The Predictive Ability of Commodities Currencies Volatility Risk Premium

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Abstract

This article evaluates if the Volatility Risk Premium – the difference between an implied volatility and a realized volatility – of the so-called commodities currencies is able to predict future commodities returns. Empirical results show a positive and statistically significant relationship between Volatility Risk Premium of commodities currencies and future commodities indexes returns. This result holds not only for the main broad spot commodity index, but also for sub-indexes like Energy, Metals and Agriculture. Results hold for forecast horizons ranging from one to ten weeks. Results are robust also to the inclusion of control variables like the past returns of commodities and currencies. The predictive ability of the commodities currencies extends to the returns of other asset classes, such as currencies and equities. The intuition behind is that, when risk aversion sentiment increases, the market quickly discounts the risky asset (e.g., equity, currency or commodity), and latter this discount is "accrued", leading to subsequent positive returns over a period.

I. Introduction

Predicting commodities movements is an important issue for exporting and importing countries, as well as for many companies. Commodities prices have an interdependence with exchange rates of producing countries (Cashin et al 2004). Indeed, many forecast approaches use exchange rates. It is well accepted that commodities prices in US Dollar move on the opposite direction of the US Dollar nominal rate against a basket of currencies. Chen et al (2014) make a factor analysis on 51 commodities and find that the first common factor is inversely linked to the US nominal exchange rate. Another paper, Chen et al (2010) finds that the so-called commodities currencies[1] are able to predict many commodities prices. The explanation would be that exchange rates are more forward-looking than commodities prices, so that expectations about futures development on these markets are reflected first on these currencies and then on to commodities prices. However, recent papers support also the reverse causality: from commodities prices to exchange rates. This is the case of Zhang, Dufour and Galbaith (2016) and Kohlscheen, Avalos and Schrimpf (2016).

Another promising area for forecasting financial asset prices is to track the Volatility (or Variance) Risk Premium, i.e., the difference between an implied volatility and a realized volatility[2]. Bollerslev, Tauchen and Zhou (2009) and Bollerslev et al (2014) find that the variance risk premium for developed equity markets can predict future equity indexes returns. Bollerslev, Tauchen and Zhou (2009) also propose a model to explain this result. The intuition of their model is that, when risk aversion sentiment increases (decreases), equity prices are quickly discounted, resulting in high (low) futures returns. Similar patterns can also be found on exchange rates. For instance, Ornelas (2015) and Londono and Zhou (2016) find that the Volatility Risk Premium of exchange rate options could predict currency returns on a time-series perspective, although empirical results of these papers do not match. Della Corte el al (2016) find that variance risk premium can be useful for predicting exchange rates cross-section behavior.

This paper investigates whether the Volatility Risk Premium (henceforth VoRP) of the Commodities Currencies (henceforth CC) can predict future commodities movements, as well as movements in other asset classes. Our regression results find a positive and statistically significant relationship between VoRP of CC and future commodities indexes returns. This result holds not only for the main broad spot commodity index, but also for sub-indexes like Energy, Metals and Agriculture, and also for other asset classes like equities, currencies and corporate bonds. Furthermore, results hold for forecast periods ranging from one week to ten weeks, and are robust to the inclusion of control variables like the past returns of commodities and currencies. Each percentage point of CC VoRP leads to approximately 15 percentage points of annualized commodities returns.

As a comparison, we evaluate also the predictive ability of the non-commodities currencies (non-CC) VoRP. They have a lower predictive power than CC for commodities indexes, as expected. The difference between commodities and non-commodities VoRP also predicts commodities prices indexes. This difference can be viewed as the commodities component of the risk premium embedded in currencies options.

As is common in the literature, we also perform a comparison of our CC VoRP predictor with a random walk, in a pseudo-out-of-sample test. Results show a better performance of the VoRP for the broad spot commodities index and for all sub-indexes, except Precious Metals. Other predictors like non-CC VoRP and CC returns fail to beat the random walk. The CC VoRP beats the random walk also for most equities and currencies indexes, but fails to predict bonds and corporate spreads.

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[1] The commodities currencies considered are the Australian Dollar, the Canadian Dollar and the New Zealand Dollar. See Chen and Rogoff (2003) for a discussion.

[2] Although many papers define Volatility Risk Premium in this way, several other papers define in an inverse way: the realized minus implied.

The intuition behind our empirical results can be gathered from the theoretical model of Bollerslev, Tauchen and Zhou (2009). In their paper, the risky asset is an equity index (S&P 500), which can be forecasted by its own Variance Risk Premium (henceforth VaRP), in a direct relationship. Here, we argue that commodities can be viewed as the risky asset. The intuition in our case is that, when risk aversion sentiment increases (decreases), risky assets (in our case, commodities) are quickly discounted, and are latter this discount is accrued, leading to high (low) futures commodities returns. Thus, the VoRP of the commodities currencies would be the measure of the risk sentiment on the commodities markets.

Overall, this paper contributes to the literature by showing robust evidence that the currency volatility and variance risk premia can predict not only future commodities prices, but also other asset classes. The mechanism of this prediction ability seems to be linked to risk aversion sentiment of the commodities and currencies markets.

In the following sections, we describe the sample on section II, and the volatility and variance risk premia calculation methodology on section III. Empirical results are on section IV. Finally, section V concludes the paper.

II. Sample

Our main sample uses implied volatility from OTC (over-the-counter) exchange rate options. These are not actual trades, but estimates collected from JP Morgan's data query application. We use ATM (at-the-money) options with one-week maturity. The realized volatility is based on the tick-by-tick quotes provided by Gain Capital on their website[3]. We calculate 5-minute log returns by aggregating tick-by-tick ask quotes into a 5-minute time-series, and then taking the first difference of the log. The 5-minutes realized volatility is calculated

$$\sigma = \sqrt{\left(\frac{1}{n-1}\right)\sum_{t}[r_t - \bar{r}]^2} \tag{1}$$

Return *r* is the log return considering the last ask price for a 5-minute period. We then annualize it by multiplying by the square root of 72,800, which is an approximation of the number of 5 minutes in a trading week.

The sample time period goes from February 2003 to December 2014, so that we have approximately 12 years of weekly data. The main statistics are summarized on Table I.

The sample has data for six currencies pairs, all against the US Dollar. The currencies are from developed countries: Australian Dollar (AUD), British Pound (GBP), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), and Swiss Franc (CHF). This currency selection is based by data availability for the whole sample period.

It is interesting to note that the ATM implied volatility is lower than the realized volatility for four currencies. Thus, the risk premium calculated is negative on average in many cases.

As a robustness check, we also use an alternative sample with one-month options. Results for this sample are shown on Appendix.

[3] http://www.gaincapital.com/

Table I – Summary Statistics

Currency	ATM Volatility	Realized Volatility	Volatility Risk Premium
AUD	12,02	12,80	-0,78
CAD	9,50	10,13	-0,63
CHF	10,45	10,63	-0,18
EUR	10,04	9,62	0,41
GBP	9,09	9,25	-0,16
JPY	10,65	10,28	0,37
Overall Mean	10,29	10,45	-0,16

This table shows average volatilities for a sample of six currencies against the US Dollar. The columns show the average values of the at-the-money (ATM), realized volatilities and VoRP using the forward approach for each currency. The realized volatility is calculated for each week using 5-minute log returns based on the ask price. The last row show the average values for all currencies. The currencies are Australian dollar (AUD), British Pound (GBP), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), Swiss Franc (CHF). Option data is from JP Morgan and foreign exchange quotes are from Gain Capital website. The sample period is from February 2003 to December 2014, with 622 weekly observations. Volatilities are shown on an annualized basis in percentage points. The maturity of the options is one week. Options are quoted considering an exchange rate expressed as foreign currency per U.S. Dollar, except for AUD, EUR, and GBP.

III. Volatility Risk Premium Calculation

The VoRP calculation requires a measure of implied (Risk-Neutral) volatility of returns and a measure of realized (physical) volatility of returns. The realized volatility can be easily calculated once we have a time-series of returns. Bollerslev, Tauchen and Zhou (2009) point out that realized volatility calculated with intraday data can provide better estimates of the true unobserved volatility than traditional measures based on daily data. The main issue is to obtain the high-frequency data. This paper uses volatility based on 5-minute returns.

The implied volatility can be harder to calculate. One simple way to measure is just take the implied volatility of an at-the-money (ATM) option. This way has the advantage of being readily available through data providers. Another way is to calculate the risk-neutral (implied) variance from options with several strikes, and then take the square root. This is called a model-free implied volatility when no parametric model assumption is done. The VIX index, the most known volatility index, is calculated by CBOE using several options on the S&P500 index, with different strikes. Our main sample uses ATM options, but a robustness check on the Appendix shows an alternative sample using a model-free implied volatility.

Having both risk-neutral and physical measures, one can calculate the Volatility (or Variance) Risk Premium. Ideally, the volatility risk premium should be the difference of a Risk-Neutral measure $E^{\mathbb{Q}}[\sigma]$ and an expected physical measure $E^{\mathbb{P}}[\sigma]$, both for the same time period:

$$VoRP_t = E^{\mathbb{Q}}\left[\sigma_{t,t+T}\right] - E^{\mathbb{P}}\left[\sigma_{t,t+T}\right] \tag{2}$$

Although the Risk-Neutral volatility can be gathered from option prices, the expected future volatility is not available. The traditional way in the literature (including Bollerslev et al, 2009 and Della Corte et al, 2016) to address this issue is to use the current implied volatility and the past realized volatility with a period ending in the current date, i.e., a backwards volatility. This method implicitly assumes that $E^{\mathbb{P}}[\sigma_{t,t+T}] = \sigma_{t-T,t}$, i.e., that agents expect that volatility has an unit autocorrelation. However, realized volatility does not have a unit correlation, but rather behave in clusters. In this setting, there is a mismatch between the period for which volatility was forecasted and the period of the realized volatility. The market may expect that the future volatility will be different from the past, but this approach ignores this issue.

An alternative approach is to follow Ornelas (2015) and compare the risk-neutral volatility forecasted between *t - T* and *t* with the (future) realized volatility also between *t - T* and *t*. In this way, we compare the risk-neutral volatility with realized volatility for the same period of the forecast, so that there is no need to assume unit autocorrelation of realized returns. This VoRP "forward" approach is calculated as follows:

$$VoRP_t = E^{\mathbb{Q}}[\sigma_{t-T,t}] - \sigma_{t-T,t} \tag{3}$$

This approach the drawback of using the risk-neutral volatility information *T* periods lagged, in order to ensure that we use only information available at time *t*. Furthermore, it implicit assumes $E^{\mathbb{P}}[\sigma_{t-T,t}] = \sigma_{t-T,t}$, which means a perfect forecast by agents. But in practice, the forecast error is not zero. Therefore, the measure of equation (3) is actually the ideal VoRP measure of equation (2) plus the forecast error. It is possible that the forecast error can predict the returns on our empirical investigation, instead of the volatility risk premium. However, we cannot disentangle these two components. In addition, it could be the case that forecast errors are correlated with the ideal VoRP. When the actual volatility is unexpectedly high, it is likely that risk aversion and risk premium will increase, prices will go down and future returns will be positive, and vice-versa.

Besides the volatility, we also use the variance risk premium calculated using the forward approach, which can be represented as follows:

$$VaRP_t = E^{\mathbb{Q}}[\sigma^2_{t-T,t}] - E^{\mathbb{P}}[\sigma^2_{t-T,t}] \tag{4}$$

In this paper, we show results only for the VoRP and VaRP using this approach based on equations 3 and 4. Results for the backward method are always weaker, and thus are omitted.

IV. Baseline Regressions

Initially, we consider regressions with one explanatory variable at a time. Our main explanatory variables are the VoRP and VaRP from two commodities currencies: Australian Dollar and Canadian Dollar. We do not use the New Zealand Dollar due to lack of intraday data availability in the beginning of the sample. As a comparison, we consider also the risk premia from four non-commodities currencies Swiss Franc, Euro, British Pound and Japanese Yen. As some articles use VaRP and others use VoRP, we try both. The VoRP is calculated again according to equation 3, while the VaRP follows equation 4. Both use one-week ATM options for the risk-neutral component $E^{\mathbb{Q}}[\sigma_{t-T,t}]$, and 5-minute realized returns for the physical component $E^{\mathbb{P}}[\sigma_{t-T,t}]$, so that the time window *T* in these formulas is one week. Our main dependent variables are commodities indexes weekly returns. We use the Bloomberg broad spot commodity index provided, and five sub-indexes: Energy, Agriculture, Industrial Metals, Precious Metals and Crude Oil. We evaluate also dependent variables from other asset classes, such as equity indexes, currency indexes and bond yields. Our baseline regression specification (3) includes also a constant and the lagged dependent variable:

$$R_t = \alpha + \beta_1 R_{t-1} + \beta_2 VRP_{t-1} + \varepsilon_t \tag{5}$$

Where

R_t is the index weekly return of week *t* for commodities, currencies and equity indexes, and the yield weekly variation for the bond yields and corporate spread. Both are in percentage points.

VRP_{t-1} are the risk premium variables. We use the VoRP and VaRP of two set of currencies: Commodities Currencies (CC) and non-commodities currencies (non-CC). These premia are calculated based on the realized volatility or variance of the previous week (t – 1) and the implied ATM volatility of two weeks before (t - 2). Commodities currencies are Australian Dollar and Canadian Dollar, and the non-commodities currencies are Swiss Franc, Euro, British Pound and Japanese Yen. In both cases, we use an equally weighted average of each VRP for each currency.

Results are on Table II. On Panel A, commodities returns coefficients are positive, indicating that a high (low) risk premium lead to future positive (negative) returns. Coefficients for the VoRP are around 15, meaning that one percentage point of the VoRP leads to a 15% annualized return over the following week. Recall that the mean VoRP is near zero in our sample, while the implied and realized volatilities are around 10%, so that one percentage point is a reasonably large number.

When the independent variables are the CC VaRP and VoRP, all the coefficients are statistically significant, mostly at 1%. The non-CC risk premia have a poorer performance in forecasting commodities, supporting our view of that CC options are related to the commodities markets. The adjusted R^2 of the CC VRPs regressions are more than three times higher those of non-CC regressions. VoRP has a slightly better adjusted R^2 than VaRP.

The Broad spot commodities index has the best adjusted R^2 and also the highest t-statistics. Perhaps this is evidence that the idiosyncratic component of individual commodities returns are harder to forecast. Precious metals and Energy subindexes have the lowest adjusted R^2. Industrial metals is the easiest subindex to forecast.

Panel B shows results using currencies indexes as dependent variables. We use four indexes:

- Dollar index, which measures the value of the US Dollar against a basket of currencies weighted by trading volume;
- JP Morgan EM currency index, which measures the strength of the most traded developing country currencies against the US dollar;
- Bloomberg JP Morgan Latam currency index, which measures the strength of the most traded Latin American currencies against the US Dollar;
- Bloomberg JP Morgan Asia currency index, which measures the strength of the most traded Asian currencies against the US dollar.

Note that, while the Dollar Index measures the value of the Dollar against a basket (of mainly developed currencies), the other three indexes measure the value of a basket of currencies against the US Dollar, so that they are inversely correlated by construction.

Coefficients estimates of Panel B support that a high risk premium lead an appreciation of the US Dollar and depreciation of the other currencies. This is consistent with the idea that the US Dollar is the strong currency, and the others are risky currencies. These coefficients for currencies are in line with results of Ornelas (2015), but contrast with those of Londono and Zhou (2016).

The two CC Risk Premia have statistically significant coefficients for all currency indexes, while the non-CC Risk Premia fail to predict only the Dollar Index. The coefficients for the Emerging Markets currencies and regional currencies are positive, consistent with the risk premia discounting model, while the negative coefficient of the Dollar Index means that the other currencies are discounted and not the US Dollar.

The CC VRPs predict better the Latam and Emerging markets currencies than Asian and developed countries currencies, and this is expected as these currencies are mainly from commodities exporting countries.

Results of Panel C show equity indexes as dependent variables. We use five capitalization-weighted indexes: MSCI World, from developed countries, MSCI Emerging Markets, MSCI Energy, with companies from the Energy Sector, Russell 2000, with small capitalization companies from the US markets and S&P500, with large capitalization companies from the US market. The CC Risk Premia have a good predictive ability over these equity indexes, with all coefficients significant at 1%, and adjusted R^2 over 10%, except for the Small Cap index. The non-CC risk premia also have several significant coefficients, but adjusted R^2 are much lower. This predictive ability of currency VRPs over equity indexes can be explained by a high positive correlation between Equity and Currencies risk premia. As in the Equity VRP literature, coefficients are positive, indicating that a high (low) risk premium lead to future positive (negative) returns.

Panel D tests the predictive ability of the VoRP on bond yields. We use as dependent variables the first difference of Treasury bond yields and corporate bond spreads, measured in percentage points. The corporate bonds are those with ratings A and BBB from US companies. The treasury bonds are zero coupon bonds with maturity 10 years for five different countries: USA, Germany, Japan, Canada and Australia. Most of the coefficients on Panel D are negative, which is in line with risk premia discounting model. Recall that we can have the following first-order approximation for the return of a bond:

$$Ret \approx -D \times \Delta y \tag{6}$$

Where

Ret is the return, D is the duration of the bond and Δy is the difference between the yield in two periods. In our case, we can omit the duration term, as it is constant for the bonds we are analyzing. As the relation between the return and the difference in the yield is negative, we should expect negative coefficients in the regressions, showing a positive influence of the Volatility (or Variance) Risk Premium on future bonds returns, again consistent with a risk premia discounting model.

The results show that the level of significance is considerable for the corporate bonds, especially the A-rated ones. This can be led by the energy companies bonds. The Treasury Bonds, particularly the Japanese and Australian 10-year zero coupon bonds, also show significance in the regressions. Furthermore, Treasury Bonds can be better forecasted by the non-CC VRP than by CC VRP. Canadian bonds appear to be the hardest to be forecasted. Therefore, although Canadian economy is strongly influenced by the commodities business, its bond market seems not to be influenced by the CC VRP.

We also tried to use the EMBI spread as dependent variable (not reported); however, the VRP is not able to forecast it.

Overall, the CC VRP regressions have significant coefficients for commodities, currencies, equities, and corporates spreads, but not for Treasury bond yields. The non-CC VRP regressions have good performance for currencies, equities and bonds, but not for commodities.

Table II – Baseline Regression Results

Dependent Variables	*Coefficients*				*HH t-stats*				*Adjusted R^2*			
	VoRP		*VaRP*		*VoRP*		*VaRP*		*VoRP*		*VaRP*	
	CC	*non CC*	*CC*	*non CC*	*CC*	*non CC*	*CC*	*non CC*	*CC*	*non CC*	*CC*	*non CC*
Panel A - Commodities												
Broad Spot	14,5	8,8	22,3	22,6	**4,03*****	**2,02****	**6,06*****	1,55	5,5%	1,3%	4,6%	1,1%
Energy	14,8	8,7	24,8	20,3	**2,44****	1,35	**3,76*****	0,99	2,2%	0,5%	2,2%	0,4%
Agriculture	13,5	9,2	19,8	25,4	**3,51*****	**1,82***	**4,46*****	1,51	3,5%	1,1%	2,7%	1,1%
Indust Metals	18,8	15,4	28,7	41,0	**3,87*****	**2,28****	**5,17*****	**1,81***	5,1%	2,1%	4,3%	1,9%
Prec. Metals	11,4	2,7	12,8	2,8	**3,39*****	0,53	**2,58*****	0,18	2,3%	0,1%	1,0%	0,0%
Crude Oil	20,4	9,4	34,9	12,6	**2,62*****	1,11	**3,61*****	0,45	3,6%	0,7%	3,7%	0,4%
Panel B - Currencies												
Dollar Index	-4,5	-2,5	-6,9	-9,2	**-3,36*****	-1,05	**-9,93*****	-1,27	2,6%	0,5%	2,2%	0,9%
EM Currency Index (JPM)	10,6	9,5	17,1	26,4	**5,78*****	**3,53*****	**11,58*****	**3,05*****	15,9%	7,9%	14,5%	7,9%
Latam FX Index	11,9	11,5	20,6	33,1	**4,27*****	**3,11*****	**9,28*****	**2,49****	15,1%	8,7%	15,6%	9,1%
Asia FX Index	2,9	2,4	4,4	7,4	**4,54*****	**2,10****	**7,04*****	**1,98****	7,0%	3,2%	5,8%	3,7%
Panel C - Equities												
MSCI World	23,2	18,7	41,8	51,6	**3,60*****	**2,60*****	**7,04*****	**1,91***	14,7%	6,0%	16,5%	5,8%
MSCI EM	31,3	25,9	51,8	70,0	**5,41*****	**3,36*****	**10,17*****	**2,71*****	15,7%	6,7%	15,0%	6,2%
Russell 2000	18,7	14,9	33,5	37,0	**3,08*****	**2,02****	**5,08*****	1,41	6,0%	2,5%	6,7%	2,0%
MSCI Energy	30,4	22,4	52,7	62,1	**3,69*****	**2,74*****	**6,28*****	**2,02****	13,6%	4,8%	14,2%	4,7%
SP500	19,4	15,2	36,1	40,1	**3,07*****	**2,34****	**5,50*****	1,63	11,0%	4,5%	13,2%	4,1%
Panel D - Bonds												
10-year T-Bond - US	-0,3	-0,8	-0,3	-2,4	-1,35	**-1,85***	-1,20	**-2,14****	0,5%	1,2%	0,4%	1,4%
10-year T-Bond - Germany	-0,2	-0,6	-0,2	-1,7	-1,48	**-1,97****	-1,05	**-2,07****	1,2%	1,7%	1,0%	1,9%
10-year T-Bond - Japan	-0,1	-0,3	-0,2	-0,7	**-1,91***	**-2,37****	**-3,38*****	**-2,29****	0,5%	0,9%	0,4%	0,8%
10-year T-Bond - Australia	-0,3	-0,8	-0,6	-2,7	-1,43	**-1,81***	**-2,31****	**-2,06****	1,4%	2,1%	1,4%	2,5%
10-year T-Bond - Canada	-0,0	-0,4	-0,0	-1,3	-0,23	-1,44	-0,10	**-1,79***	0,3%	0,8%	0,3%	0,9%
US Corporate Spreads (A)	-0,7	-0,5	-1,4	-1,5	**-2,55****	**-2,10****	**-6,43*****	**-1,82***	15,6%	11,8%	19,4%	12,4%
US Corporate Spreads (BBB)	-0,4	-0,4	-1,0	-1,3	**-2,14****	**-2,36****	**-9,54*****	**-3,37*****	9,8%	8,9%	11,5%	9,5%

This table shows results of 88 regressions: $R_t = \alpha + \beta_1 R_{t-1} + \beta_2 VRP_{t-1} + \varepsilon_t$ *. There are 22 dependent variables and 4 independent variables. Each regression has as independent variables: one risk premium, the one-week lagged dependent variable and a constant. The dependent variables on Panels A, B and C are the weekly returns of: broad spot commodity index, the sub-indexes of Energy, Agriculture, Industrial Metals, Precious Metals and Crude Oil; the Dollar index, the JP Morgan EM currency index, the Bloomberg JP Morgan Latam currency index, the Bloomberg JP Morgan Asia currency index, MSCI World, MSCI Emerging Markets, MSCI Energy, Russell 2000 and S&P500. The dependent variables on Panel D are the first difference of the bond yields from 10-year Treasury bonds from the US, Germany, Japan, Australia, Canada; and the first difference of corporate bond spreads from US companies. All the independent variables are lagged. The independent variables are commodities currencies volatility risk premium (CC VoRP), commodities currencies variance risk premium (CC VaRP), non-commodities currencies volatility risk premium (non-CC VoRP) and non-commodities currencies variance risk premium (non-CC VaRP). The commodities currencies are AUD and CAD. The non-commodities currencies are CHF, EUR, GBP and JPY. The CC and non-CC VRP are calculated with equal weights for each currency. Estimates of the constants are omitted. The statistics marked with *** are significant at 1%, ** shows significance at 5% and * at 10%. The t-statistics are Hansen-Hodrick HAC with 2 lags. The sample period is from February 2003 to December 2014, with 622 weekly non-overlapping observations. VRPs and returns are expressed on an annualized basis in percentage points. The maturity of the options is one week.*

V. Differential Analysis

In this subsection, we perform a test to verify the predictive ability of the differential between the VoRP of CC and non-CC on the dependent variables. Our expectation is that this independent variable works better on predicting the commodities indexes we are testing: the broad spot commodity index and five sub-indexes (Energy, Agriculture, Industrial Metals, Precious Metals and Crude Oil).

Table III shows results for regression 5 using the difference (CC VoRP - non-CC VoRP) of the VRP independent variable. To facilitate the comparison, we repeat results for CC VoRP of Table II. As we can see on Panel A, indeed the commodities indexes are more sensible to the differential than to the CC VoRP alone. Coefficients and t-statistics are higher for the difference than for the CC VoRP. However, adjusted R^2 are lower for the difference.

On Panel B, there is a reduction on the coefficients of the differential compared to the CC VoRP, as well as on the level of significance. The only exception is the coefficient of the Dollar Index, which is higher in magnitude for the differential (this coefficient is negative, as the higher perception of risk leads to an immediate increase on the Dollar value, culminating in lower future returns). The higher level of the coefficient may be explained by the composition of the Dollar Index, which is comprised by almost 10% of Canadian Dollar (when excluding the non-CC, the CAD Dollar plays a larger role in the coefficient). The adjusted R^2 decreases significantly.

Panel C (the Equities variables) shows the same tendency as Panel B: the coefficients and the t-statistics are mostly lower, except for the MSCI Energy, which is one p.p. higher. This result makes sense, as this index is linked to a commodity. For this group of variables, the adjusted R^2 is also lower.

Finally, Panel D shows the results for the group of Corporate Spreads and Treasury bonds. The differential regression results mostly in positive coefficients, while they are all negative for the original analysis of CC VoRP. Although, as most of them are not statistically significant, we focus our analysis on the significant ones: Canada Treasury Bond shows a positive significant coefficient on the differential regression, in contrast to the negative non-significant coefficient for the original regression. This result is as expect, once the Canadian Dollar is a CC. The US Corporate Spreads, in turn, show a higher significance level, even though the coefficient values are very similar between the two analyses.

Table III – Differential VoRP: (CC – non CC)

Dependent Variables	Coefficients		HH t-stats		Adjusted R^2	
	VoRP		VoRP		VoRP	
	CC - non CC	CC	CC - non CC	CC	CC - non CC	CC
Panel A - Commodities						
Broad Spot	17,1	14,5	**6,11*** **	**4,03*** **	4,1%	5,5%
Energy	17,8	14,8	**3,29*** **	**2,44** **	1,7%	2,2%
Agriculture	14,7	13,5	**4,30*** **	**3,51*** **	2,2%	3,5%
Indust Metals	17,7	18,8	**4,96*** **	**3,87*** **	2,4%	5,1%
Prec. Metals	18,3	11,4	**3,34*** **	**3,39*** **	3,2%	2,3%
Crude Oil	27,6	20,4	**3,92*** **	**2,62*** **	3,5%	3,6%
Panel B - Currencies						
Dollar Index	-5,6	-4,5	**-3,01*** **	**-3,36*** **	2,2%	2,6%
EM Currency Index (JPM)	9,3	10,6	**4,26*** **	**5,78*** **	6,5%	15,9%
Latam FX Index	9,5	11,9	**3,15*** **	**4,27*** **	5,0%	15,1%
Asia FX Index	2,8	2,9	**3,80*** **	**4,54*** **	3,6%	7,0%
Panel C - Equities						
MSCI World	22,3	23,2	**3,00*** **	**3,60*** **	7,1%	14,7%
MSCI EM	28,9	31,3	**4,53*** **	**5,41*** **	7,1%	15,7%
Russell 2000	17,8	18,7	**2,81*** **	**3,08*** **	3,0%	6,0%
MSCI Energy	31,4	30,4	**3,12*** **	**3,69*** **	7,8%	13,6%
SP500	18,8	19,4	**2,66*** **	**3,07*** **	5,7%	11,0%
Panel D - Bonds						
10-year T-Bond - US	0,26	-0,32	0,84	-1,35	0,3%	0,5%
10-year T-Bond - Germany	0,20	-0,22	0,81	-1,48	1,0%	1,2%
10-year T-Bond - Japan	0,05	-0,14	0,62	**-1,91***	0,3%	0,5%
10-year T-Bond - Australia	0,25	-0,33	0,92	-1,43	1,2%	1,4%
10-year T-Bond - Canada	0,35	-0,04	**1,78***	-0,23	0,6%	0,3%
US Corporate Spreads (A)	-0,68	-0,66	**-2,84*** **	**-2,55** **	13,2%	15,6%
US Corporate Spreads (BBB)	-0,38	-0,42	**-2,49** **	**-2,14** **	8,9%	9,8%

*This table shows results of 44 regressions, of which 22 are repeated from table II to facilitate comparison. From Table II, we repeat regressions $R_t = \alpha + \beta_1 R_{t-1} + \beta_2 VoRP_{t-1} + \varepsilon_t$. VoRP is the commodities currencies volatility risk premium. We estimate also regressions $R_t = \alpha + \beta_1 R_{t-1} + \beta_2 DifV_{t-1} + \varepsilon_t$. $DifV$ is the difference between commodities currencies volatility risk premium and non-commodities currencies volatility risk premium. The dependent variables R on Panels A, B and C are the weekly returns of: broad spot commodity index, the sub-indexes of Energy, Agriculture, Industrial Metals, Precious Metals and Crude Oil; the Dollar index, the JP Morgan EM currency index, the Bloomberg JP Morgan Latam currency index, the Bloomberg JP Morgan Asia currency index, MSCI World, MSCI Emerging Markets, MSCI Energy, Russell 2000 and S&P500. The dependent variables on Panel D are the first difference of the bond yields from 10-year Treasury bonds from the US, Germany, Japan, Australia, Canada; and the first difference of corporate bond spreads from US companies. All the independent variables are lagged. The commodities currencies are AUD and CAD. The non-commodities currencies are CHF, EUR, GBP and JPY. The CC and non-CC VRP are calculated with equal weights for each currency. Estimates of the constants are omitted. The statistics marked with *** are significant at 1%, ** shows significance at 5% and * at 10%. The t-statistics are Hansen-Hodrick HAC with 2 lags. The sample period is from February 2003 to December 2014, with 622 weekly non-overlapping observations. VRPs and returns are expressed on an annualized basis in percentage points. The maturity of the options is one week.*

VI. Long-term returns

In this section, we evaluate if the predictive ability presented in the last section for one-week returns survives over longer-term horizons. Thus, our dependent variables are long-term (cumulative) returns of one, two, three, five, ten, 15 and 20 weeks. On this regression specification, the lagged return of the dependent variable is not included to allow us to use more data. Therefore, the only independent variable is the VoRP, which is calculated again according to equation 3 with one-week ATM options and 5-minute realized returns, so that the time window *T* is still one week. Given the overlapping structure of this regression, we use Hansen-Hodrick t-statistics with *n* + 1 lags, where n is the size of the return window.

$$LTR_{t,t+n} = \alpha + \beta_1 VoRP_{t-1} + \varepsilon_t \quad (7)$$

Table IV shows results for returns. Only the commodities currencies VoRP is shown, but the VaRP have even better results (omitted).

Where $LTR_{t,t+n}$ is the index return from week t to week *t + n* for commodities, currencies and equity indexes, and the yield variation from week t to week *t + n* for the bond yields and corporate spread. Both are in percentage points. We annualize returns of commodities, currency and equity by multiplying by 52 / *n,* in order to make them comparable. Bond yields and spreads are simply the variation of the (annualized) yield.

For commodities indexes, coefficients on Panel A of Table IV are significant up to ten weeks, except for the Crude oil. Industrial metals extends the predictability up to 20 weeks. Coefficients decrease as the range of the return increases, indicating a strong impact in the short-run and then a fading out effect. The Adjusted R^2 (not reported) also decreases when we consider returns with many weeks.

For equities and for most of the currencies, this predictability extends to 15 weeks, except for the Dollar Index, which is significant up to ten weeks. Excluding the MSCI Emerging Markets, which is only significant up to 15 weeks, all the other equity indexes are significant up to 20 weeks. As for the currencies, two of the indexes are significant up to 20 weeks: EM Currency Index (JPM) and Asia FX Index.

The bonds, in turn, are mostly not significant for long-term analysis. None of the Treasury bonds shows significance from two to five weeks returns, even though most of them are significant for ten weeks, but not for 15 or 20. Corporate bonds (US Corporate Spreads rated A and BBB) are significant for the whole analysis, except for the one week return of the BBB rated.

These results show that the predictive ability of the VoRP is significant for many assets up to ten weeks.

Table IV – Long-Term Regression Results

Dependent Variable	Coefficients of Commodities Currencies Volatility Risk Premium						
	1 week	2 weeks	3 weeks	5 weeks	10 weeks	15 weeks	20 weeks
Panel A - Commodities							
Broad Spot	**14,2*** **	**8,1*** **	**7,3*** **	**4,5***	**3,9***	2,4	2,0
Energy	**14,4** **	**8,8*** **	**7,6** **	5,0	**5,0***	4,0	**3,7***
Agriculture	**13,7*** **	**7,3*** **	**6,0** **	3,2	**3,1***	1,0	0,8
Indust Metals	**19,2*** **	**11,4*** **	**10,8*** **	**7,4** **	**5,9** **	**4,3** **	**3,5***
Prec. Metals	**11,5*** **	**4,9***	**5,5*** **	**3,1** **	**1,8*** **	0,6	-0,6
Crude Oil	**20,2*** **	**13,0*** **	**8,9***	6,2	5,6	4,6	4,4
Panel B - Currencies							
Dollar Index	**-4,6*** **	**-1,8** **	**-2,3*** **	**-1,9*** **	-0,7	-0,3	-0,3
EM Currency Index (JPM)	**10,6*** **	**5,0*** **	**4,3*** **	**2,6*** **	**1,7** **	**1,2** **	**1,0***
Latam FX Index	**12,0*** **	**4,9*** **	**4,4*** **	**2,9** **	**2,2** **	**1,5** **	1,2
Asia FX Index	**3,1*** **	**1,5*** **	**1,6*** **	**1,0*** **	**0,6** **	**0,4** **	**0,4***
Panel C - Equities							
MSCI World	**23,3*** **	**10,6*** **	**8,2*** **	**6,4*** **	**4,4** **	**3,3*** **	**3,0*** **
MSCI EM	**32,2*** **	**17,6*** **	**14,2*** **	**8,4*** **	**5,4** **	**3,8** **	3,0
Russell 2000	**18,9*** **	**9,0*** **	**7,9*** **	**6,7*** **	**4,7** **	**3,7*** **	**3,3*** **
MSCI Energy	**29,9*** **	**13,1*** **	**9,0*** **	**6,1*** **	**4,3*** **	**2,7*** **	**2,2** **
SP500	**19,1*** **	**8,7*** **	**6,8*** **	**5,7*** **	**4,1** **	**3,3*** **	**3,0*** **
Panel D - Bonds							
10-year T-Bond - US	-1,5	-0,8	-0,5	-0,6	**1,9*** **	**1,8***	**1,9***
10-year T-Bond - Germany	**-1,55***	-0,1	0,0	0,5	**2,3** **	1,2	1,0
10-year T-Bond - Japan	**-2,0** **	-0,7	-1,1	-1,5	-0,3	-0,3	-0,3
10-year T-Bond - Australia	-2,1	-1,0	0,5	-0,6	**1,7***	1,1	0,8
10-year T-Bond - Canada	-0,5	-0,7	-0,7	-0,8	**1,5***	**1,6** **	**2,3** **
US Corporate Spreads (A)	**-3,8*** **	**-3,4*** **	**-4,1*** **	**-3,9*** **	**-4,0*** **	**-3,8*** **	**-4,9*** **
US Corporate Spreads (BBB)	-1,5	**-2,1** **	**-2,8*** **	**-2,4** **	**-2,8*** **	**-2,9*** **	**-3,3*** **

*This table shows results of 154 regressions: $LTR_{t,t+n} = \alpha + \beta_1 VoRP_{t-1} + \varepsilon_t$, The dependent variables $LTR_{t,t+n}$ are returns of n weeks. There is only one independent variable: the commodities currencies weekly VoRP with one lag. The commodities currencies are Australian Dollar (AUD), Canadian Dollar (CAD). The commodities currencies VoRP is calculated with equal weights. The dependent variables are: broad spot commodity index, the sub-indexes of Energy, Agriculture, Industrial Metals, Precious Metals and Crude Oil; the Dollar index, the JP Morgan EM currency index, the Bloomberg JP Morgan Latam currency index, the Bloomberg JP Morgan Asia currency index, MSCI World, MSCI Emerging Markets, Russell 2000, MSCI Energy, S&P500, 10 years Treasury bonds for the US, Germany, Japan, Canada and Australia, besides the US Corporate Spreads rated A and BBB. Estimates of the constants are omitted. The coefficients marked with *** are significant at 1%, ** shows significance at 5% and * at 10%. The t-statistics are Hansen-Hodrick HAC with n+1 lags, where n is the number of weeks of the returns. The sample period is from February 2003 to December 2014, with 622 weekly non-overlapping observations. VRPs and returns are expressed on an annualized basis in percentage points. The maturity of the options is one week.*

VII. Adding Control Variables

Given the co-movement reported on the literature of the US Dollar nominal value (Chen et al, 2014) and also of past commodities currencies (Chen et al, 2010) with commodities prices, regression (8) adds these past returns to specification (5) in order assess if they help to forecast commodities prices:

$$R_t = \alpha + \beta_1 R_{t-1} + \beta_2 VRP_{t-1} + \beta_3 RFX_{t-1} + \varepsilon_t \tag{8}$$

Where

RFX_t is the weekly return of an exchange rate index. Two indexes are used: the Dollar index, which measures the value of the US Dollar against a basket of currencies weighted by trading volume; and an equally weighted index with the returns of the commodities currencies: Australian Dollar, New Zealand Dollar and Canadian Dollar. These are the three classic commodities currencies as defined by Chen and Rogoff (2003). It is important to recall that the CC VoRP that we use throughout our work is based only on the Australian Dollar and Canadian Dollar, due to lack of intraday data availability for the New Zealand Dollar in the beginning of the sample.

In this analysis, we use weekly returns. Results on Panel A of Table V show that the lagged Dollar Index returns can help prediction for the Energy sub index, improving the Adjusted R^2 in about half percentage point compared to Table II. The coefficients are positive, meaning that a rise in the US Dollar leads to a higher commodity price. This is inconsistent with results from previous papers, where the coefficient for the Developed Currencies Returns are positive[4]. However, those results are based on monthly returns, while here returns are on a weekly basis. In any case, results on table V gives robustness support for the predictive ability of the commodities currencies VoRP.

Results on Panel B of Table V show that the lagged Commodities Currencies returns does not improve prediction for any of the commodities indexes. Coefficients are not significant and Adjusted R^2 are almost the same of Table II.

[4] recall that the Dollar Index measures the value of the US Dollar, while the returns of the other developed currencies are against the US Dollar, and thus should have the opposite direction

Table V – Regression with control Variables

Panel A

	Coefficients Estimates			*HH t-statisics*			
	VoRP CC	Lag Dollar Index Returns	*Lag Comm Returns*	VoRP CC	Lag Dollar Index Returns	*Lag Comm Returns*	R^2
Broad Spot	*14,74*	0,15	-0,01	**4,21*****	*1,60*	-0,21	5,9%
Energy	15,73	0,29	-0,01	**2,58*****	**1,88***	-0,32	2,7%
Agriculture	13,72	0,10	0,01	**3,71*****	0,97	0,24	3,6%
Indust Metals	18,63	-0,07	-0,02	**3,71*****	-0,55	-0,54	5,2%
Prec. Metals	11,41	0,01	-0,01	**2,20****	0,10	-0,35	2,3%
Crude Oil	20,94	0,17	-0,05	**2,68****	0,95	-0,95	3,8%

Panel B

	Coefficients Estimates			*HH t-statisics*			
	VoRP CC	Lag CC Returns	*Lag Comm Returns*	VoRP CC	Lag CC Returns	*Lag Comm Returns*	R^2
Broad Spot	*14,43*	0,01	-0,05	**4,20*****	*0,14*	-0,75	5,5%
Energy	14,99	-0,05	-0,03	**2,53****	-0,40	-0,66	2,2%
Agriculture	13,56	-0,02	0,00	**3,71*****	-0,22	0,07	3,5%
Indust Metals	18,62	0,06	-0,03	**3,67*****	0,57	-0,60	5,2%
Prec. Metals	11,31	0,02	-0,02	**2,16****	0,14	-0,43	2,3%
Crude Oil	20,82	-0,10	-0,05	**2,68*****	-0,94	-0,80	3,7%

*This table shows results of 12 regressions: $R_t = \alpha + \beta_1 R_{t-1} + \beta_2 VRP_{t-1} + \beta_3 RFX_{t-1} + \varepsilon_t$. There are six dependent variables and three independent variables on each regression. The independent variables are: the (lagged) ATM commodities currencies volatility risk premium (VoRP CC), the lagged independent variable, and the lagged weekly currency return. The CC VoRP is based on options from Australian Dollar (AUD) and Canadian Dollar (CAD), with equal weights. On Panel A, the lagged currency weekly return is the Dollar Index. On Panel B, the lagged commodities currency return is the equally weighted weekly return of the Australian Dollar, New Zealand Dollar and Canadian Dollar. The dependent variables are: broad spot commodity index, the sub-indexes of Energy, Agriculture, Industrial Metals, Precious Metals and Crude Oil. All the independent variables are lagged. Estimates of the constants are omitted. The statistics marked with *** are significant at 1%, ** shows significance at 5% and * at 10%. The t-statistics are Hansen Hodrick with 3 lags. The sample period is from February 2003 to December 2014, with 622 weekly non-overlapping observations. VRPs and returns are expressed on an annualized basis in percentage points. The maturity of the options is one week.*

VIII. Random Walk Comparison

In order to further analyze the predictive ability of the CC VoRP, in this section we perform a pseudo-out-of-sample assessment of our predictors against a random walk benchmark using the commonly used framework of Diebold and Mariano (1995), although there is some controversy regarding this kind of analysis, as Diebold (2015) himself mention. Thus, this section should be taken as a robustness test.

In this assessment, regressions are estimated based on a 4-year (208 weeks) moving window. The regression parameters are estimated for each window. Then, the latest values of the independent variables in the window are used to forecast one-week-ahead dependent variables. These forecasts are then compared with actual values. As usual, the squared errors are used as penalty function, and a statistical test inspired on Diebold and Mariano (1995) is performed.

The regressions are:

$$R_t = \alpha + \beta_1 X_{t-1} + \varepsilon_t \tag{9}$$

Where *R* is the one-week log-returns of the dependent variable for commodities, currencies and equity indexes, and the first difference of the bond yields or spreads. The independent variable *X* is one of four variables: ATM CC VoRP, non-CC VoRP, lagged returns of the commodities currencies, and one-week lag of the dependent variable.

The forecast is compared with the actual realization in the remaining years of the sample, for each week. Then, the squared forecast errors are compared with those of a random walk forecast, i.e., a zero return forecast. The statistical inference is based on a time series of the difference between the forecasted squared errors and random walk squared errors. This time series is regressed on a constant. If this constant is statistically negative, the error of the regression is smaller than the random walk error, and so that variable shows a better predictive ability than the random walk.

Results can be seen on Table VI. The CC VoRP regression, shown on the first column, has a MSE lower than the Random Walk on most of the cases (in 18 out of 22 variables). This better performance is not statistically significant for bonds but, for most of the other assets, it has mostly statistically significant negative coefficients.

For non-CC VoRP, as expected, the results are much worse. Only 13 out of 22 variables show negative coefficients, of which only three are significant. These three variables are JPM EM Currency Index, Latam FX Index and MSCI World. For all the other variables, there is no statistical evidence that the model proposed performs better than a random walk with non-CC VoRP as independent variable.

The results for the regressions using Lag CC Returns and the Lag Return of the dependent variable only show positive coefficients. One of them is statistically significant for the Lag CC Returns regressions (Energy) and two of them are significant for the Lag Return regressions (Industrial Metals and Asia FX Index). These results show that these independent variables do not seem to aggregate information on predicting the returns of the dependent variables we analyze.

Table VI – Random Walk Out-of-sample Comparison

Weekly Returns	Differential MSE				HH t-statistics			
	VoRP CC	*VoRP non-CC*	Lag CC Returns	Lag Return	VoRP CC	*VoRP non-CC*	Lag CC Returns	Lag Return
Panel A - Commodities								
Broad Spot	*-0,46*	0,02	0,11	0,10	**-2,07**	0,09	1,36	1,07
Energy	-0,45	0,14	0,34	0,10	-1,41	0,60	**2,62**	1,36
Agriculture	-0,30	0,04	0,16	0,13	**-2,33**	0,26	1,27	1,06
Indust Metals	-0,76	-0,03	0,29	0,25	**-2,67**	-0,12	1,39	**1,85**
Prec. Metals	0,07	0,27	0,14	0,12	0,17	1,00	1,61	1,24
Crude Oil	-1,03	0,20	0,40	0,18	**-2,47**	0,61	1,56	1,08
Panel B - Currencies								
Dollar Index	*-0,04*	0,02	0,02	0,01	-1,38	0,97	1,13	1,61
EM Currency Index (JPM)	-0,28	-0,11	0,03	0,05	**-3,23**	**-2,52**	0,98	1,21
Latam FX Index	-0,35	-0,18	0,06	0,09	**-2,73**	**-5,51**	1,07	1,09
Asia FX Index	-0,02	0,00	0,01	0,00	-1,57	-0,38	1,12	**1,71**
Panel C - Equities								
MSCI World	*-1,03*	-0,40	0,28	0,38	**-2,50**	**-1,68**	1,25	1,17
MSCI EM	-2,50	-0,76	0,44	0,45	**-2,95**	-1,60	1,14	1,15
Russell 2000	-0,52	-0,10	0,25	0,34	-1,14	-0,30	1,13	1,26
MSCI Energy	-1,85	-0,50	0,45	0,52	**-2,34**	-1,61	1,24	1,19
SP500	-0,52	-0,22	0,20	0,28	**-2,01**	-1,11	1,11	1,07
Panel D - Bonds								
10-year T-Bond - US	-0,06	-1,46	-	0,09	0,14	-0,67	-	0,42
10-year T-Bond - Germany	-0,08	-0,12	-	-0,02	-0,06	-1,56	-	0,07
10-year T-Bond - Japan	0,14	-0,93	-	-0,21	-0,83	-0,64	-	-0,19
10-year T-Bond - Australia	2,11	0,61	-	1,47	-0,03	-0,23	-	-0,77
10-year T-Bond - Canada	-0,06	-0,94		-0,89	0,21	-0,79	-	-0,29
US Corporate Spreads (A)	-1,70	0,41	-	-4,67	-0,82	0,45	-	-0,91
US Corporate Spreads (BBB)	0,17	1,36	-	-6,94	0,14	1,08	-	-1,01

This table shows results for an out-of-sample assessment. In a first step, four univariate models are estimated using a weekly rolling estimation window of 4 years. The univariate regressions are $R_t = \alpha + \beta_1 X_{t-1} + \varepsilon_t$. Variable R is the one-week log-returns of the dependent variable on Panels A, B and C and the first difference of the bond yield or spread on Panel D. The independent variable X is one of four variables: ATM Commodities Currencies Volatility Risk Premium (VoRP CC), ATM non-Commodities Currencies Volatility Risk Premium (VoRP non-CC), lagged returns of the commodities currencies, and one-week lag of the dependent variable. The CC VoRP is based on options from Australian Dollar (AUD) and Canadian Dollar (CAD), with equal weights. The commodities currency return is the equally weighted weekly return of the Australian Dollar, New Zealand Dollar and Canadian Dollar (as previously mentioned, the CC VRP does not use the NZ Dollar due to lack of data). The non-CC VoRP is based on options from Swiss Franc, Euro, GB Pound and Japanese Yen, with equal weights. On the second step, the realization of the independent variables on the last day of the window is used to forecast the variable R one week ahead. Then, a time series of the squared difference between the forecasted returns and actual returns is built to represent squared errors of the model. The Random walk error is calculated as the squared returns. The differential Squared Errors time series is built by subtracting the random walk squared error from the model's squared error time series. This differential Squared Errors time series is then regressed over a constant. The first four columns on the left show the point estimate of this regression, while the following four columns show the Hansen-Hodrick t-statistics, with 52 lags. The sample period is from February 2003 to December 2014. Returns are expressed in percentage points. The maturity of the options is one week. The realized volatility is calculated based on 5-minute log-returns with one-week windows. Returns, VRPs, yields and spreads are expressed in percentage points. VRPs and yields are annual, while returns are weekly.

IX. Final Remarks

The empirical evidence throughout this paper provides strong support for a positive relationship of commodities currency variance and volatility risk premia and future commodities returns. The intuition is that, when risk aversion sentiment increases, the market quickly “discounts” commodities prices, and latter this discount is accrued, leading to commodities positive returns over some weeks. The volatility risk premium of commodities currencies is also able to predict returns of other asset classes such as currencies and equities, although this result is not controlled for other variables. Extending the analysis to the first difference of Treasury bond yields and corporate bond spreads, the results show that non-commodities currencies seem to be especially adequate in predicting future returns. The commodities currencies also show some significance for the corporate bond spreads, but not for most Treasury bonds.

Further analysis using the difference between the commodities currencies and non-commodities currencies volatility risk premium shows that the predictive ability on commodities indexes seem to increase. Comparing these results to the original regression, which uses the commodities currencies volatility risk premium alone, we observe higher coefficients and t-statistics for the assets related to commodities (the indexes and MSCI Energy, for instance).

We also test the regressions for longer-term returns, up to 20 weeks. The commodities indexes show significance up to ten weeks on average. For equities and for most of the currencies, this predictability extends to 15 weeks. The bonds, in turn, are mostly not significant for long-term analysis, although the corporate bond spreads show significance.

Future research may investigate the predictive ability for other asset classes controlling for known predicting variables. Another avenue for future research is to use the volatility risk premium from options on commodities. Using a specific volatility risk premium may improve the predictive ability.

X. References

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XI. Appendix

This Appendix shows a robustness check using another sample. Data about implied volatility surface is also not actual trades, but estimates collected by data providers. Option data is collected from Bloomberg, and comes from a pool with several foreign exchange dealers.

We use the model-free approach for the implied volatility as opposed to the ATM volatility in the main text. The realized volatility is based on intraday returns (30-minutes) taken from Bloomberg. Options have one-month maturities. Given that this sample time span is shorter, we use overlapping data on a daily basis. Besides exchange rate data, we have collected commodities and equity index data from Bloomberg to be used on both parts of the sample. The characteristics of the sample can be summarized as follows:

Table A.I - Sample Characteristics

Source of option data	Bloomberg
Type of implied volatility	Model-free
Time to maturity of Option data	One-month
Overlapping	Yes, on a daily basis
Source of realized volatility data	Bloomberg
Frequency of returns for realized volatility calculation	30-minute returns
Time period	Oct 2007 to Aug 2014

The exchange rate option prices used in this part is collected from Bloomberg. Options have one-month expiration, and have a daily periodicity, thus we have an overlapping structure. This sample uses realized volatilities based on 30-minute intraday quotes. Bloomberg calculates this intraday volatility on a daily basis using 30-minute quotes. We aggregate this data in order to have monthly volatilities based on 30-minutes data using the following formula $\sigma_T^2 = (1/T)\sum_{i=1}^{T}\sigma_i^2$, where σ_i is the intraday volatility taken from Bloomberg.

The sample time period goes from October 2007 to August 2014, approximately 7 years of daily data. The mains statistics are summarized on Table A.II.

The original data from Bloomberg consists of four risk-reversals, four butterflies, besides the at-the-money volatility. Risk-reversals and butterflies have four different deltas: 10, 15, 25 and 35. These quotes are then converted to Call and Put options volatilities with 10, 15, 25 and 35 delta, and an at-the-money volatility.

The main sample includes 10 currencies pairs, all against the US Dollar. The currencies are from developed countries, the so-called G-10 currencies: Australian Dollar (AUD), British Pound (GBP), Canadian Dollar (CAD), Danish Krone (DKK), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), and Swiss Franc (CHF).

Besides the options data, we have collected also data from the spot exchange rate and deposit rate. All spot and deposit rates are from Bloomberg. Deposit rates are Libor-like rates.

It is interesting to note that the ATM implied volatility is lower than the realized volatility for most of the currencies. However, the model-free implied volatility is higher than the realized volatility.

Table A.II – Summary Statistics

Currency	ATM Volatility	Model-free Volatility	Realized Volatility	Volatility Risk Premium
AUD	13,25	18,87	14,03	4,96
CAD	10,32	14,61	10,56	4,14
CHF	11,03	15,66	11,17	4,52
DKK	9,86	13,93	10,15	3,71
EUR	10,90	15,47	10,16	5,34
GBP	9,96	14,16	9,89	4,31
JPY	11,44	16,40	10,95	5,55
NOK	13,23	18,55	13,74	4,71
NZD	13,96	19,90	14,92	5,13
SEK	13,47	18,95	13,83	5,01
Overall Mean	**11,74**	**16,65**	**11,94**	**4,74**

This table shows the average values for a sample of 10 currencies pairs. The first three columns show the average values of the at-the-money (ATM) implied volatility, model-free implied volatility and 30-minute realized volatility for each currency. The last column shows the VoRP calculated using forward approach described in equation 3. The last row show the average values for all currencies. The currencies are Australian Dollar (AUD), British Pound (GBP), Canadian Dollar (CAD), Danish Krone (DKK), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), and Swiss Franc (CHF). Data is from Bloomberg. The sample period is from October 2007 to August 2014, with 1809 daily observations for each currency pair. Volatilities and VoRP are shown on an annualized basis in percentage points. The maturity of the options is one month. Options are quoted considering an exchange rate expressed as foreign currency per U.S. Dollar, except for AUD, EUR, GBP and NZD. The realized volatility is calculated on a rolling monthly basis based on 30-minute returns.

Results for One-Month Options with Overlapping data

We consider one-month options and a realized volatility based on 20-business-day window, with 30-minute returns. The implied volatility is calculated using the model-free approach. The VoRP is calculated with the forward approach, as in equation 3.

Initially, we consider regressions with only one explanatory variable at a time. The regression specification (10) uses 20 business days' returns of several commodities indexes as dependent variable, a constant and several explanatory variables ***X***. The regression specification is the following:

$$R_{t,t+19} = \alpha + \beta_1 X_{t-1} + \varepsilon_t \tag{10}$$

Where

R_t is a commodity index 20-business-day cumulative return starting at time t. Besides the broad spot commodity index, we use also six sub-indexes: Energy, Agriculture, Grains, Petroleum, Industrial Metals and Precious Metals.

X_{t-1} is one of the following explanatory variables:

- Commodities Currencies Volatility Risk Premium (CC VoRP): it is the annualized forward VoRP from AUD, CAD and NZD on business day *t*-1. It is the difference between the model-free one-month implied volatility on day *t* - 21 and the 20-business-day realized volatility ending at time t-1;
- Non-Commodities Currencies Volatility Risk Premium (non-CC VoRP): it is the annualized forward VoRP from CHF, DKK, EUR, GBP, JPY, NOK[5] and SEK on business day *t* - 1. It is the difference between the model-free one-month implied volatility on day *t* - 21 and the 20-business-day realized volatility ending at time *t* - 1;
- Lag Commodities Returns: the commodity index 20-business-day cumulative return ending at day *t - 1*;
- Lag Developed Currencies Returns: the equally weighted 20-business-day cumulative return ending at day *t - 1* from ten pairs of developed currencies against the USD: AUD, CAD, CHF, DKK, EUR, GBP, JPY, NOK, NZD and SEK;
- Lag Commodities Currencies Returns: the equally weighted 20-business-day cumulative return ending at day *t - 1* from three pairs of developed currencies against the USD: AUD, CAD and NZD;
- Equity Volatility Risk Premium (Equity VoRP): is the S&P500 VoRP on business day *t* - 1 using the forward approach (like equation 4) with the VIX index as implied volatility and realized volatility calculated with S&P 500 daily data over 20 business days;

Results of Table A.III show that all independent variables have significant coefficients for the broad spot commodities index, except for its own lagged returns. The three VoRP have positive coefficients, consistent with the idea that, when risk aversion sentiment increases, the market quickly “discounts” the commodity price, and latter this discount is accrued, leading to positive returns over a month. The lagged exchange rate returns (Comm. Currencies and Developed Currencies) are also able to predict commodities returns, consistent with articles of Chen et al (2010, 2014). The idea behind is that the exchange rates are more forward-looking than commodities and thus may embed some information about future movements in the commodity markets.

The sub-indexes show similar patterns. The notable exception is the precious metal sub-index, which has almost-significant coefficients for the currencies VoRP and a significant negative coefficient for the lagged returns. This reversal behavior has not been documented in the literature, and perhaps it is due to some sample period specific characteristic. On the analysis of the next section, with a longer period, this reversal behavior has no statistical significance.

The Commodities Currencies VoRP has the best explanatory power in terms of adjusted R^2, expect for the Agriculture and Grains sub-indexes. In general, the VoRPs have better explanatory power than returns. The Industrial Metals and Petroleum sub-indexes have the highest R^2, around 15% for the Commodities Currencies VRPs.

Regarding the economic interpretation of the coefficients, we can say that a percentage point of Comm. Curr. VoRP leads to around 5 percentage points of annual commodities returns, or almost half percentage point of monthly return. For Petroleum and Industrial Metals, this sensitivity is twice higher.

Next, we check if the Commodities Currencies VoRP predictive power survives when we add control variables. We use two specifications, both with lagged commodities returns and Equity VoRP, besides a currency lagged

[5] The Norwegian Krone is certainly related to oil prices, but not to a broader spectrum of commodities. Thus, it is not considered a commodity currency in the literature.

return. In one specification, the currency lagged return of the commodities currencies and in the other, the currency lagged returns of all developed currencies.

$$R_{t,t+19} = \alpha + \beta_1 CCVoRP_{t-1} + \beta_2 R_{t-20,t-1} + \beta_3 CurRet_{t-20,t-1} + \beta_4 EqVoRP_{t-1} + \varepsilon_t \quad (11)$$

The variables are thus the same of equation (10), but now together. *CurRet* is either the currency lagged return of the commodities currencies or the currency lagged returns of all developed currencies.

Results of Table A.IV confirms the predictive ability of the CC VoRP. Both specifications show higher adjusted R^2 and higher t-statistics. Specification of Panel B, which uses the lagged developed currency returns, shows better results than the specification of Panel A, which uses lagged Commodities Currencies returns. The Equity VoRP was never significant, while the lagged commodity return was significant for some commodities indexes, and again with negative coefficients.

Overall, the specification of Panel B for the Broad Commodity Spot index shows an adjusted R^2 of 13.9%, which is 2 percentage points higher than the univariate case.

Table A.III – Individual Regressions Results

Panel A - Coefficients						
Dependent Variables	Comm. Curr. VoRP	Non-CC VoRP	Lag Comm Returns	Lag Dev Cur Ret	Lag CC Returns	Equity VoRP
Broad Spot	5,74	6,63	0,08	0,41	0,28	1,48
Energy	6,33	5,68	0,05	0,53	0,36	2,12
Agriculture	4,91	6,79	0,02	0,41	0,25	0,82
Grains	5,52	7,96	0,01	0,44	0,27	0,83
Petroleum	10,26	10,19	0,11	0,72	0,54	2,88
Indust Metals	9,27	12,00	0,09	0,59	0,41	2,14
Prec. Metals	2,90	3,62	-0,12	-0,07	0,04	0,99
Panel B - HH t-stats						
Dependent Variables	Comm. Curr. VoRP	Non-CC VoRP	Lag Comm Returns	Lag Dev Cur Ret	Lag CC Returns	Equity VoRP
Broad Spot	**3,26**	**2,43**	0,58	**2,11**	**1,73**	**1,80**
Energy	**2,26**	1,34	0,38	1,61	1,40	**1,72**
Agriculture	**2,70**	**2,40**	0,24	**1,74**	1,47	1,15
Grains	**2,76**	**2,45**	0,07	**1,65**	1,33	1,07
Petroleum	**3,27**	**1,99**	0,66	**1,86**	1,63	**1,71**
Indust Metals	**4,47**	**3,83**	0,73	**2,22**	**2,01**	**2,00**
Prec. Metals	**1,83**	1,53	**-1,91**	-0,42	0,28	1,39
Panel C - Adjusted R^2						
Dependent Variables	Comm. Curr. VoRP	Non-CC VoRP	Lag Comm Returns	Lag Dev Cur Ret	Lag CC Returns	Equity VoRP
Broad Spot	11,7%	8,4%	0,7%	3,9%	3,1%	4,8%
Energy	7,0%	3,0%	0,3%	3,1%	2,7%	4,8%
Agriculture	5,1%	5,2%	0,1%	2,3%	1,5%	0,9%
Grains	4,8%	5,4%	0,0%	2,0%	1,3%	0,7%
Petroleum	14,2%	7,5%	1,2%	4,6%	4,4%	6,9%
Indust Metals	16,8%	15,1%	0,8%	4,5%	3,7%	5,5%
Prec. Metals	2,1%	1,7%	1,5%	0,1%	0,0%	1,5%

This table shows results of 42 bivariate regressions described on equation (10). There are 7 independent variables and 6 dependent variables. Each regression has just one independent variable and a constant. The dependent variable is one commodity index return: broad spot commodity index, and the sub-indexes of Energy, Agriculture, Grains, Petroleum, Industrial Metals and Precious Metals. All the independent variables are lagged. The independent variables are: commodities currencies volatility risk premium, non-commodities currencies volatility risk premium, commodity index returns (the lagged independent variable), the (lagged) developed currency returns, the (lagged) commodities currencies returns and the (lagged) equity volatility risk premium. Estimates of the constants are omitted. On panel A, each cell shows the coefficient estimates. On panel B, each cell shows t-statistics with Hansen Hodrick HAC with 21–lags. On Panel C, each cell shows the adjusted R^2. The sample period is from October 2007 to August 2014, with 1809 daily observations. VoRPs and returns are expressed on an annualized basis in percentage points. The maturity of the options is one month. The t-statistics in bold are statistically significant at 10%.

Table A.IV – Regressions with Control Variables

Dependent Variables	Comm. Curr. VoRP	Lag Comm Returns	Lag Dev Cur Ret	Lag Comm Curr Returns	Equity VoRP	Adjusted R^2
Panel A - Coefficients						
Broad Spot	5,61	-0,13	-	0,10	0,30	12,6%
Energy	4,70	-0,06	-	0,10	1,01	7,9%
Agriculture	5,71	-0,07	-	0,11	-0,61	5,8%
Grains	6,56	-0,07	-	0,12	-0,82	5,6%
Petroleum	9,28	-0,07	-	0,09	0,77	14,8%
Indust Metals	9,97	-0,15	-	0,08	0,23	18,2%
Prec. Metals	3,34	-0,16	-	-0,05	0,49	5,1%
Panel B - HH t-stats						
Broad Spot	**3,29**	-1,17	-	0,74	0,57	-
Energy	**1,97**	-0,53	-	0,45	1,15	-
Agriculture	**2,87**	-0,70	-	0,54	-1,12	-
Grains	**2,74**	-0,74	-	0,47	-1,32	-
Petroleum	**3,59**	-0,62	-	0,38	0,77	-
Indust Metals	**3,41**	**-1,91**	-	0,46	0,31	-
Prec. Metals	**1,66**	**-2,38**	-	-0,30	0,69	-
Panel C - Coefficients						
Broad Spot	5,34	-0,18	0,32	-	0,35	13,9%
Energy	4,24	-0,09	0,33	-	1,01	8,6%
Agriculture	5,46	-0,09	0,29	-	-0,62	6,5%
Grains	6,27	-0,08	0,30	-	-0,83	6,2%
Petroleum	8,75	-0,10	0,37	-	0,77	15,5%
Indust Metals	9,55	-0,19	0,36	-	0,25	19,2%
Prec. Metals	3,31	-0,16	-0,07	-	0,47	5,1%
Panel D - HH t-stats						
Broad Spot	**3,14**	-1,64	**1,91**	-	0,67	-
Energy	**1,80**	-0,79	1,26	-	1,20	-
Agriculture	**2,86**	-0,99	1,25	-	-1,10	-
Grains	**2,76**	-0,98	1,09	-	-1,27	-
Petroleum	**3,20**	-1,00	1,48	-	0,82	-
Indust Metals	**3,20**	**-2,37**	**1,79**	-	0,34	-
Prec. Metals	**1,66**	**-2,13**	-0,29	-	0,68	-

This table shows results of 14 regressions described on equation (11). There are 7 dependent variables and two sets of 5 independent variables. Each regression has four independent variables and a constant. The dependent variable is one commodity index return: broad spot commodity index, and the sub-indexes of Energy, Agriculture, Grains, Petroleum, Industrial Metals and Precious Metals. All the independent variables are lagged. The independent variables of Panel A are commodities currencies volatility risk premium, commodity index returns (the lagged independent variable), the (lagged) commodities currencies returns and the (lagged) equity volatility risk premium. Panel B are the HH t-statistics for the coefficients on Panel A. The independent variables of Panel C are commodities currencies volatility risk premium, commodity index returns (the lagged independent variable), the (lagged) developed currency returns and the (lagged) equity volatility risk premium. Panel D are the HH t-statistics for the coefficients on Panel C. Estimates of the constants are omitted. The t-statistics in bold are statistically significant at 10%. The t-statistics are Hansen-Hodrick HAC with 21–lags. The sample period is from October 2007 to August 2014, with 1809 daily observations. VRPs and returns are expressed on an annualized basis in percentage points. The maturity of the options is one month.