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Commodity-currencies or currency-commodities: Evidence from causality tests

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ABSTRACT

This paper presents a comparative analysis of the return and volatility spillovers across the commodity and currency markets for an expanded set of commodity-exporters and currencies that includes several emerging commodity-exporting nations in addition to the developed exporters that have often been the focus in the literature. Strong causal effects are observed, largely in the direction of commodities from currencies with several cases of bidirectional causality, particularly between gold and the New Zealand dollar, Brent oil and the Brazilian real, and copper and the Chilean peso. The causal effects from currencies to commodities are not only limited to return causality, but exist in the case of volatility as well, implying the presence of significant risk transmissions from currencies. We also show that causal effects from currencies to commodities have become more widespread during the period following the 2007–2008 global financial crisis. Overall, our findings imply that currency market dynamics have informative value for commodity return and volatility with significant implications for volatility forecasting and active management of commodity price fluctuations.

1. Introduction

The basic premise of currency carry trade strategies is that interest rate differentials across countries can be exploited by investing in high interest rate currencies like the Australian dollar and funding this position by borrowing a low interest rate currency like the Japanese yen. While classic interest rate parity theories suggest that the arbitrage-profitability of such a strategy should be nullified by the depreciation of the higher interest rate currency by an amount that is equal to the interest rate spread, in reality, the literature documents evidence of excess returns offered by the currencies of commodity-exporting nations, hence the term "commodity-currencies," challenging theoretical models.

Attempting to provide risk-based explanations to this puzzle, Lustig et al. (2011) document a slope factor in exchange rates that high interest rate currencies have greater exposures to and suggest that the premia offered by high interest rate currencies reflect a risk exposure with respect to global equity market volatility, in line with high excess returns observed for commodity-currencies. Recently, Powers (2015) and Ready et al. (2017) extend the risk-based explanations and argue that one source of differences in interest rates and excess currency returns is due to the composition of trade as well as their exposure to global risks driven by the technological differences in the production side of their economies. If one follows the argument that the differences in the composition of trade across nations serve as a driver of excess returns for their currencies, then a unidirectional spillover effect from commodity prices to currencies can be suggested to exist, particularly for the currencies of major commodity-exporting nations. However, the evidence in the literature is mixed and quite limited, focusing only on developed exporting nations like Canada, Australia and New Zealand without expanding the analysis to emerging markets that tend to be more significantly affected by global commodity price fluctuations.

In this study, we present a comparative analysis of the return and volatility transmissions across the commodity and currency markets via the causality-in-variance test developed by Hafner and Herwartz (2006). Specifically, we contribute to this literature by (i) expanding the set of commodity-exporters and currencies to a larger set that also includes several emerging exporting nations like Russia, Brazil, South Africa, and Chile, among others; (ii) expanding the set of commodities beyond gold and oil to also include some other major export commodities like copper and coffee; (iii) examining not only causality in returns, but also causality in variance via the causality-in-variance test by Hafner and Herwartz (2006); and (iv) exploring the economic implications of the currency-commodity interactions in a hedging setting. To that end, we provide new insight to the broader literature on commodity currencies by applying a dual-pronged approach (both causality

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in the returns and also in measuring volatility interactions) to better gauge the currency-commodity relationship and exploring possible economic implications.

Modelling volatility interactions between the commodity and currency markets is a matter of particular importance for both corporations and policy makers in their strategies to manage exchange rate fluctuations and mitigate the negative effects of cross-market (i.e. across commodity and currency markets) shocks that can hurt businesses and individuals alike. The issue is even more important for emerging nations that tend to be more vulnerable to global shocks and often lack an active derivatives market that market participants can utilize to hedge exposures to currency risks. Furthermore, given the evidence in the literature of strong commodity-currency interactions, particularly in the case of major exporting nations, the nature and direction of causal effects could be utilized to devise effective risk management strategies to mitigate price fluctuations in these markets. To that end, this study contributes to the literature on the commodity-currency nexus from multiple aspects and presents comprehensive evidence from advanced and emerging economies with significant implications for both practitioners and policy makers.

The discussion on commodity reserve currencies can in fact be traced back to the seminal papers by Hayek (1943) and Friedman (1951) who evaluate the viability of a commodity standard as a medium of exchange with the goal of maintaining stability in exchange rates. Following the liberalization of the currency market, a number of early studies have pointed to the challenges of explaining or predicting nominal exchange rates (e.g. Meese and Rogoff, 1983; Frankel and Rose, 1995; Cheung et al., 2005). More recent studies, however, document evidence of predictability in currency markets due to commodity prices (Joy 2011; Ciner et al., 2013; Reboredo, 2013; Apergis, 2014), with a particular focus on gold. The strand of the literature on commodity-currencies generally finds that commodity prices drive exchange rate fluctuations in commodity-exporting countries (Cashin et al., 2004; Chen and Rogoff, 2003), consistent with the risk-based explanations discussed earlier. On the other hand, Zhang et al. (2016) recently document evidence of bidirectional causality between commodity prices and exchange rates, with stronger causal effects in the direction of commodity price to exchange rates. These studies, however, largely focus on developed commodity-exporters like Australia, New Zealand, Canada, Norway, and in some cases Chile, in their empirical analysis and examine the causal relationships in returns without extending the analysis to risk transmissions across the currency and commodity markets.

Clearly, understanding the relationship between commodity prices and currency return dynamics is of high importance both from a policy making perspective as commodity price shocks can have significant effects on the success of monetary policies (see Ayres et al. 2014), but is also important from an investment perspective as such a relationship could be used to devise active commodity trading strategies conditional on the signals from the currency market. The policy issue is particularly critical when it comes to developing commodity-exporting nations as commodity price fluctuations can account for a significant percentage of the variation in their revenues, presenting challenges to the implementation of policies for economic growth and stability.

Looking ahead, our findings indicate strong causal effects largely in the direction of commodities from currencies with mostly insignificant commodity-to-currency effects observed. However, several cases of bidirectional causality are also observed, particularly between gold and the New Zealand dollar, Brent oil and the Brazilian real, and copper and the Chilean peso, suggesting that commodity and currency market fundamentals are informative over each other's return dynamics. The causal effects from currencies to commodities are not only limited to return causality but exist in the case of volatility as well, specifically from the Australian dollar, the New Zealand dollar and the South African rand to gold, the Chilean peso to copper and the Mexican peso to West Texas Intermediate (WTI). This suggests that significant risk transmissions from currency to commodity markets also exist.

Examining the pre- and post-global financial crisis periods, we see that the observed causal effects from currency to commodity markets are largely driven by the return and risk spillovers during the post-crisis period. The findings in general imply that currency market dynamics have informative value for commodity return and volatility, more so than the other direction; and that this is particularly the case during the period following the 2007/2008 global financial crisis. Indeed, using the crisis period as a dividing line, we observe that significant hedging gains could be obtained by taking short positions in currencies to mitigate risk exposures to commodity price fluctuations during the post-crisis period. Considering that the foreign exchange market is the largest financial market globally, with daily trading volume multiple times greater than international trade flows, the observed directional pattern in causality suggests that currency traders indeed have predictive ability over commodity market expectations with significant implications for volatility forecasting and risk management strategies.

The rest of this paper is organized as follows: Section 2 presents the data and methodology. Section 3 discusses the empirical findings from causality tests during the pre- and post-global financial crisis periods; and Section 4 concludes the paper with a discussion of policy and investment implications.

2. Data and methodology

2.1. Data

We use daily nearby futures prices for exchange rates and commodities obtained from Commodity Systems Inc. We focus on the futures prices as most of these assets are actively traded on the futures market where price discovery is argued to occur. The only exceptions for which we use spot price data instead are the Chilean peso, which started trading on the futures market in 2016 and the Colombian peso, which does not have an active futures market. The sample period ends in April of 2016 with individual starting dates for each asset, depending on when the data becomes available as listed in Table 1.

Major export commodities examined include crude oil (Brent and WTI), gold, copper, and coffee that are actively traded on the CME Group derivatives marketplace. In addition to the individual commodities, we also replicate our tests using the Goldman Sachs commodity index (GCI) in order to capture the general trend in the commodity market although this index tends to be weighted towards crude oil in its composition. Following the literature on commodity-currencies, we examine a number of advanced market currencies including the Australian dollar (AUD), the Canadian dollar (CAD), the New Zealand dollar (NZD) and the Norwegian krone (NOK), all measured relative to the U.S. dollar. In addition to these major currencies, we also include in our analysis some of the developing market currencies that have a heavy reliance on commodity exports including the Brazilian real (BRR), the Russian ruble (RUR), the Chilean peso (CHP), the Mexican peso (MEP), the South African rand (SAR) and the Colombian peso (COP).

It must be noted that in addition to the causality tests between the Goldman Sachs commodity index and currencies in our list, we also perform individualized tests by matching the export commodity with the corresponding currency. For example, we perform pairwise bidirectional tests of crude oil with the Canadian dollar, the Russian ruble and the Norwegian krone as these nations are major oil exporters, while the Australian dollar is matched with gold as it is one of the top producers of gold globally. In addition, we explore causalities across several additional pairs like coffee and the Colombian peso (major coffee exporter) or copper and the Chilean peso (one of the top copper exporting nations globally). As noted earlier, the literature on commodity-currencies largely focuses on the currencies of developed nations, while little to no evidence is documented when it comes to emerging market currencies that can be argued to bear greater risk exposures with

Table 1
Summary statistics.

	Mean	Std. Dev.	Min.	Max.	Skewness	Kurtosis
	Panel A: Pre-crisis period (– August 2007)					
Canadian dollar, CAD (Feb. 83)	0.003%	0.347%	– 1.949%	1.974%	– 0.017	2.588
Australian dollar, AUD (Nov. 86)	0.005%	0.635%	– 4.162%	4.939%	– 0.282	3.002
South African rand, SAR (May 97)	– 0.018%	1.090%	– 9.058%	11.451%	– 0.038	12.297
New Zealand dollar, NZD (May 97)	0.003%	0.747%	– 5.078%	4.349%	– 0.208	2.318
Russian Ruble, RUR (Apr. 98)	– 0.056%	2.088%	– 28.956%	53.410%	5.259	259.721
Brazilian real, BRR (Nov. 95)	– 0.024%	0.968%	– 8.824%	8.822%	– 0.510	18.072
Mexican peso, MEP (May 95)	– 0.020%	0.605%	– 6.937%	6.292%	– 0.620	15.473
Norwegian krone, NOK (Feb. 83)	0.003%	0.648%	– 6.818%	4.788%	– 0.305	4.980
Chilean peso, CHP (Nov. 90)	– 0.011%	0.468%	– 3.960%	5.304%	0.109	10.194
Colombian peso, COP (Nov. 89)	– 0.032%	0.514%	– 9.449%	5.311%	– 1.990	44.544
Brent oil (June 88)	0.033%	2.189%	– 38.564%	13.151%	– 1.353	24.259
WTI oil (Apr. 83)	0.015%	2.384%	– 40.204%	19.861%	– 1.077	20.101
Gold (Feb. 83)	0.002%	0.949%	– 12.890%	9.844%	– 0.574	14.570
Coffee (Feb. 83)	– 0.003%	2.685%	– 33.712%	36.920%	0.643	31.077
Copper (Feb. 83)	0.027%	1.590%	– 12.765%	38.634%	1.967	62.569
Goldman Commodity Index (Feb. 83)	0.015%	1.147%	– 18.465%	7.523%	– 0.719	13.799
	Panel B: Post-crisis period (August 2007 – April 2016)					
Canadian dollar (CAD)	– 0.011%	0.658%	– 3.385%	3.778%	– 0.108	2.627
Australian dollar (AUD)	– 0.006%	0.974%	– 7.556%	7.989%	– 0.371	9.195
South African rand (SAR)	– 0.035%	1.171%	– 14.839%	6.949%	– 1.261	15.577
New Zealand dollar (NZD)	– 0.006%	0.950%	– 6.450%	4.598%	– 0.405	2.995
Russian Ruble (RUR)	– 0.047%	1.061%	– 12.410%	11.880%	– 0.844	24.670
Brazilian real (BRR)	– 0.030%	1.123%	– 6.697%	8.336%	– 0.200	5.980
Mexican peso (MEP)	– 0.022%	0.813%	– 7.601%	7.148%	– 0.550	10.385
Norwegian krone (NOK)	– 0.019%	0.878%	– 4.633%	3.848%	– 0.195	1.858
Chilean peso (CHP)	– 0.014%	0.711%	– 4.638%	3.599%	– 0.421	4.114
Colombian peso (COP)	– 0.023%	0.833%	– 5.130%	6.384%	– 0.127	6.619
Brent oil	– 0.007%	2.237%	– 10.892%	12.707%	– 0.023	3.578
WTI oil	– 0.035%	2.561%	– 13.065%	21.277%	0.340	5.976
Gold	0.027%	1.297%	– 9.596%	7.732%	– 0.337	5.527
Coffee	0.007%	2.123%	– 19.714%	19.249%	– 0.025	13.495
Copper	– 0.020%	1.875%	– 8.988%	11.432%	0.228	4.520
Goldman Commodity Index	– 0.022%	1.586%	– 7.973%	7.209%	– 0.228	3.281

Note: The table presents the summary statistics for daily logarithmic returns. The starting month for each series is provided in the first column in Panel A; all series end in April 2016. The break point for the global financial crisis is August 9, 2007, which is considered the beginning of the active phase of the liquidity crisis when BNP Paribas terminated withdrawals from three hedge funds citing "a complete evaporation of liquidity".

respect to their major export commodities. To that end, our study provides comprehensive insight to the currency-commodity nexus via a comparative analysis of advanced and emerging nations.

Table 1 presents the summary statistics for daily logarithmic returns during the pre- and post-global financial crisis periods. We use August 9, 2007 as the break point for the 2007/2008 credit crunch as this date is considered to be the beginning of the active phase of the liquidity crisis when BNP Paribas terminated withdrawals from three hedge funds citing a complete evaporation of liquidity.[1] Examining the pre-financial crisis statistics in Panel A, we observe that advanced economy currencies generally outperform emerging market currencies yielding positive average returns, while all emerging market currencies lie in the negative return territory with the Russian ruble as the worst performer (-0.056%). The lowest average return observed for the ruble is paired with the greatest return volatility for this currency. Commodities, on the other hand, generally have positive average returns, with the exception of coffee, while they generally experience greater return volatility than currencies.

Examining the post-crisis statistics in Panel B, however, we see a clear shift in the return dynamics where all assets experience negative average returns, with the exception of gold, the traditional safe haven, and coffee. The reversal in the sign of mean returns is accompanied with greater return volatility during the post-crisis period, suggesting the presence of a possible regime shift due to this global shock. These initial observations suggest that performing a pre- and post-crisis analysis could provide valuable insight about the causal interactions across these assets.

2.2. Model specification

The primary method of examining spillover effects across paired factors involves examining the direction of transmissions via causality analysis. In simple terms, variable Y is said to cause variable X in a given moment if Y has predictive power for forecasting the moment for X. Although the causality in mean test of Granger (1980) has been extensively utilized in the literature, subsequent studies including Cheung and Ng (1996) and Hong (2001) utilize GARCH-type models within causality tests in order to capture causalities both in mean and in variance. More recently, Hafner and Herwartz (2006) propose a Lagrange Multiplier (LM) based test to capture causality in variance and show, via Monte Carlo simulations, that this approach addresses some of the shortcomings associated with the models proposed by Cheung and Ng (1996) and Hong (2001).

In our empirical analysis, we examine the presence and direction of volatility transmissions via the causality-in-variance test of Hafner and Herwartz (2006). The general HH test follows two steps. In the first step, a univariate GARCH(1,1) model is estimated and the conditional variance as a function of past values of both squared residuals and variances is obtained. Let $R_{fx,t}$ and $R_{c,t}$ be the return for a given currency (fx) and commodity (c) on day t, respectively. The GARCH(1,1) model to explore causality from the commodity to the currency return series is specified as

$$R_{fx,t} = \varphi_0 + \sum_{i=1}^{q} \varphi_i R_{fx,t-i} + \sum_{j=1}^{p} \lambda_i R_{c,t-j} + \varepsilon_{fx,t} \tag{1a}$$

[1] Larry Elliott, economics editor of The Guardian (August 5, 2012). *"Three myths that sustain the economic crisis"*.

$$R_{c,t} = \varphi_0 + \sum_{i=1}^{m} \varphi_i R_{c,t-i} + \quad \varepsilon_{c,t} \tag{1b}$$

$$h_{k,t} = \omega_k + \alpha_k \varepsilon^2_{k,t-1} + \beta_k h_{k,t-1} \;\; (k = fx,\, c) \tag{1c}$$

where $h_{k,t}$ ($k = fx,c$) is the conditional variance. We include the lagged return term in the mean equation for each currency (Eq. 1a) and commodity (Eq. 1b) in order to control for potential autocorrelation in return series. Having estimated the residuals and the volatility process for each time series, the next step consists of testing the null hypothesis of non-causality in variance for the currency (fx) and commodity (c) returns specified as

$$H_0\text{: } \mathrm{Var}(\varepsilon_{fx,t}\,|\mathrm{I}_{t-1}) = Var(\varepsilon_{fx,t}\,|\mathrm{J}_{t-1})$$

where $I_t = \{R_{fx,t-j};\, j \geq 0\}$ and $J_t = \{R_{fx,t-j},\, R_{c,t-j};\, j \geq 0\}$, representing the information set at time t-1 based on past exchange rates (I_t) and based on both commodity returns and exchange rates (J_t), respectively.

Following Hafner and Herwartz (2006), the null hypothesis of non-causality in variance can be tested by $\mathrm{H}_{0:}\ \pi = 0$ in $\varepsilon_{fx,t} = \xi_{fx,t}\sqrt{\mathrm{h}_{\mathrm{fx},t} g_t}$, where $g_t = 1 + z'_{c,t}\pi$ and $z_{c,t} = (\varepsilon^2_{c,t-1},\, h_{c,t-1})'$. In this specification, $\xi_{fx,t}$ and $h_{fx,t}$ denote the standardized residuals and the conditional variance for currency return series, respectively. Similarly, $\varepsilon^2_{c,t-1}$ and $h_{c,t-1}$ denote the squared disturbance term and the conditional variance for commodity return series. The null hypothesis of non-causality in variance (H_0: $\pi = 0$) against the alternative hypothesis (H_1: π ‡ 0) implies the lack of volatility spillover effects from commodity to foreign exchange markets, suggesting non-causality in variance. In simple terms, the null hypothesis of $\pi = 0$ implies that the information contained in commodity returns has no predictive power for forecasting the variance of currency returns. The null hypothesis is then tested using the LM statistic (λ_{LM}), which Hafner and Herwartz (2006) show to follow an asymptotic Chi-square distribution with two degrees of freedom, obtained as follows:

i. Estimate the univariate GARCH model for return series fx and c for $\varepsilon_{fx,t}$ and $\varepsilon_{c,t}$ and obtain the standardized residuals ($\xi_{fx,t}$), the volatility process ($h_{c,t}$) entering $z_{c,t}$, and the derivatives ($x_{fx,t}$) where $x_{fx,t} = h^{-1}_{fx,t}(\frac{\partial h_{fx,t}}{\partial \theta_{fx}})$, $\theta_{fx} = (\omega_{fx},\, \alpha_{fx},\, \beta_{fx})'$.

ii. Regress $\xi^2_{fx,t} - 1$ on $(x_{fx,t})'$ and the misspecification indicators in $(z_{c,t})'$.

iii. λ_{LM} = (number of observations) $\times R^2$ where R^2 is the goodness of fit measure for the regression in (ii).

Note that the procedure is performed to detect causality in both directions between the commodities and currencies although the equations present the case for commodity-to-currency causality as a general representation. In a recent study, Bouri and Demirer (2016) use this approach to examine volatility transmissions between the oil and a number of emerging oil importing and exporting nations and show significant volatility spillovers from oil prices to stock market returns for emerging importers during the post-global financial crisis period. However, the use of the HH framework to examine causalities across the currency and commodity markets in the context of commodity-currencies is novel and supplements the standard causality-in-means, i.e. Granger Causality, approach used more commonly in the literature.

3. Empirical findings

3.1. Causality test results

Table 2 reports the results from causality tests for the null hypothesis of no causality for the whole sample period, represented by the symbol "‡›". Panels A and B report the tests for causality in mean and variance (HH test results), respectively. As mentioned earlier, we examine each asset individually and assess whether a directional relationship can be found in one or both. In addition to the tests of each

Table 2
Causality tests.

Panel A: Causality-in-mean							
Commodity-to-Currency		*Currency-to-Commodity*		*Commodity-to-Currency*		*Currency-to-Commodity*	
Null hypothesis	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*
GCI ‡› AUD	0.482	AUD ‡› GCI	10.020***	Gold ‡› AUD	4.041	AUD ‡› Gold	132.29***
GCI ‡› CAD	1.080	CAD ‡› GCI	15.730***	WTI ‡› CAD	0.665	CAD ‡› WTI	12.456***
GCI ‡› NZD	3.568	NZD ‡› GCI	5.721*	Gold ‡› NZD	7.295**	NZD ‡› Gold	58.550***
GCI ‡› NOK	5.305*	NOK ‡› GCI	3.723	Brent ‡› NOK	0.039	NOK ‡› Brent	255.940***
GCI ‡› RUR	3.023	RUR ‡› GCI	0.312	Brent ‡› RUR	1.674	RUR ‡› Brent	3.768
GCI ‡› SAR	0.773	SAR ‡› GCI	12.626***	Gold ‡› SAR	1.384	SAR ‡› Gold	54.352***
GCI ‡› BRR	8.607**	BRR ‡› GCI	23.093***	Brent ‡› BRR	6.809**	BRR ‡› Brent	70.35***
GCI ‡› CHP	3.726	CHP ‡› GCI	2.125	Copper ‡› CHP	11.645***	CHP ‡› Copper	9.621***
GCI ‡› COP	0.616	COP ‡› GCI	4.278	Coffee ‡› COP	1.274	COP ‡› Coffee	5.162*
GCI ‡› MEP	0.125	MEP ‡› GCI	17.413***	WTI ‡› MEP	0.050	MEP ‡› WTI	11.102***
Panel B: Causality-in-variance							
Commodity-to-Currency		*Currency-to-Commodity*		*Commodity-to-Currency*		*Currency-to-Commodity*	
Null hypothesis	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*
GCI ‡› AUD	0.487	AUD ‡› GCI	0.359	Gold ‡› AUD	0.868	AUD ‡› Gold	90.847***
GCI ‡› CAD	6.495**	CAD ‡› GCI	2.365	WTI ‡› CAD	0.943	CAD ‡› WTI	0.836
GCI ‡› NZD	0.930	NZD ‡› GCI	2.586	Gold ‡› NZD	3.077	NZD ‡› Gold	40.303***
GCI ‡› NOK	36.667***	NOK ‡› GCI	6.456**	Brent ‡› NOK	2.528	NOK ‡› Brent	0.954
GCI ‡› RUR	6.801**	RUR ‡› GCI	7.129**	Brent ‡› RUR	0.362	RUR ‡› Brent	0.174
GCI ‡› SAR	0.841	SAR ‡› GCI	4.097	Gold ‡› SAR	2.104	SAR ‡› Gold	66.762***
GCI ‡› BRR	19.040***	BRR ‡› GCI	10.713***	Brent ‡› BRR	3.502	BRR ‡› Brent	0.363
GCI ‡› CHP	7.385**	CHP ‡› GCI	9.070**	Copper ‡› CHP	10.784***	CHP ‡› Copper	8.632**
GCI ‡› COP	0.093	COP ‡› GCI	9.807***	Coffee ‡› COP	3.934	COP ‡› Coffee	2.619
GCI ‡› MEP	0.993	MEP ‡› GCI	15.099***	WTI ‡› MEP	0.961	MEP ‡› WTI	10.808***

Note: The table reports the χ^2 statistics for the null hypothesis of no causality for the whole sample period, represented by the symbol "‡›". Panels A and B report the tests for causality in mean and variance, respectively. The commodity market variables include the Goldman Commodity Index (GCI), Gold, Brent oil, WTI oil, Copper and Coffee. The currencies include Australian dollar (AUD), Brazilian real (BRR), Canadian dollar (CAD), Chilean peso (CHP), (inverted) Colombian peso (COP), Mexican peso (MEP), New Zealand dollar (NZD), Norwegian krone (NOK), Russian ruble (RUR), and South African rand (SAR). ***,**, * indicate a rejection of the null hypothesis at the 1%, 5% and 10% significance levels, respectively.

currency against the Goldman commodity index (GCI), we also test individual pairs by matching each currency with the corresponding export commodity (e.g. Russian ruble and crude oil or Chilean peso and copper). Our findings for the whole period indicate strong causal effects largely in the direction of commodities from currencies with mostly insignificant commodity-to-currency effects implied by insignificant test statistics in both panels. However, consistent with the recent finding by Zhang et al. (2016), we observe several cases of bidirectional causality, particularly between gold and the New Zealand dollar, Brent oil and the Brazilian real and copper and thr Chilean peso, suggesting that commodity and currency market fundamentals are informative over each other's return dynamics.

Comparing the findings in Panels A and B, we see that the causal effects from currencies to commodities are not only limited to return causality but also exist in the case of volatility as well, specifically from the Australian dollar, New Zealand dollar and South African rand to gold, the Chilean peso to copper and the Mexican peso to WTI. The causality-in-variance tests reported in Panel B show that significant risk transmissions from currency to commodity markets also exist. This finding has important implications for volatility forecasting in commodity markets and suggests that supplementing commodity volatility models with currency market variables may improve the performance of volatility forecasts for these commodities, an issue of high importance for policy makers in emerging nations whose economies are highly sensitive to commodity imports/exports. In fact, Liu et al. (2017) recently show that using currency returns in bivariate multifractal models yields superior volatility forecasts compared to univariate multifractal and GARCH based alternatives for stock market forecasting. To that end, an immediate implication of our findings for future research is to explore whether commodity volatility forecasts can be improved by supplementing multifractal models with currency returns as an additional predictor.

3.2. The effect of the global financial crisis

Tables 3 and 4 present the causality test results for the pre- and post-global financial crisis subsamples, respectively. As mentioned earlier, we use August 9, 2007 as the initial point for the 2007/2008 credit crunch as this date is considered to be the beginning of the active phase of the liquidity crisis. Comparing the test results for these two periods, we observe that the strong causal effects from currencies to commodities are largely driven by the return and risk spillovers during the post-crisis period. Commodity-to-currency effects are mostly non-existent during the post-crisis period with a few exceptions, particularly in the case of return causality reported in Panel A. The same pattern is also observed in Panel B with more widespread risk transmissions from currency to commodity markets during the post-crisis period. We also see that the cases of bidirectional causality largely disappear during this period, indicating the return and risk transmissions primarily emanate from the currency market. The observed currency-to-commodity effects suggest that the currency market possesses predictive power over price dynamics in the commodity market, more so than the other direction and that this is particularly the case during post-global crisis period. This result is in fact not unexpected given that the foreign exchange market is the largest financial market globally, with daily trading volume multiple times greater than international trade flows. To that end, the observed directional pattern in causality suggests that currency traders indeed have predictive ability over commodity market fundamentals.

3.3. Economic implications

From an investment point of view, the finding that currency returns have informative value regarding commodity market dynamics suggests that commodity investors can utilize information on currency rates in

Table 3
Causality tests for the pre-financial crisis period.

Panel A: Causality-in-mean							
Commodity-to-Currency		*Currency-to-Commodity*		*Commodity-to-Currency*		*Currency-to-Commodity*	
Null hypothesis	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*
GCI ‡› AUD	1.274	AUD ‡› GCI	0.115	Gold ‡› AUD	6.245**	AUD ‡› Gold	59.715***
GCI ‡› CAD	7.056**	CAD ‡› GCI	0.274	WTI ‡› CAD	5.705*	CAD ‡› WTI	0.148
GCI ‡› NZD	4.142	NZD ‡› GCI	3.685	Gold ‡› NZD	5.132*	NZD ‡› Gold	19.385***
GCI ‡› NOK	8.388**	NOK ‡› GCI	1.051	Brent ‡› NOK	0.585	NOK ‡› Brent	1.874
GCI ‡› RUR	1.688	RUR ‡› GCI	0.512	Brent ‡› RUR	1.485	RUR ‡› Brent	1.734
GCI ‡› SAR	1.376	SAR ‡› GCI	0.085	Gold ‡› SAR	9.057**	SAR ‡› Gold	41.285***
GCI ‡› BRR	3.495	BRR ‡› GCI	3.532	Brent ‡› BRR	3.713	BRR ‡› Brent	4.590
GCI ‡› CHP	10.300***	CHP ‡› GCI	6.195**	Copper ‡› CHP	8.597**	CHP ‡› Copper	2.821
GCI ‡› COP	0.320	COP ‡› GCI	2.625	Coffee ‡› COP	0.730	COP ‡› Coffee	0.120
GCI ‡› MEP	0.022	MEP ‡› GCI	6.147**	WTI ‡› MEP	0.056	MEP ‡› WTI	5.044*
Panel B: Causality-in-variance							
Commodity-to-Currency		*Currency-to-Commodity*		*Commodity-to-Currency*		*Currency-to-Commodity*	
Null hypothesis	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*
GCI ‡› AUD	0.061	AUD ‡› GCI	0.433	Gold ‡› AUD	5.044*	AUD ‡› Gold	70.354***
GCI ‡› CAD	5.154*	CAD ‡› GCI	1.813	WTI ‡› CAD	0.124	CAD ‡› WTI	0.260
GCI ‡› NZD	2.497	NZD ‡› GCI	3.361	Gold ‡› NZD	5.289*	NZD ‡› Gold	26.188***
GCI ‡› NOK	16.610***	NOK ‡› GCI	4.705*	Brent ‡› NOK	1.521	NOK ‡› Brent	1.561
GCI ‡› RUR	4.551	RUR ‡› GCI	5.054*	Brent ‡› RUR	0.213	RUR ‡› Brent	0.440
GCI ‡› SAR	2.704	SAR ‡› GCI	0.148	Gold ‡› SAR	4.142	SAR ‡› Gold	38.816***
GCI ‡› BRR	6.587**	BRR ‡› GCI	5.078*	Brent ‡› BRR	0.966	BRR ‡› Brent	0.676
GCI ‡› CHP	10.452***	CHP ‡› GCI	11.103***	Copper ‡› CHP	14.903***	CHP ‡› Copper	4.379
GCI ‡› COP	0.793	COP ‡› GCI	10.351***	Coffee ‡› COP	4.000	COP ‡› Coffee	1.201
GCI ‡› MEP	3.298	MEP ‡› GCI	12.801***	WTI ‡› MEP	1.948	MEP ‡› WTI	11.225***

Note: The table reports the χ^2 statistics for the null hypothesis of no causality for the pre-financial crisis period, represented by the symbol "‡›". We use August 9, 2007 as the break point for the 2007/2008 credit crunch as this date is considered to be the beginning of the active phase of the liquidity crisis. Panel A and B report the tests for causality in mean and variance, respectively. The commodity market variables include the Goldman Commodity Index (GCI), Gold, Brent oil, WTI oil, Copper and Coffee. The currencies include Australian dollar (AUD), Brazilian real (BRR), Canadian dollar (CAD), Chilean peso (CHP), (inverted) Colombian peso (COP), Mexican peso (MEP), New Zealand dollar (NZD), Norwegian krone (NOK), Russian ruble (RUR), and South African rand (SAR). ***,**, * indicate a rejection of the null hypothesis at the 1%, 5% and 10% significance levels, respectively.

Table 4
Causality tests for the post-financial crisis period.

Panel A: Causality-in-mean							
Commodity-to-Currency		*Currency-to-Commodity*		*Commodity-to-Currency*		*Currency-to-Commodity*	
Null hypothesis	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*
GCI ‡› AUD	1.988	AUD ‡› GCI	7.764**	Gold ‡› AUD	1.976	AUD ‡› Gold	55.909 * **
GCI ‡› CAD	0.527	CAD ‡› GCI	10.879***	WTI ‡› CAD	0.612	CAD ‡› WTI	7.114 * *
GCI ‡› NZD	0.603	NZD ‡› GCI	3.549	Gold ‡› NZD	3.640	NZD ‡› Gold	35.456 * **
GCI ‡› NOK	0.934	NOK ‡› GCI	6.265**	Brent ‡› NOK	0.580	NOK ‡› Brent	2.256
GCI ‡› RUR	6.026**	RUR ‡› GCI	0.494	Brent ‡› RUR	3.643	RUR ‡› Brent	2.726
GCI ‡› SAR	1.671	SAR ‡› GCI	18.522***	Gold ‡› SAR	1.677	SAR ‡› Gold	36.218 * **
GCI ‡› BRR	4.821*	BRR ‡› GCI	19.402***	Brent ‡› BRR	3.314	BRR ‡› Brent	12.712 * **
GCI ‡› CHP	3.914	CHP ‡› GCI	5.920*	Copper ‡› CHP	0.621	CHP ‡› Copper	45.148 * **
GCI ‡› COP	0.304	COP ‡› GCI	4.930*	Coffee ‡› COP	1.965	COP ‡› Coffee	4.005
GCI ‡› MEP	1.745	MEP ‡› GCI	22.144***	WTI ‡› MEP	1.605	MEP ‡› WTI	19.760 * **
Panel B: Causality-in-variance							
Commodity-to-Currency		*Currency-to-Commodity*		*Commodity-to-Currency*		*Currency-to-Commodity*	
Null hypothesis	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*	*Null hypothesis*	*χ^2 statistic*
GCI ‡› AUD	0.304	AUD ‡› GCI	13.235***	Gold ‡› AUD	3.100	AUD ‡› Gold	55.909**
GCI ‡› CAD	0.755	CAD ‡› GCI	8.526**	WTI ‡› CAD	0.540	CAD ‡› WTI	2.177
GCI ‡› NZD	3.552	NZD ‡› GCI	1.537	Gold ‡› NZD	4.067	NZD ‡› Gold	38.035***
GCI ‡› NOK	39.478 * **	NOK ‡› GCI	4.937**	Brent ‡› NOK	1.681	NOK ‡› Brent	0.597
GCI ‡› RUR	28.892 * **	RUR ‡› GCI	1.048	Brent ‡› RUR	2.143	RUR ‡› Brent	0.447
GCI ‡› SAR	3.270	SAR ‡› GCI	24.588***	Gold ‡› SAR	3.821	SAR ‡› Gold	39.216***
GCI ‡› BRR	32.364 * **	BRR ‡› GCI	19.364***	Brent ‡› BRR	3.030	BRR ‡› Brent	0.756
GCI ‡› CHP	5.771 *	CHP ‡› GCI	23.219***	Copper ‡› CHP	0.970	CHP ‡› Copper	11.500***
GCI ‡› COP	1.518	COP ‡› GCI	8.670**	Coffee ‡› COP	2.319	COP ‡› Coffee	11.008***
GCI ‡› MEP	4.162	MEP ‡› GCI	18.224***	WTI ‡› MEP	5.387 *	MEP ‡› WTI	11.880***

Note: The table reports the χ^2 statistics for the null hypothesis of no causality for the post-financial crisis period, represented by the symbol "‡›". We use August 9, 2007 as the break point for the 2007/2008 credit crunch as this date is considered to be the beginning of the active phase of the liquidity crisis. Panel A and B report the tests for causality in mean and variance, respectively. The commodity market variables include the Goldman Commodity Index (GCI), Gold, Brent oil, WTI oil, Copper and Coffee. The currencies include Australian dollar (AUD), Brazilian real (BRR), Canadian dollar (CAD), Chilean peso (CHP), (inverted) Colombian peso (COP), Mexican peso (MEP), New Zealand dollar (NZD), Norwegian krone (NOK), Russian ruble (RUR), and South African rand (SAR). ***,**, * indicate a rejection of the null hypothesis at the 1%, 5% and 10% significance levels, respectively.

their active investment strategies in order to time their investments in and out of commodities. This is especially important for commodity funds that have experienced a surge of investments thanks to the greater participation of financial investors in commodity trading during the first decade of 2000 – a phenomenon termed as "commodity financialization" in the literature (see Demirer et al., 2015 for a review). Therefore, given the predictive power of currency price dynamics over commodity returns and volatility, one can devise market timing strategies in which the investor switches between indexing and commodity investments conditional on the state of the currency market. Finally, risk managers can utilize information from the currency market in order to devise more effective hedges for their firms' costs and revenue streams, possibly use measures of currency volatility in selective hedging strategies, in which firms determine the size and timing of hedges based on commodity market fundamentals (see Adam et al., 2017).

In order to explore the economic impact of the findings, we examine the hedging implications of the observed currency effect on commodity return dynamics. Given that causal effects are observed mostly in the direction of commodities from currencies, we examine whether currencies can help mitigate volatility risks in the corresponding commodities by taking offsetting positions across the commodity and currency. Following our earlier notation that $R_{fx,t}$ and $R_{c,t}$ denote the return for a given currency (*fx*) and commodity (*c*) on day *t*, respectively, we form a hedge portfolio (*hp*) with the portfolio's return formulated as $R_{hp,t} = R_{c,t} - hR_{fx,t}$ where *h* is the hedge ratio. The rationale here is if the currency market serves as the driver of volatility in the export commodity for a given country, then investors can take an offsetting position in the currency in such a way that commodity price fluctuation is mitigated as much as possible. Of course, one might ask why one would not consider using the futures contract for the commodity to achieve this goal. However, given that the currency market is the largest financial market globally with uninterrupted liquidity across the different time zones, and that some commodities may not even have an active futures market present, using currencies as hedging instruments may help reduce transaction costs and thus lead to more effective hedges.

Having defined the hedge portfolio as a combination of a given currency and commodity pair examined in our empirical tests, the optimal hedge position (h_t^*) for each pair is then estimated as the minimum-variance hedge ratio formulated as $h_t^* = \rho_{if,t}\sigma_{i,t}/\sigma_{f,t}$ where $\rho_{if,t}$ and $\sigma_{i,t}$ are the commodity-stock market correlation and standard deviations for month *t*, respectively. In order to make the analysis more realistic, consistent with our earlier analysis, we break the sample into two sub-periods using August 9, 2007 as the break point. We then use the first sub-period to estimate the optimal hedge ratio as described earlier. Next, assuming the investor takes this hedge position in the currency, we then estimate the return volatility of the hedge portfolio in the second sub-sample. Finally, we compute the out-of-sample hedge performance as the percent reduction in the return variance compared to an un-hedged position, i.e. the variance of returns for the commodity.

Table 5 reports the estimated optimal hedge ratios and out-of-sample hedging performances for each commodity, currency pair. As noted earlier, the optimal hedge ratio denotes the short position in the corresponding currency that minimizes the return variance for the hedge portfolio. The findings in Table 5 suggest that significant hedging gains can be obtained by taking short positions in currencies to mitigate risk exposures to commodity price fluctuations. Notable hedging gains, i.e. reduction in return volatility, are observed by utilizing particularly the Canadian dollar, Norwegian krone and Chilean peso to offset price fluctuations in WTI, Brent and Copper, respectively, with the commodity price volatility reduced as much as 12.4% reduction. On the other hand, we observe that the emerging currencies including Russian rouble, South African rand and Colombian peso are not very effective to

Table 5
Hedging implications.

Asset pair	*Optimal hedge ratio*	*Out-of-sample hedging performance*
Gold, AUD	0.414	1.795%
WTI, CAD	0.630	12.396%
Gold, NZD	0.340	3.130%
Brent, NOK	0.353	10.209%
Brent, RUR	0.007	0.244%
Gold, SAR	0.145	0.433%
Brent, BRR	0.028	0.944%
Copper, CHP	0.467	7.862%
Coffee, COP	0.061	0.556%
WTI, MEP	0.319	5.510%

Note: The table reports the estimated optimal hedge ratios and out-of-sample hedging performances for each (commodity, currency) pair based on the minimum-variance hedge ration estimation described in Section 3.3. The optimal hedge ratio denotes the short position in the corresponding currency that minimizes the return variance for the hedge portfolio. The hedging performance denotes the percent reduction in the return variance compared to an unhedged position, i.e. the variance of returns for the commodity. Hedge ratios are computed using data until August 9, 2007 and the out-of-sample hedging performance is calculated using the sub-period following that date.

hedge corresponding commodity price fluctuations.

Nevertheless, given that the second sub-period corresponds to the post-crisis period during which the commodity market suffered significant losses and rise in volatility, the findings offer fresh insight to how the currency effect on commodity return dynamics could be utilized for hedging purposes. Particularly, comparing the commodity return volatility estimates in Panels A and B in Table 1, the hedging performance values reported in Table 5 suggest that currencies could be effective hedging tools for commodities with the potential to lower commodity return volatility to levels lower than pre-crisis values. To that end, it would be interesting to explore in future research whether these so-called commodity-currencies can be utilized in active hedging strategies in order to mitigate price fluctuations in commodities, depending on the risk exposure of the country to these fluctuations (based on export/import characteristics of the economy).

4. Conclusion

Classic interest rate parity models have often failed to explain the return patterns observed for high interest rate currencies and currencies of major commodity exporting nations. Risk based theories relate the return premia on the so-called commodity-currencies to the differences in the composition of trade across countries as well as their exposure to global risks. Consequently, a growing strand of the literature has shown that commodity prices drive exchange rate fluctuations in commodity-exporting countries (Cashin et al., 2004; Chen and Rogoff, 2003), while Zhang et al. (2016) recently document bidirectional causality between commodity prices and exchange rates. This study contributes to this discussion by presenting a comparative analysis of return and volatility transmissions across the commodity and currency markets for an expanded set of commodity-exporters and currencies that includes several emerging commodity-exporting nations like Russia, Brazil, South Africa and Chile in addition to the developed exporters like Canada, Australia and Norway that have often been the focus in this strand of the literature. Furthermore, we examine not only causality in returns, but also the volatility interactions via the causality-in-variance test by Hafner and Herwartz (2006).

We document strong causal effects largely in the direction of commodities from currencies with mostly insignificant commodity-to-currency effects with a few exceptions. However, we observe several cases of bidirectional causality, particularly between gold and the New Zealand dollar, Brent oil and the Brazilian real and copper and the Chilean peso, suggesting that commodity and currency market fundamentals are informative over each other's return dynamics. The causal effects from currencies to commodities are not only limited to return causality, but exist in the case of volatility as well, specifically from the Australian dollar, New Zealand dollar and South African rand to gold, the Chilean peso to copper and the Mexican peso to WTI, suggesting the presence of significant risk transmissions from currency to commodity markets.

The findings in general imply that currency market dynamics have informative value for commodity return and volatility, more so than the other direction; and this is particularly the case during the period following the 2007/2008 global financial crisis. Indeed, using the crisis period as a breaking point, we observe that significant hedging gains could be obtained by taking short positions in currencies to mitigate risk exposures to commodity price fluctuations during the post-crisis period. Considering that the foreign exchange market is the largest financial market globally, with daily trading volume multiple times greater than international trade flows, the observed directional pattern in causality suggests that currency traders indeed have predictive ability over commodity market expectations with significant implications for volatility forecasting and risk management strategies.

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