) are helpful in predicting currency returns, but in general RR are predicted by but do not predict carry trade returns. Evidence based on country vector autoregressions (VARs) and a panel VAR (PVAR) indicate that RR react in a procyclical way to carry returns, i.e., it is cheaper (more expensive) to buy protection against currency weakness after positive (negative) total returns. All in all, it is found that crash risk accounts for a small share of carry trade returns variance, which seems to be more related to global risk aversion shocks. A sentiment indicator of crash risk in emerging market currencies is highly correlated with the VIX.

Keywords: Carry trade, risk reversal, exchange rate, crash risk.

JEL Codes: F31, G15.

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Resumo

Este artigo analisa o conteúdo informacional dos “risk reversals” para dez moedas de países emergentes. Em contraste com os resultados encontrados nas principais moedas de países desenvolvidos, encontra-se que em alguns casos os “risk reversals” auxiliam na previsão de retornos das moedas. Em geral, os risk reversals são previstos, mas não predizem os retornos de estratégias de “carry trade”. Evidências a partir de modelos de vetores autoregressivos (VAR’s) estimados com dados das moedas dos países analisados, e também por meio de um VAR em painel (PVAR) indicam que os “risk reversals” reagem de uma forma procíclica aos retornos do “carry trade”. Desta forma, torna-se mais barato (mais caro) comprar proteção contra a desvalorização da moeda após ela ter tido retornos positivos (negativos). Em geral, encontra-se que os riscos de desastre respondem por uma parte pequena da variância dos retornos do “carry trade”, que tendem a ser mais relacionados com choques globais de aversão ao risco. Um indicador de sentimento de risco de desastre em moedas de países emergentes é altamente correlacionado com o VIX.

Palavras-chave: carry trade, “risk reversal”, taxa de câmbio.

1. Introduction

Is it possible to predict future returns of emerging market currencies based on information embedded in options prices? This paper investigates whether risk reversals (RR) – a measure of the skewness of exchange rate expected distribution - contain information about future returns of emerging market currencies.

Risk reversals consist in the difference between the implied volatilities of out-of-the-money call and put, of a given maturity and delta. With these parameters fixed, it implies a long position in a call and a short position in a put. Thus, by showing if the call or put has a higher cost in terms of implied volatility, it reveals the expectation of the market regarding the distribution of the exchange rate underlying the option. Risk reversals are often described as the slope of the volatility smile curve, which plots, for a given maturity, the implied volatility associated with each delta for calls and puts.

Information embedded in options prices receives considerable attention of both practitioners and authorities, since they convey forward looking information that may be useful for central banks and market participants in general.

The predictability of foreign currencies through risk reversals have been tested for major currencies. Kurbanov (2010) examined risk reversals for the EURUSD exchange rate, using weekly data. Using univariate meth-

ods, he found a positive contemporaneous relationship between changes in risk reversals and EURUSD returns. In terms of predictability, he found a negative association between past RR changes and exchange rate returns, but with limited explanatory power, casting doubt on the usefulness of risk reversals for forecasting exchange rate returns.

Along the same lines, Dunis and Lequeux (2001) analyzed the information content of risk reversals for the pairs USDJPY, USDCHF, GBPUSD and AUDUSD, using daily data and multivariate time series methods, also finding little evidence for the usefulness of risk reversals in assessing the future evolution of exchange rates.

Brunnermeier et al. (2009) investigated crash risk of currencies, i.e., sudden and abrupt depreciations of the target currency of the investment. They found that the interest rate differentials are negative associated with realized skewness, interpreting this result as a measure of crash risk. On the other hand, carry returns are positively associated with risk reversals, meaning that investors buy insurance against crash risk. Galati, Heath and McGuire (2007) argued that risk reversals capture directional uncertainty about the exchange rate, and associate this with carry trade risks. Gagnon and Chaboud (2007) documented that risk reversals increase after episodes of presumed unwinding of carry trades, in which the Yen is sharply appreciated, meaning that investors are frightened by losses, but they also found that there is no evidence of purchase of protection through risk reversal when carry trade positions are building up.

Farhi et al. (2015) developed a model to estimate a time series of the compensation for global disaster risk exposure based on exchange rate data of major currencies. The disaster risk exposure measure obtained in the model showed a strong correlation with risk-reversals. As in Brunnermeier et al. (2009), they associated risk reversals with the level of interest rate differentials, meaning that expected carry trade returns compensate investors for the risk of a sharp depreciation of the target currency.

Carr and Wu (2007) investigated exchange rate dynamics of the pairs USDJPY and GBPUSD, developing a model that delivers stochastic volatility and skewness, influenced by the time-varying feature of risk reversals found in the data. As in the afore-mentioned studies, they also documented a positive and strong correlation between currency returns and risk reversals, but the correlation between butterfly spreads and currency returns is much lower. Finally, De Bock and Carvalho Filho (2015) found that risk reversals are positively correlated with currency weakness during risk-off

episodes, appearing significantly in regressions that explain the drivers of currency movements during the periods analyzed.

Despite the evidence for major currencies, at present no research has focused on the empirical content of risk reversals in emerging market currencies. The main contribution of this paper is to provide such evidence. From a theoretical point of view, this paper is related to the ongoing research on disasters and its implications for potentially solving asset pricing problems (Barro,2006; Barro and Ursúa, 2008; Tsai and Watcher,2015). Disasters are usually modeled as a shock that induces negative skewness in the distribution of output. As mentioned previously, as the price of skewness, risk reversals capture the expected skewness in the context of foreign exchange (FX) markets.

This paper is organized as follows. Apart from this introduction, section 2 presents the data used and how some variables were constructed. Section 3 pursues with analysis of the relationship between currency returns and risk reversals, mainly on the forecast ability power from one variable to the other. Section 4 examines the relationship between global risk aversion, carry trade returns, risk reversals and interest rate differentials in VAR models estimated for each country. Section 5 constructs an indicator of crash risk sentiment in emerging market currencies and shows that it is highly correlated with the VIX. Section 6 continues with the analysis of the relationship between global risk aversion, carry trade returns, risk reversals and interest rate differentials, but with a PVAR model. Finally, section 7 concludes. Appendices present unit root tests, figures of the carry trade returns series used and robustness evidence for the findings.

2. Data and Descriptive Analysis

I used daily data, spanning from November 10, 2010 to October 28, 2015, for the following pairs: Brazilian Real (USDBRL, BRL), Chilean Peso (USDCLP, CLP), Indian Rupee (USDINR, INR), Indonesia Rupiah (USDIDR, IDR), Mexican Peso (US-DMXN, MXN), Polish Zloty (USD-PLN, PLN), South African Rand (USDZAR, ZAR), Korean Won (USD-KRW, KRW), Israeli Shekkel (USDILS, ILS) and Turkish Lira (US-DTRY, TRY).

I also collected some data on interest rate differentials for the currencies employed. I used 3-month interest rates. For Brazil, it is the implied NDF rate, for Chile is the CLF GVT Zero Yield, for India is the 3- month T-Bill yield, for Indonesia, Poland, Turkey and Israel I used the interbank

rate, for Mexico is the 90-day CETES rate, for South Korea is the 90-day NCD rate, and finally, for South Africa, it was the JIBAR 3-month rate. In order to construct the interest rate differential series, I subtracted each interest rate series from the 3-month US T-Bill rate. All data come from Datastream, and interest rate series used reflect availability in this program. Even though information about risk reversals for some of these currency pairs is available before the sample start date, I chose to begin the sample on the same date for all of them, for the sake of uniformity of the analysis.

Brunnermeier et al. (2009) used 25 delta 1-month risk reversals. De Bock and Carvalho Filho (2015) used 25 delta at the 3-month maturity. Carr and Wu (2007) presented data for 10 and 25 delta risk reversals for many maturities. Kurbanov (2010) employed 1-month 10 and 25 delta risk reversals and butterflies. Lastly, Dunis and Luqueux (2001) analyzed 1-month 25 delta risk reversals. Aligned with the related literature, I have chosen to use 25 delta 3-month risk reversals. Table 1 reports a strong positive correlation across deltas and maturities, revealing a strong co-movement between risk reversals of a given currency pair. Figure 2 shows the evolution of risk reversals and exchange rates in the sample period.

I also constructed carry trade return series (variables z_t , as specified on equation 2 below) for the currency pairs used in the analysis, which encompasses both the currency returns and interest rate carry. Following Brunnermeier et al. (2008), the return series have been constructed using the following formulas:

$$s_t = \log(\text{nominal exchange rate}) \quad (1)$$

$$z_{t+1} \equiv (i_t - i_t^*) - \Delta s_{t+1} \quad (2)$$

Where z_t , the carry trade return, is the sum of FX and interest rate returns, and Δs_{t+1} is the currency return. A positive value for the currency returns means a depreciation of the domestic (emerging market) currencies relative to the dollar. For the interest rate differential, I used the series constructed and described above, considering a year with 52 weeks.¹ Therefore, I have daily data on total returns, exchange rate returns, 25-delta 3-month

¹To get interest differentials expressed on a daily basis, I divided the rates by 260. I am aware this option might overlook business days conventions. To overcome this possible criticism, I also use daily carry trade returns data from Bloomberg as a robustness exercise. Results are presented in the Appendix.

Table 1

Correlations between different risk reversals series

	Maturity		Delta	
	1-month	3-months	10 Δ	25 Δ
Currency	Corr(10 Δ ,25 Δ)	Corr(10 Δ ,25 Δ)	Corr(1m,3m)	Corr(1m,3m)
BRL	0,99	0,99	0,95	0,96
CLP	0,98	0,99	0,39	0,41
CNY	0,93	0,95	0,99	0,98
INR	0,80	0,83	0,95	0,96
IDR	0,94	0,95	0,94	0,94
ILS	0,95	0,95	0,90	0,91
MXN	0,99	0,98	0,98	0,98
PHP	0,39	0,45	0,92	0,81
PLN	0,88	0,91	0,98	0,97
ZAR	0,82	0,61	0,58	0,98
KRW	1,00	0,99	0,96	0,97
TWD	0,96	0,96	0,96	0,97
SGD	0,86	0,82	0,90	0,86
THB	0,59	0,86	0,94	0,67
TRY	0,99	0,99	0,93	0,93

risk reversals and 3-month interest rate differentials. In order to provide additional evidence to the empirical analysis, I used in the estimations daily total return data obtained from Bloomberg as well. For each currency, I had 1296 observations, from November 2010 to October 2015. The exception is the Chilean peso, for which the interest rate data begin in June 2011, and therefore I used a shorter sample in the analysis.

Figure 2 plots, for each currency pair, currency levels and risk reversals over the sample. Figure 3 presents interest differential data, while figures 9 and 10 in the Appendix show the carry trade return series used, respectively the variables z_t constructed and the daily return series from Bloomberg.

Figure 1 shows that, with the exception of the INR, there is a positive correlation between the average level of risk reversals and average interest rate differentials over the sample period, implying that overall higher interest rate differentials lead to higher risks, or investors in high yielding currencies are exposed to crash risks - sudden or abrupt depreciations of the currencies in which investments were made- and to compensate for such risks they demand higher interest rates. For the INR, over the sample

Figure 1
Risk Reversals and Interest Rate Differentials

period there is an unusual combination of high average interest rate differential and low level of risk reversals. Excluding the INR, the correlation of risk reversals and interest rate differentials across currencies is 0.6.

With the exception of a small period for the PLN, risk reversals are always positive for all currencies analyzed in the sample, which means that the FX market always embedded some risk of abrupt depreciation of emerging market currencies. Since the convention of the currencies in this study is to quote them with the dollar (USD) as the base currency, upward movements in the pairs mean that emerging currencies are weakening against the dollar. Positive risk reversals mean that, for a given delta, calls on USD are more expensive than puts, in implied volatility units. The higher risk reversals are, higher it is the implied crash risk on the currency.

3. Do risk reversals help to forecast exchange rate returns in emerging markets ?

In this section, I examine the predictability of emerging market currencies based on risk reversals. First, I have examined the stationarity of risk

Figure 2
Exchange Rates and Risk Reversals

Figure 3
Interest Rate Differentials

reversals and exchange rate returns, based on the DF- GLS and Philips Peron tests. Then, I estimated bivariate VAR's between both series for each currency pair, and assess predictability based on Granger (1969) causality.

In a bivariate VAR as below:

$$y_t = a(L)y_{t-1} + b(L)x_{t-1} + \varphi_t \quad (3)$$

$$x_t = c(L)x_{t-1} + d(L)y_{t-1} + \nu_t \quad (4)$$

we say that variable y_t does not Granger cause variable x_t if $d(L) = 0$, in other terms, if we can remove the lags of y_t of the equation of x_t .

Table 9 in the Appendix presents the quantity of lags used in each bivariate VAR, and the corresponding Lagrange Multiplier statistic at that lag, to assess the autocorrelation. The lags were selected based on the information criteria. When the residuals still showed signs of autocorrelation at the indicated lag, more lags were added to the VAR, until the residuals showed

Table 2
Granger Causality Tests Between Currency Returns and Risk Reversals

Equation	Excluded	χ^2	Prob> χ^2	Equation	Excluded	χ^2	Prob> χ^2
DRR_BRL	RET_BRL	23.531	0.000***	RET_BRL	DRR_BRL	18.958	0.000***
RR_CLP	RET_CLP	1.547	0.461	RET_CLP	RR_CLP	10.275	0.598
RR_IDR	RET_IDR	12.581	0.006***	RET_IDR	RR_IDR	15.774	0.665
RR_ILS	RET_ILS	45.629	0.000***	RET_ILS	RR_ILS	31.836	0.364
RR_INR	RET_INR	18.343	0.003***	RET_INR	RR_INR	12.696	0.026**
RR_KRW	RET_KRW	23.161	0.000***	RET_KRW	RR_KRW	53.392	0.149
RR_MXN	RET_MXN	73.797	0.000***	RET_MXN	RR_MXN	34.719	0.482
RR_PLN	RET_PLN	10.964	0.578	RET_PLN	RR_PLN	.03262	0.984
RR_TRY	RET_TRY	98.022	0.000***	RET_TRY	RR_TRY	82.566	0.083*
RR_ZAR	RET_ZAR	40.298	0.000***	RET_ZAR	RR_ZAR	26.893	0.261

Note: RR stands for risk reversal and RET for the currency return Δs_t . The null is that the excluded variable does not Granger cause the equation variable.

***, ** and * denotes, respectively, statistical significance at 1%, 5% and 10%.

no autocorrelation. Unit root tests, presented in the Appendix, indicated a unit root for the BRL risk reversal. For the other currency returns and risk reversals, tests indicated stationarity, and therefore entered the VAR in levels, while for the BRL the risk reversal entered the VAR in first differences.

The left side of table 2 shows the Granger causality tests when FX returns are removed from the risk reversals equations, while the right side of table 2 presents the Granger causality tests to investigate whether risk reversals help to predict currency returns.

The results indicate that for the BRL, INR and TRY, risk reversals are helpful in predicting the corresponding exchange rate returns. This finding contrasts with those for major developed currencies, since Dunis and Luqueux (2001) and Kurbanov (2010) did not find that risk reversals were helpful in predicting exchange rate returns. On the other hand, risk reversals for BRL, IDR, ILS, INR, KRW, MXN, TRY and ZAR are Granger-caused by their returns, suggesting that option market prices are influenced by the recent behaviour of exchange rate returns, but in many cases fail to anticipate their movements.

4. Global Risk Aversion, Carry Trade Returns and the Price of Skewness

In this section there is an investigation of the role of risk reversals in a more dynamic setting. Along the same lines of Brunnermeier et al. (2009),

for each currency I estimate VAR's with the following variables: the VIX index, interest rate differential, carry trade returns (variables z_t) and risk reversal (the price of skewness).

Attempting to investigate the carry trade - the strategy of borrowing in low yield currencies and investing in high yield currencies - and major failures of the uncovered interest parity (UIP) - firstly documented by Fama (1984) - Brunnermeier et al. (2009) estimated a standard recursive system with the following order, using quarterly data: interest rate differential, total return z_t , - as in expression 2-, realized skewness and futures positioning, as a proxy for carry trade activity for five currencies: Canadian Dollar (CAD), Japanese Yen (JPY), Swiss Franc (CHF), Great Britain Pound (GBP) and Euro (EUR).

Since there are no positioning data for the currencies in our analysis, and data are on a daily frequency, a smaller specification has been opted, without positioning data and replacing the realized skewness for the risk reversals. Brunnermeier et al. (2009) constructed a quarterly measure of realized skewness from daily exchange rate returns. As our analysis is based on daily data, it was not possible to include this variable in the estimated models. Feroli et al. (2014) defend the use of daily data to assess a positive feedback loop between returns and bond flows².

Regarding positioning, their analysis is based on futures positioning from the Commodity Futures Trading Commission (CFTC), but they acknowledge the limitations of using this data³, and also argue that returns tend to be highly associated with an increase in positioning^{4,5}. Given these arguments, we assume that the lack of positioning data is harmless in our

² "Ideally, we would have liked to use even higher frequency data (such as daily observations) to test for the feedback loop. At the daily frequency, it would be easier to defend the assumption that flow movements cause price adjustments. However, daily data are not available." (p. 27)

³ "A positive futures position is economically equivalent to a currency trade in which the foreign currency is the investment currency and the dollar is the funding currency, and, indeed, few speculators implement the carry trade by actually borrowing and trading in the spot currency market. We note, however, that the position data are not perfect because of the imperfect classification of commercial and noncommercial traders, and, more importantly, because much of the liquidity in the currency market is in the over-the-counter forward market. Nevertheless, our data are the best publicly available data, and they give a sense of the direction of trade for speculators." (p. 321)

⁴ "Perhaps the past return is a better measure of speculator positions given the problems with the position data from the CFTC." (p.330)

⁵ "Times when past returns are high also tend to be times when futures positions are high" (p.330)

analysis. This idea is also consistent with models and empirical evidence in mutual funds whereby a feedback loop emerges between flows and returns, in which high returns attract flows, which further enhance returns, until a crash happens (Feroli et al. 2014).

The VIX index, based on the implied volatility of the S&P 500, is widely recognized as a proxy of global risk aversion, risk on/risk off sentiment (Rey, 2013), and uncertainty (Bloom, 2009) and was included in the estimated VAR's in order to control for these factors. Brunnermeier et al. (2009) argues that bouts of global risk aversion could trigger funding constraints through higher margins and capital requirements, associated with unwinding of carry trades. Consistent with the literature on uncertainty shocks (Bloom, 2009), it was ordered first in the estimated VAR's under the Cholesky identification scheme. Thus, the order of the models implies that the VIX affects contemporaneously interest rate differentials, carry trade returns (variables z_t) and risk reversals, while shocks to risk reversals only impact the other variables with lags. This specification follows Brunnermeier et al. (2009), with the inclusion of the VIX ordered first in the VAR's.

The Autocorrelation tests and lags that were used are shown on table 10 in the Appendix. All VAR's passed the stability conditions, i.e., all eigenvalues lied inside the unit circle, and stability tests are reported on figures 14 and 15 in the Appendix. Finally, the normality of the residuals is frequently rejected, as pointed out by the Jarque-Bera test.

In the appendix is presented evidence of a robustness exercise, in which the constructed measure of carry trade returns (z_t) is replaced by the carry trade returns measure obtained on Bloomberg⁶. Since there was no daily carry return for the ILS and KRW on Bloomberg, I ended up with carry returns for 8 currencies, instead of the 10 with the previous measure. I have also estimated the VAR's with a different ordering, in which risk reversals exerts a contemporaneously effect on z_t , that is, this variable is ordered third in the VAR's. The results, although not shown, do not reveal any substantial difference between those reported on Figures 4, 5 and 6 below.

Table 3 presents Granger causality tests between carry trade returns and risk reversals. We found that in the case of the BRL, CLP, IDR and INR risk reversals help to forecast carry trade returns in the 4-variable VAR estimated for each country. On the other hand, with the exception of the PLN, in all other cases we found that carry trade returns Granger cause risk

⁶Obtained on the screen WCRS

Table 3Granger Causality Tests Between Carry Returns (Variable z_t) and Risk Reversals

Equation	Excluded	χ^2	Prob> χ^2	Equation	Excluded	χ^2	Prob> χ^2
z_brl	drr_brl	30.046	0.000***	drr_brl	z_brl	18.622	0.017***
z_clp	rr_clp	22.992	0.006***	rr_clp	z_clp	34.335	0.000***
z_idr	rr_idr	18.244	0.006***	rr_idr	z_idr	15.477	0.017**
z_ils	rr_ils	72.297	0.512	rr_ils	z_ils	43.316	0.000***
z_inr	rr_inr	17.085	0.029**	rr_inr	z_inr	19.089	0.014**
z_krw	rr_krw	52.413	0.263	rr_krw	z_krw	15.869	0.003***
z_mxn	rr_mxn	5.385	0.716	rr_mxn	z_mxn	73.459	0.000***
z_pln	rr_pln	21.738	0.115	rr_pln	z_pln	19.136	0.208
z_try	rr_try	85.636	0.128	rr_try	z_try	86.746	0.000***
z_zar	rr_zar	41.113	0.767	rr_zar	z_zar	23.414	0.001***

Note: Z stands for total returns, as in equation 2, and RR for risk reversals. The null is that the excluded variable does not Granger cause the equation variable.

***, ** and * denotes, respectively, statistical significance at 1%, 5% and 10%.

reversals. Overall, this evidence indicate that in general risk reversals are Granger-caused by the returns, implying that option prices, or the prices of skewness, tend to follow the behaviour of carry trade movements. On the other direction, for the BRL, CLP, INR, and IDR, it was found that risk reversals convey useful information in predicting carry trade returns, meaning that option prices contain useful information for the returns. Since many of these currencies are used as target in the carry trade, I found that risk reversals provide useful information for these kinds of transactions.

Although Granger causality tests indicate that risk reversals are helpful in predicting both the exchange and carry trade returns of some currencies, they do not provide information about the shape of the relationship between these variables. For this reason, it is presented below the impulse response of risk reversals to a shock in carry trade returns (variable z_t), based on the estimated VAR's. The order of the models implies that the VIX contemporaneously affect interest rate differentials, carry trade returns and risk reversals, while shocks to risk reversals only impact the other variables with lags.

The goal was to investigate the interaction between global risk aversion, carry trade returns and the price of skewness, more specifically to see show risk reversals in emerging market currencies react to a selloff or a rally in some currency. In case the currency strengthens, there is a questioning if the price of insurance becomes more expensive, reflecting the risk of a

Figure 4Response of Risk Reversals to a Carry Trade Return Shock (Variable z_t)

Note: responses of risk reversals of BRL, CLP, INR and IDR

Note: responses of risk reversals of ILS, MXN, PLN and ZAR

Note: responses of risk reversals of KRW and TRY

crash in the future, or if it reacts in a somehow procyclical way, becoming cheaper to insurance against a crash.

Overall, with the exception of the PLN, I found that risk reversals react negatively to a shock in z_t . The response of BRL risk reversal is slightly different, in the sense that risk reversals immediately fall after the shock, and then quickly recovers the original level, while for the other currencies the risk reversal response is more persistent after the shock. This difference might be due to the way the BRL risk reversals enter in the VAR - in first differences, while the others enter on levels. In any case, as in the others, the response after the shock is negative and statistically significant, with 95% confidence bands in gray. After the shock, risk reversals decline and

slowly returns to the previous value, showing a lot of persistence.

This result implies that the market often follows the behaviour in carry trade returns, that is, when there is a positive shock to the returns in the carry trade, the price of insurance against a crash in currency markets actually falls. Therefore, it becomes cheaper to buy protection after a rally in the market, while whenever the market sells off, the price of skewness increases, suggesting that market gets spooked and purchase insurance against additional falls in the returns.

Figure 5 shows how risk reversals react to a positive shock in the VIX, taken as a measure of global risk aversion. Risk reversals respond in a positive way, meaning that episodes of risk off in the market lead to an increase in the price of insurance of a devaluation in emerging market currencies against the dollar. This evidence is consistent with the presented in Brunnermeier et al. (2009) for risk reversals of developed currencies,

Finally, figure 6 reports the response of carry trade returns to a shock in the VIX. For all currencies carry trade returns fall right after the shock, and bounces back in a few days. This evidence is aligned with the interpretation of Brunnermeier et al. (2009) and Feroli et al. (2014), in which global risk off episodes leads to tighter funding liquidity, unwinding of carry trades and a procyclical spiral of flows and returns.

Based on the estimated VAR's, it is also presented the variance decomposition of the variables in the estimated VAR's.

According to results shown on table 4, risk reversals in emerging market currencies are mainly explained by their own shocks, carry trade returns and global risk aversion. I found that risk reversals in MXN, ZAR, PLN, CLP and KRW are very linked to global risk aversion movements, represented by shocks on the VIX. On the other hand, risk reversals for the BRL, INR and ILS are relatively insulated from global risk aversion, with less than 10% of their variance explained by shocks on the VIX. Carry trade returns are the main drivers of the TRY risk reversals, explaining 52% of its variability. Carry trade returns are also important determinants of the risk reversals of the KRW, MXN, CLP, ILS and BRL, explaining more than 10% of their variability in the estimated VAR's.

Table 4 also indicate how much variation in the carry trade returns in due to currency crash risk embedded on risk reversals, or, in other terms, how much compensation for currency risk is included in carry returns for the period under study. As shown in the second panel, I found that crash risk shocks, or shocks to risk reversals, explain a small share of carry trade

Figure 5
Response of Risk Reversals to a Shock on the VIX

Note: responses of risk reversals of BRL, CLP, INR and IDR

Note: responses of risk reversals of ILS, MXN, PLN and ZAR

Note: responses of risk reversals of KRW and TRY

Figure 6

Response of Carry Trade Returns (Variable z_t) to a Shock on the VIX

Note: responses of carry trade returns (Variable z_t) of BRL, CLP, INR and IDR

Note: responses of carry trade returns (Variable z_t) of ILS, MXN, PLN and ZAR

Note: responses of carry trade returns (Variable z_t) of KRW and TRY

Table 4

Variance Decomposition of the VAR's

Variance Decomposition of Risk Reversals				
Currency	Share Explained by:			
	VIX	Interest RateDifferential	Carry TradeReturns	RiskReversals
BRL	7%	1%	11%	82%
CLP	25%	0%	18%	57%
INR	1%	2%	10%	88%
IDR	8%	1%	8%	83%
ILS	5%	1%	17%	77%
MXN	52%	0%	22%	26%
PLN	28%	1%	1%	70%
ZAR	41%	0%	9%	49%
KRW	23%	2%	23%	53%
TRY	15%	3%	52%	31%

Variance Decomposition of Carry Trade Returns				
Currency	Share Explained by:			
	VIX	Interest RateDifferential	Carry TradeReturns	RiskReversals
BRL	7%	1%	90%	2%
CLP	10%	1%	87%	2%
INR	6%	1%	91%	1%
IDR	4%	1%	94%	1%
ILS	3%	1%	96%	1%
MXN	15%	0%	85%	0%
PLN	9%	2%	88%	1%
ZAR	11%	1%	88%	0%
KRW	7%	1%	92%	0%
TRY	8%	1%	90%	1%

Variance Decomposition of Interest Rate Differentials				
Currency	Share Explained by:			
	VIX	Interest RateDifferential	Carry TradeReturns	RiskReversals
BRL	0%	99%	0%	0%
CLP	5%	94%	1%	0%
INR	0%	98%	1%	1%
IDR	1%	98%	1%	1%
ILS	5%	85%	3%	7%
MXN	1%	97%	1%	1%
PLN	2%	96%	1%	2%
ZAR	0%	99%	0%	0%
KRW	0%	99%	0%	0%
TRY	1%	96%	3%	1%

Note: Variance Decomposition after 45 days.

returns. Rather than crash risk shocks, global risk aversion, represented by shocks on the VIX, are much more important for explaining carry trade returns. The MXN, ZAR and CLP exhibit the larger exposure to global risk aversion shocks, while the IDR and ILS are more insulated from global risk aversion. In a panel VAR setting, the share of risk reversals shocks on the variability of carry returns remain small. Results are described in more detail in section 6.

Finally, interest rate differentials are mainly driven by their own shocks. In the case of ILS and CLP, rate differentials are more exposed to shocks on global risk aversion. On the former case, shocks on risk reversals explain around 7% of the variability of interest rate differentials.

5. Crash Risk Sentiment in Emerging Market Currencies and Global Risk Aversion

This section investigates how coordinated are risk reversal movements across different currencies. To assess the co-movements of risk reversals, a factor analysis was done, shown on table 5. The first factor explains more than half of the variability of risk reversals over the period. Observing uniqueness of the factors on table 5, we find that the MXN, PLN, IDR and BRL are more exposed to the common factor, while the CLP, INR and ILS are less sensitive to the common cycle, with around 30-40% of their variability driven by idiosyncratic factors.

Feroli et al. (2014) extract a principal component of bond flows and identify the first principal component as an indicator of bond market sentiment. They show that the derived bond sentiment indicator shows little correlation with the VIX, which they take as positive, implying that the indicator captures more than the volatility of equity markets, and is unrelated with the global financial cycle explored by Rey (2013) and uncertainty (Bloom, 2009).

I proceed in a similar way here, extending the analysis in Feroli et al. (2014)⁷. Figure 7 compares the first factor extracted from the risk reversals, which I label FX crash risk sentiment indicator in emerging markets, and

⁷“Finally, there are many ways in which the sentiment index could be extended and improved. It would be natural to incorporate other risk classes to expand the investigation. For instance, adding carry trades that involve government bonds in different markets would be a natural addition to the index. It might also make sense to look at commodity markets. Besides looking at other asset classes, it might also be fruitful to include asset managers from outside the United States. The investigation in this report is only a first step in looking at these risks.” (p.45)

Table 5
Factor Analysis of Risk Reversals

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	4.35077	3.85834	0.5275	0.5275
Factor2	0.49243	-0.68226	0.0597	0.5873
Factor3	1.17468	0.33576	0.1424	0.7297
Factor4	0.83893	-0.33866	0.1017	0.8314
Factor5	1.17759	0.96474	0.1428	0.9742
Factor6	0.21285	.	0.0258	1.0000
Variable	Factor1	Factor2	Factor3	Uniqueness
rr_brl	0.8942	-0.0424	0.1078	0.0712
rr_clp	0.2283	-0.0210	-0.1187	0.3875
rr_inr	0.1303	-0.1132	0.1710	0.4429
rr_idr	0.3455	0.1361	0.9285	0.0000
rr_ils	0.5325	0.1752	0.4235	0.3400
rr_mxn	0.9903	-0.1393	-0.0011	0.0000
rr_pln	0.7859	0.6183	-0.0066	0.0000
rr_zar	0.7536	0.1607	0.2433	0.1953
rr_krw	0.8466	-0.0123	-0.0375	0.1734
rr_try	0.4429	-0.0231	0.1328	0.1425
Obtained via Maximum Likelihood with 1296 observations				

the VIX. In contrast to the findings in Feroli et al (2014) for bond flows, the crash risk sentiment indicator in emerging market currencies shows a strong correlation with the VIX. The correlation coefficient is 0.81, statistically significant at the 1% level. Thus, crash risk sentiment is highly associated with global risk aversion. This finding is consistent with risk off episodes in which uncertainty leads to higher volatility, tighter funding liquidity, unwinding of carry trades, and risk reversals reacting in a procyclical way, with the price of insurance increasing after the market sells off.

6. Panel VAR Evidence

This section presents further evidence on the relationship between risk reversals and carry returns. Unlike in section 4, in which it was showed results based on VAR's estimated for each country, here I present evidence based on a panel VAR (PVAR), from Abrigo and Love (2015). Overall PVAR's follow the same structure of VAR's, treating all variables in the system as endogenous, but with the addition of a cross-section dimension,

Figure 7
Crash Risk Sentiment in Emerging Currencies and the VIX

which brings three features to the model: i) lags of all endogenous variables of all units enter the model for one specific unit, ii) the error terms are generally correlated across different units and iii) the intercept, the slope and the variance of the shocks may be unit specific (Canova and Ciccarelli, 2013). Thus, the model is:

$$Y_{it} = \Gamma_0 + \sum_{s=0}^n \Gamma_s Y_{i,t-s} + f_i + e_{it} \quad (5)$$

I have an unbalanced panel. With the exception of Chilean data, I have 1296 daily observations for a total of 8 currencies. For the CLP, our data began in the middle of 2011, more specifically on June 28, whereas for the other countries the dataset began on November 11, 2010. Along the same lines of section 4, the panel VAR was estimated using series of interest rate differentials, total returns (both constructed -variables z_t - and from Bloomberg) and risk reversals, in this order. So,

$Y_{it} = [\text{interest rate differentials}, \text{carry trade returns}, \text{risk reversals}]'$ for country i and day t .

The fixed effects variable, f_i , which conveys the information about the individual heterogeneity, was removed by forward mean-differencing (fod), which removes the mean of forward future observations available for each

country and day (Arellano and Bover, 1995), and is the default option in the package of Abrigo and Love (2015). I also present evidence considering the case when the fixed effect was removed by first differences (fd).

The information criteria⁸ (not shown) pointed to 1 lag for the panel VAR, with both the MBIC and MQIC achieving their lowest levels, while the MAIC achieved its lowest level with 3 lags. This happens both when the model is estimated with the variables z_t and with the measure from Bloomberg. The PVAR (1) was estimated using the lags from 2 to 10 of interest rate differentials, total returns and risk reversals as instruments. The large number of observations in our dataset allowed us to be generous in this respect, allowing a large number of instruments. Using these instruments, I failed to reject the null hypothesis of the Hansen (1982) J-test of overidentifying restrictions⁹. Therefore, I failed to reject the hypothesis that the instruments were valid instruments, uncorrelated with the error term in the generalized method of moments (GMM) estimation. All estimated PVAR models satisfied the stability condition, i.e., all eigenvalues from the estimated models lie inside the unit circle.

Concerning Granger causality tests in the context of the estimated PVAR models, broadly speaking it failed to point that some variable in the system Granger-cause the other. The exception was interest rate differentials in the equation of risk reversals, which means that interest rate differentials are helpful in predicting risk reversals at the 10% level (p-value = 0.078). In terms of variance decompositions, results show that carry trade returns (measured by variables z_t) account for up to 5% of risk reversals variance.

Since the Cholesky decomposition is used in the PVAR, implying that the first variables exerts a contemporaneous effect on the other variables in the system, I also estimated the system with a different order, with risk reversals before carry trade returns, in an attempt to provide robustness to the results. Ordering risk reversals before carry trade returns, I did not found a statistically significant negative response of risk reversals to carry trade returns shocks.

Table 6 presents the variance decomposition of the estimated PVAR's.

⁸ Information criteria in Abrigo and Love (2015) follows Andrews and Lu (2001).

⁹For the PVAR(1) estimated with variable z_t and fod, the Hansen's J statistic is 79, with associated p-value of 0.257. For the PVAR(1) estimated with carry trade returns from Bloomberg and fod, the Hansen's J statistic is 86 with associated p-value of 0.124. For the PVAR(1) estimated with variable z_t and fd, the Hansen's J statistic is 72 with p-value of 0.468. Finally, for the PVAR(1) estimated with carry trade returns from Bloomberg and fd, the Hansen's J statistic is 80, with p-value of 0.24.

Figure 8

Response of risk reversals to a carry trade return shock

Note: Clockwise: Response of risk reversals to carry trade return (variable z_t) shock in a PVAR (1) estimated with forward mean-differencing (fod), response of risk reversals to a carry trade return (variable z_t) shock in a PVAR (1) estimated with first differences, response of risk reversals to a carry trade return (Bloomberg) shock in a PVAR(1) estimated with fd, and response of risk reversals to a carry trade return (Bloomberg) shock in a PVAR(1) estimated with fod.

Crash risk, or risk reversal shocks, account for only a small portion of the variability of carry trade returns, with a maximum share of 3.7% when the PVAR(1) is estimated with first-differences and with carry trade returns obtained from Bloomberg, suggesting that the role of crash risk shocks in explaining carry trade returns in emerging markets is probably small. On the other hand, carry trade returns shock account for up to 6% of the variability of risk reversals in the 10-day horizon, implying that carry trade return shocks explain a larger share of the variability of risk reversals than the other way around.

7. Conclusion

This paper has looked at the information content of risk reversals - the slope of the volatility smile - in ten emerging market currencies. Granger causality tests indicated that in some cases (BRL, INR and TRY), risk reversals are helpful in predicting currency returns. Though, with the exception of the CLP and PLN, for the other currencies examined risk reversals are

Table 6
Variance Decomposition

Method	Response of Carry Trade Returns				Response of Risk Reversals			
	fod	fod	fd	fd	fod	fod	fd	fd
response	z	carry	z	carry	Risk Reversal			
impulse	Risk Reversal				z	carry	z	carry
0	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
1	0,0%	0,0%	0,0%	0,0%	2,3%	1,1%	5,1%	5,9%
2	0,0%	0,0%	1,5%	3,6%	3,9%	0,9%	5,1%	5,9%
3	0,0%	0,0%	1,6%	3,7%	4,6%	0,8%	5,1%	5,9%
4	0,0%	0,0%	1,6%	3,7%	4,9%	0,8%	5,1%	5,9%
5	0,0%	0,0%	1,6%	3,7%	5,1%	0,7%	5,1%	5,9%
6	0,0%	0,0%	1,6%	3,7%	5,3%	0,7%	5,1%	5,9%
7	0,0%	0,0%	1,6%	3,7%	5,4%	0,7%	5,1%	5,9%
8	0,0%	0,0%	1,6%	3,7%	5,4%	0,7%	5,1%	5,9%
9	0,0%	0,0%	1,6%	3,7%	5,5%	0,7%	5,1%	5,9%
10	0,0%	0,0%	1,6%	3,7%	5,5%	0,7%	5,1%	5,9%

Note: "Carry" means the daily carry trade return measure obtained on Bloomberg

Granger-caused by currency returns. This evidence is somehow at odds with that of major currencies, analyzed by Dunis and Lequeux (2001) and Kurbanov (2010), who found that risk reversals are not valuable in terms of predictability of currency returns.

It was then investigated whether risk reversals Granger-caused carry trade returns (measured by the variables z_t), finding evidence for this in the cases of the BRL, CLP, IDR and INR, but on the other hand risk reversals are Granger-caused by carry returns in all but the PLN case. Overall, the evidence suggests a lagged response of risk reversals to currency and carry trade returns.

Following Brunnermeier et al. (2008), the analysis of the relationship between carry trade returns and risk reversals proceeded in a dynamic context with VAR models estimated for each country and PVAR's. On the former, I found overwhelming evidence that risk reversals react in a negative way to carry trade return shocks: the price of skewness becomes cheaper (more expensive) after positive (negative) returns, which I take as indication that the market gets frightened after negative returns and purchase more protection against further losses. In turn, sentiment improves after positive returns, and the market fails to anticipate that a crash may come. On the latter, I also found evidence of the same kind of response, but not robust to

a different ordering.

Finally, I have found that crash risk shocks, or shocks on risk reversals, account for a small share of the variance of carry trade returns in emerging market currencies in the context of the estimated models. The forecast error variance decompositions indicate that carry trade returns in emerging market currencies are more related to global risk aversion shocks, proxied by the VIX. Although in a different, model-free framework, this finding somehow contrasts those from Farhi et al. (2015), who have found a sizeable (around 30%) role for disaster risk in explaining carry trade risk premium for advanced economies in their model. Lastly, along the same lines but in contrast to the findings in Feroli et al. (2014), it was found that an indicator of crash risk in emerging markets strongly correlates with the VIX, suggesting that global risk aversion plays a major role on carry trades in emerging markets.

This paper thus sheds some light on the role of risk reversals in emerging market currencies. As a byproduct, it also contributes, in an empirical way, to the ongoing research agenda of the role of crash risk shocks and their asset pricing implications (Barro, 2006; Farhi et al., 2015; Tsai and Watcher, 2015).

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Table 7
Unit Root Tests

Risk Reversals	MAIC Lag Selection	Dickey Fuller GLS		Philips-Perron	
		Statistics	SC Lag Selection	Statistics	P-value
RR.BRL	18	-1,578	1	-1,686*	0.1749
RR.CLP	1	-3,328***	1	-3,328***	0.0758
RR.INR	22	-4,866***	4	-6,243***	0.0000
RR.IDR	7	-2,725***	2	-2,675***	0.0023
RR.ILS	7	-1,27	6	-1,334	0.0259
RR.MXN	7	-2,656***	1	-2,397**	0.0847
RR.PLN	20	-2,917***	18	-3,046***	0.0002
RR.ZAR	4	-2,204**	1	-2,148**	0.0306
RR.KRW	17	-2,205**	2	-2,679***	0.0580
RR.TRY	16	-1,779*	1	-1,803*	0.0170
Currencies	MAIC Lag Selection	Statistics	SC Lag Selection	Statistics	P-value
BRL	8	2,66	1	3,231	0.9987
CLP	8	1,336	1	1,324	0.9858
INR	5	0,847	1	0,998	0.6582
IDR	5	1,576	1	1,977	0.9757
ILS	2	-1,476	1	-1,564	0.4540
MXN	13	0,895	1	0,64	0.9499
PLN	1	0,173	1	0,173	0.6958
ZAR	1	1,841	1	1,841	0.9690
KRW	1	-2,254**	1	-2,254**	0.1401
TRY	1	2,547	1	2,547	0.9784
Interest Rate Differentials	MAIC Lag Selection	Statistics	SC Lag Selection	Statistics	P-value
IR.BRL	9	-0,03	5	-0,216	0.6424
IR.CLP	14	-1,692*	2	-1,614	0.0221
IR.INR	19	-1,528	6	-1,168	0.1140
IR.IDR	22	-0,968	2	-0,106	0.9639
IR.ILS	15	0,616	1	1,365	0.9789
IR.MXN	10	-0,375	1	-0,275	0.8816
IR.PLN	15	0,4	10	0,69	0.9949
IR.ZAR	2	-0,578	1	-0,63	0.9234
IR.KRW	1	0,617	1	0,617	0.9948
IR.TRY	4	-0,852	1	-0,556	0.6744

Note: ***,** and * denotes, respectively, statistical significance at 1%, 5% and 10%. The null of both tests is that the series is non stationary.

A. Unit Root Tests

Tables 7 and 8 presents Dickey Fuller -GLS and Phillips Perron unit root tests.

B. Autocorrelation Tests

This section presents the LM autocorrelation tests on the estimated VAR's. Table 9 shows the autocorrelation tests on the bivariate VAR's, used to assess Granger causality tests of Section 3. Table 10 presents the autocorrelation tests of the country VAR's between the VIX, interest rate

Table 8
Unit Root Tests (continuation)

Currency Returns	MAIC Lag Selection	Dickey Fuller GLS		Philips-Perron	
		Statistics	SC Lag Selection	Statistics	P-value
RET_BRL	20	-1,462	7	-3,322***	0.0000
RET_CLP	19	-1,646*	12	-2,205**	0.0000
RET_INR	19	-6,739***	1	-25,592***	0.0000
RET_IDR	19	-3,112***	7	-7,076***	0.0000
RET_ILS	22	-1,113	14	-1,677*	0.0000
RET_MXN	21	-1,66*	13	-2,538**	0.0000
RET_PLN	22	-0,751	12	-1,414	0.0000
RET_ZAR	22	-1,191	10	-2,661***	0.0000
RET_KRW	21	-2,902***	8	-5,485***	0.0000
RET_TRY	20	-0,917	13	-1,362	0.0000
Currency Total Return	MAIC Lag Selection	Statistics	SC Lag Selection	Statistics	P-value
Z_BRL	7	-11,223***	1	-24,96***	0.0000
Z_CLP	12	-9,339***	1	-23,211***	0.0000
Z_INR	14	-8,203***	1	-25,922***	0.0000
Z_IDR	19	-5,827***	1	-24,281***	0.0000
Z_ILS	4	-15,519***	1	-26,113***	0.0000
Z_MXN	1	-24,761***	1	-24,761***	0.0000
Z_PLN	1	-25,659***	1	-25,659***	0.0000
Z_ZAR	1	-25,261***	1	-25,261***	0.0000
Z_KRW	8	-10,748***	1	-25,064***	0.0000
Z_TRY	7	-12,182***	1	-24,085***	0.0000
Currency Total Return (Bloomberg)	MAIC Lag Selection	Statistics	SC Lag Selection	Statistics	P-value
CARRY_BRL	20	-2,108**	8	-4,325***	0.0000
CARRY_CLP	20	-1,828*	11	-3,015***	0.0000
CARRY_INR	19	-6,577***	1	-26,871***	0.0000
CARRY_IDR	19	-3,106***	7	-7,081***	0.0000
CARRY_MXN	22	-1,391	13	-2,124**	0.0000
CARRY_PLN	22	-3,284***	6	-8,694***	0.0000
CARRY_ZAR	1	-25,19***	1	-25,19***	0.0000
CARRY_TRY	22	-5,15***	2	-22,038***	0.0000

Note: ***, ** and * denotes, respectively, statistical significance at 1%, 5% and 10%. The null of both tests is that the series is non stationary.

Table 9

Bivariate VAR's between FX returns and risk reversals

Bivariate VAR (returns and risk reversals)	Lags in the VAR	χ^2	p-value
BRL	2	45,996	0.33090
CLP	2	74,086	0.11581
IDR	3	29,262	0.57025
ILS	3	64,719	0.16657
INR	5	42,618	0.37173
KRW	3	75,818	0.10816
MXN	4	68,193	0.14575
PLN	2	25,094	0.64296
TRY	4	24,998	0.64467
ZAR	2	12,479	0.87015

Note: The null is that there is no serial correlation at the respective lag.

Table 10

VAR's (VIX, interest rate differentials, total returns, risk reversals)

VAR	lags	χ^2	P-Value	VAR (Z from Bloomberg)	lags	χ^2	P-Value
BRL: VIX-IR-Z-RR	8	166,73	0.40	BRL: VIX-IR-Z-RR	5	165,21	0.41
CLP: VIX-IR-Z-RR	9	203,02	0.20	CLP: VIX-IR-Z-RR	15	124,62	0.71
IDR: VIX-IR-Z-RR	6	146,08	0.55	IDR: VIX-IR-Z-RR	6	169,46	0.38
ILS: VIX-IR-Z-RR	8	198,77	0.22				
INR: VIX-IR-Z-RR	8	220,09	0.14	INR: VIX-IR-Z-RR	8	218,59	0.14
KRW: VIX-IR-Z-RR	4	197,79	0.23				
MXN: VIX-IR-Z-RR	8	150,17	0.52	MXN: VIX-IR-Z-RR	8	197,54	0.23
PLN: VIX-IR-Z-RR	15	166,57	0.40	PLN: VIX-IR-Z-RR	15	186,10	0.28
TRY: VIX-IR-Z-RR	5	191,85	0.25	TRY: VIX-IR-Z-RR	6	186,26	0.28
ZAR: VIX-IR-Z-RR	7	194,39	0.24	ZAR: VIX-IR-Z-RR	4	223,45	0.13

Note: The null is that there is no serial correlation at the respective lag.

differentials, carry trade returns (either variable z_t or the measure obtained from Bloomberg) and risk reversals. It is also shown the lag order selected for each model.

C. Carry Trade Returns

Figures 9 and 10 show the data for the carry trade return series used in the paper.

D. Some Robustness Tests

In this section we make some robustness analysis of the results obtained in section 4. We seek to investigate whether the results depend on the mea-

Figure 9

Variable Z, constructed using formula 2 for each currency

sure of carry trade returns. I replaced variables z_t in the estimated models by the daily carry trade return obtained on Bloomberg. Table 11 presents Granger causality tests between carry trade returns and risk reversals. Risk reversals help to predict carry trade returns for the BRL, CLP, IDR, INR and TRY. On the other hand, carry trade returns predict risk reversals in all currencies but the PLN. Again, this is consistent with a delayed response of risk reversals to carry trade returns.

Figure 11 shows that risk reversals fall after a carry trade return shock, and that the responses in general are very persistent, similar to those on figure 4. Figure 12 shows that risk reversals increase after a positive shock on the VIX, while figure 13 reveal that carry trade returns decline after a shock on global risk aversion. Overall, the responses are very consistent and qualitative similar to those in section 4.

Finally, forecast error variance decompositions of the estimated VAR's again show that risk reversals are in good part driven by carry trade returns and global risk aversion. The latter is particularly important for the MXN, ZAR, PLN and CLP, while carry trade returns are relevant for explaining risk reversals of the TRY, MXN and CLP. For the variability of carry trade returns, it was found that in general global risk aversion shocks are more

Figure 10
Daily Carry Trade Returns (Bloomberg)

important than crash risk shocks, specially for the MXN, ZAR, PLN and BRL.

E. Stability of the VAR's

This section presents the stability tests for the estimated VAR's in sections 3 and 4, comprising the VIX, interest rate differentials, carry trade returns and risk reversals. All eigenvalues lie inside the unit circle.

Figure 11

Response of Risk Reversals to a Carry Trade Return Shock (Bloomberg)

First row: responses of risk reversals of BRL, CLP, INR, IDR

Second row: responses of risk reversals of MXN, PLN, ZAR, TRY

Figure 12
Response of Risk Reversals to a Shock on the VIX

Note: responses of risk reversals of BRL, CLP, INR and IDR

Note: responses of risk reversals of MXN, PLN, ZAR and TRY

Figure 13

Response of Carry Trade Returns (Bloomberg) to a Shock on the VIX

Note: responses of carry trade returns (Bloomberg) of BRL, CLP, INR and IDR

Note: responses of carry trade returns (Bloomberg) of MXN, PLN, ZAR and TRY

Figure 14Models including Z_t as the measure of carry trade returns

First row: BRL and CLP. Second row: IDR and ILS. Third row: INR and KRW. Fourth row: MXN and PLN. Fifth row: TRY and ZAR.

Figure 15

Models including daily carry trade returns from Bloomberg

First row: BRL and CLP. Second row: IDR and INR. Third row: MXN and PLN. Fourth row: TRY and ZAR.

Table 11
Granger Causality Tests Between Carry Returns (Bloomberg) and Risk Reversals

Equation	Excluded	χ^2	Prob> χ^2	Equation	Excluded	χ^2	Prob> χ^2
carry_brl	drr_brl	19.341	0.002***	drr_brl	carry_brl	38.553	0.000***
carry_clp	rr_clp	33.064	0.005***	rr_clp	carry_clp	38.041	0.001***
carry_idr	rr_idr	19.494	0.003***	rr_idr	carry_idr	20.115	0.003***
carry_inr	rr_inr	21.162	0.007***	rr_inr	carry_inr	19.863	0.011***
carry_mxn	rr_mxn	82.979	0.405	rr_mxn	carry_mxn	152.76	0.000***
carry_pln	rr_pln	19.751	0.182	rr_pln	carry_pln	13.081	0.596
carry_try	rr_try	41.292	0.000***	rr_try	carry_try	62.497	0.000***
carry_zar	rr_zar	5.351	0.253	rr_zar	carry_zar	34.127	0.000***

Note: carry stands for carry trade returns, and RR for risk reversals. The null is that the excluded variable does not Granger cause the equation variable.

***, ** and * denotes, respectively, statistical significance at 1%, 5% and 10%.

Table 12

Variance Decomposition of the VAR's

Variance Decomposition of Risk Reversals				
Currency	Share Explained by:			
	VIX	Interest RateDifferential	Carry TradeReturns (Bloomberg)	RiskReversals
BRL	7%	1%	9%	83%
CLP	21%	1%	19%	59%
INR	1%	2%	10%	88%
IDR	8%	1%	9%	82%
MXN	50%	0%	23%	27%
PLN	28%	1%	1%	70%
ZAR	40%	0%	8%	52%
TRY	14%	2%	32%	52%

Variance Decomposition of Carry Trade Returns				
Currency	Share Explained by:			
	VIX	Interest RateDifferential	Carry TradeReturns (Bloomberg)	RiskReversals
BRL	13%	1%	84%	1%
CLP	7%	1%	89%	3%
INR	5%	1%	92%	2%
IDR	3%	1%	95%	1%
MXN	31%	0%	68%	1%
PLN	16%	2%	81%	1%
ZAR	21%	1%	77%	0%
TRY	5%	0%	92%	3%

Variance Decomposition of Interest Rate Differentials				
Currency	Share Explained by:			
	VIX	Interest RateDifferential	Carry TradeReturns (Bloomberg)	RiskReversals
BRL	0%	99%	0%	1%
CLP	5%	91%	3%	1%
INR	0%	98%	1%	1%
IDR	1%	98%	1%	1%
MXN	1%	97%	1%	1%
PLN	2%	96%	1%	2%
ZAR	0%	99%	0%	0%
TRY	1%	95%	3%	1%

Note: Variance Decomposition after 45 days.