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INTEREST RATES AND THE VOLATILITY AND CORRELATION OF COMMODITY PRICES

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We propose a novel explanation for the observed increase in the correlation of commodity prices over the past decade. In contrast to theories that rely on the increased influence of financial speculators, we examine the effect of interest rates on the volatility and correlation of commodity prices via a panel GARCH model. In theory, lower interest rates decrease the volatility of prices, as lower inventory costs promote the smoothing of transient shocks, and increase price correlation if common shocks are more persistent than idiosyncratic shocks. Empirically, we find that price volatility attributable to transitory shocks declines with interest rates, whereas particularly for metals prices, price correlation increases as interest rates decline.

Keywords: Commodity Storage, Panel GARCH, Dynamic Factor Model

1. INTRODUCTION

The period from 2003 to 2012 was marked by rising prices for many commodities including petroleum, metals, and agricultural goods. A representative index for primary commodity prices (the Dow Jones-UBS commodity index) increased almost 300% over the ten years from 2003 to 2012 (Figure 1). At the same time, both the volatility of commodity prices and the correlation of price changes across commodities increased. The increase in volatility can been seen in Figure 2, which depicts a scatter plot of the standard deviation of price changes over the 1992–2002 (the x-axis) compared with the standard deviation over the 2003–2012 period (the y-axis) for the 16 commodities considered in this paper.[1] Volatility increased for all but one commodity (live hogs) over the period. Likewise, Figure 3 shows that the majority (80%) of pairwise correlations of log price changes also increased.

In assessing the rise in commodity prices, low interest rates are frequently listed as a potential causal factor along with a slew of other possibilities, including changing global demand patterns, particularly strong growth in emerging market

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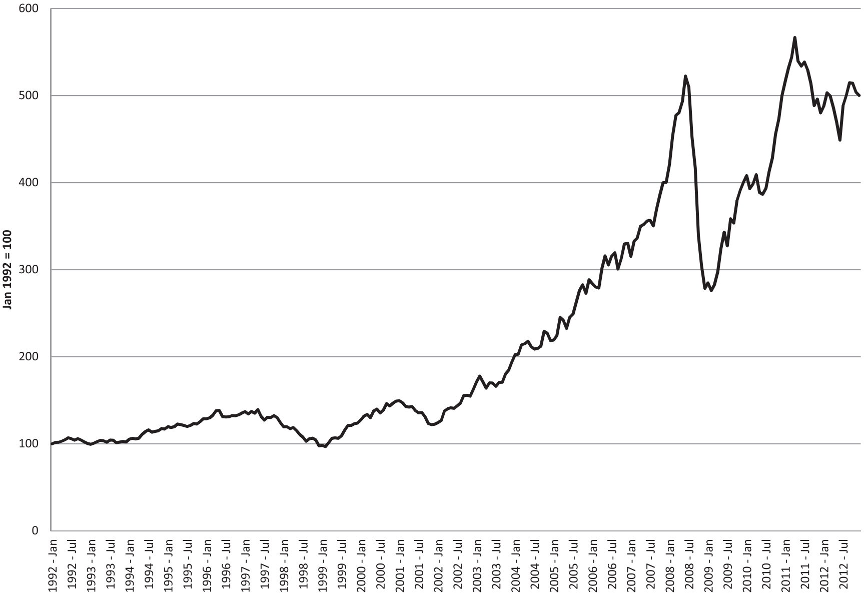

FIGURE 1. Dow Jones UBS spot commodity price index.

economies, supply disruptions, movements in the value of the dollar, and the increasing size and changing investor composition of commodity futures markets. The theory linking low interest rates to higher commodity prices is well developed. As outlined in Frankel (2008), all else equal, a decline in the interest rate is a decline in the opportunity cost of holding commodity inventories and as such should boost prices by increasing demand for inventories.[2] Frankel also theorizes that lower interest rates discourage commodity extraction by reducing the value of monetizing commodity resources on the part of producers, providing a further upward impetus to prices.[3]

Less examined has been how interest rates influence the volatility of commodity prices. In a standard storable commodity pricing model, as in Deaton and Laroque (1992, 1996), the level of the interest rate has clear implications for price volatility.[4] In the model, lower interest rates dampen the volatility of prices in response to transient shocks to commodity supply and demand by decreasing holding costs and encouraging the use of inventories to smooth prices. In contrast, low interest rates have no effect on the volatility of prices originating from persistent shocks, as long-lasting shocks imply that inventory smoothing is not profitable.[5]

Theory suggests that low interest rates are not behind the observed increase in commodity price volatility. Rather, the increase in price volatility is likely attributable to changes in the underlying shock processes. Even though the shock processes may have changed, the theory is still testable. By decomposing commodity price movements into transitory and persistent components, we can examine

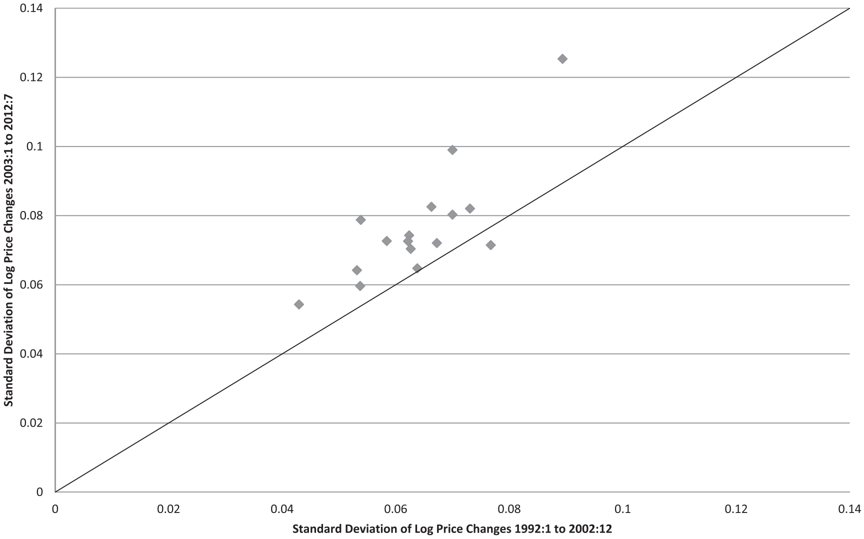

FIGURE 2. Change in commodity price volatility. Front month contracts. Average conditional standard deviation from panel GARCH(1,1) model for commodities listed in the appendix.

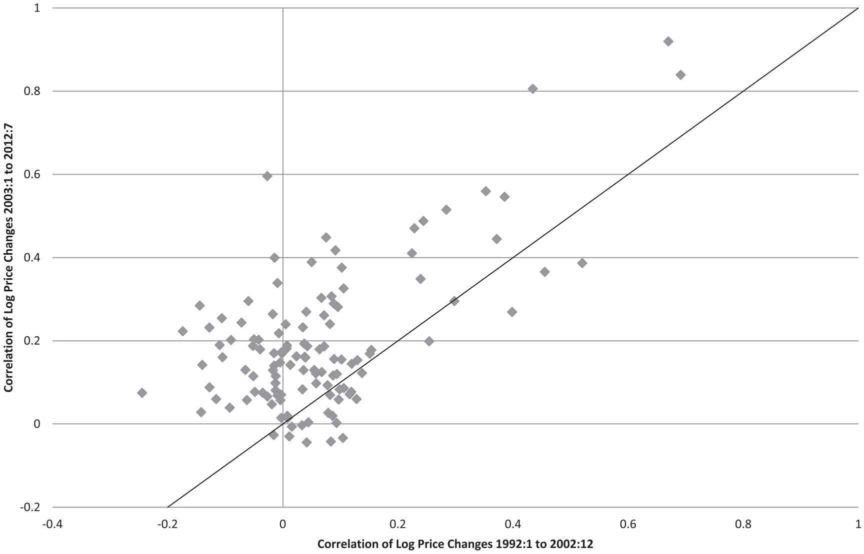

FIGURE 3. Change in pairwise correlation of commodity prices. Front month contracts. Average conditional correlation from panel GARCH(1,1) model for commodities listed in the appendix.

whether the volatility of prices attributable to transitory shocks indeed declines when interest rates are low.

Gruber and Vigfusson (2012) developed a two commodity extension of the Deaton and Laroque model to examine the effect of interest rates on the correlation of commodity prices. Conditional on the structure of the underlying shocks, a decline in the interest rate might be expected to increase the correlation of prices. In particular, if idiosyncratic shocks (such as a mine strike or crop failure) are more transitory than shocks common to all commodity prices (such as growing emerging market demand), then lower interest rates could increase commodity price correlation. Low interest rates should promote inventory smoothing in response to transitory shocks, reducing idiosyncratic volatility, while leaving the price response to persistent shocks unaffected. Therefore, for each particular commodity, lower interest rates decrease the proportion of variance stemming from idiosyncratic transient shocks and increase the proportion of variance due to common persistent shocks, thus increasing the measured correlation of prices. Importantly, this increase in correlation can occur without any change in the underlying shock processes affecting commodity markets, i.e., with no change in the relative size or persistence of idiosyncratic versus common shocks.

That low interest rates might promote commodity price correlation via lower inventory costs contrasts with other popular explanations for the observed increase in correlation. In particular, Büyükşahin and Robe (2014) and Tang and Xiong (2012) point to the increase in correlation as being evidence that the growing financialization of commodity markets has increased the importance of financial market factors in the determination of prices. Alternatively, Fattouh et al. (2012) attribute the correlation increase to greater preponderance of common fundamental shocks.

In this paper, we first examine the effect of interest rates on the volatility of commodity prices. In the spirit of Schwartz and Smith (2000), we identify persistent shocks as movements in the year-ahead futures price and temporary shocks as movements in the time spread of the futures curve, which is the price difference between the front-month contract and the year-ahead futures contract, while leaving the year-ahead (long-term) price unchanged. Using a GARCH model, we then show that the volatility due to transitory shocks (as identified by movements in the time spread) decreases significantly with the interest rate, particularly for highly storable commodities such as metals and energy products. In contrast, the volatility due to persistent shocks is unaffected by changes in the interest rate.

Looking at the correlation of prices, we first use a dynamic factor model to show that common price shocks are indeed more persistent than idiosyncratic shocks. As such, we test the hypothesis that lower interest rates (and therefore lower inventory costs) allow for increased smoothing of idiosyncratic shocks, leading to an increase in measured price correlation. Estimating a panel GARCH model, we find evidence that a decrease in the interest rate has a significant positive effect on price correlation, particularly among metals prices.

TABLE 1. Commodity price volatility standard deviation of log changes

	1	2	3	4	5	6	7	8	9
	Front month price (S_t)			Year ahead futures price (F_t)			Time spread (F_t/S_t)		
	1992:1 to 2002:12	2003:1 to 2012:7	Ratio	1992:1 to 2002:12	2003:1 to 2012:7	Ratio	1992:1 to 2002:12	2003:1 to 2012:7	Ratio
Energy									
Crude oil	0.073	0.082	1.123	0.037	0.068	1.843	0.047	0.041	0.886
Heating oil	0.070	0.080	1.147	0.036	0.063	1.761	0.045	0.039	0.851
Natural gas	0.089	0.125	1.402	0.057	0.061	1.077	0.089	0.089	1.000
Raw materials									
Cotton	0.066	0.083	1.245	0.039	0.055	1.409	0.040	0.047	1.181
Agricultural									
Cocoa	0.064	0.065	1.015	0.054	0.058	1.075	0.019	0.018	0.911
Corn	0.063	0.070	1.124	0.039	0.053	1.361	0.032	0.031	0.958
Live hogs	0.077	0.071	0.931	0.046	0.044	0.951	0.082	0.074	0.905
Orange juice	0.067	0.072	1.072	0.052	0.051	0.975	0.029	0.029	0.985
Soybeans	0.053	0.064	1.208	0.045	0.051	1.118	0.028	0.037	1.308
Soybean meal	0.058	0.073	1.244	0.048	0.055	1.142	0.039	0.045	1.151
Soybean oil	0.054	0.060	1.110	0.048	0.054	1.126	0.016	0.016	1.002
Wheat	0.062	0.074	1.191	0.042	0.053	1.254	0.037	0.041	1.116
Metals									
Aluminum	0.043	0.054	1.264	0.030	0.048	1.617	0.022	0.018	0.835
Copper	0.062	0.073	1.168	0.047	0.081	1.728	0.030	0.022	0.744
Nickel	0.070	0.099	1.414	0.061	0.083	1.355	0.021	0.039	1.864
Zinc	0.054	0.079	1.463	0.030	0.070	2.359	0.036	0.021	0.599

Note: For aluminum, copper, nickel, and zinc, year-ahead futures price is the 15-month contract. Computed as the average conditional standard deviation from a GARCH(1,1) model.

2. PRICE VOLATILITY

As shown previously in Figure 2, the volatility of prices for many commodities increased in the 2000s.[6] The first three columns of Table 1 examine the change in the volatility of front month futures prices over a wide sample of commodities.[7] To quantify the change in volatility, we first estimate a GARCH(1,1) regression over the entire sample period. The first column in Table 1 computes the average conditional standard deviation from the GARCH(1,1) regression over the 11 years between 1992 and 2002, whereas the second column reports a similar statistic for the period between 2003 and mid-2012.[8] We split the sample in 2003 as that is when commodity prices started to increase on a sustained basis following a decade of relatively flat prices. The third column then reports the ratio of the two standard deviations, with a value greater than one signifying an increase in volatility. With the exception of live hogs, the front month contract for all commodities recorded an increase in volatility between the two periods.

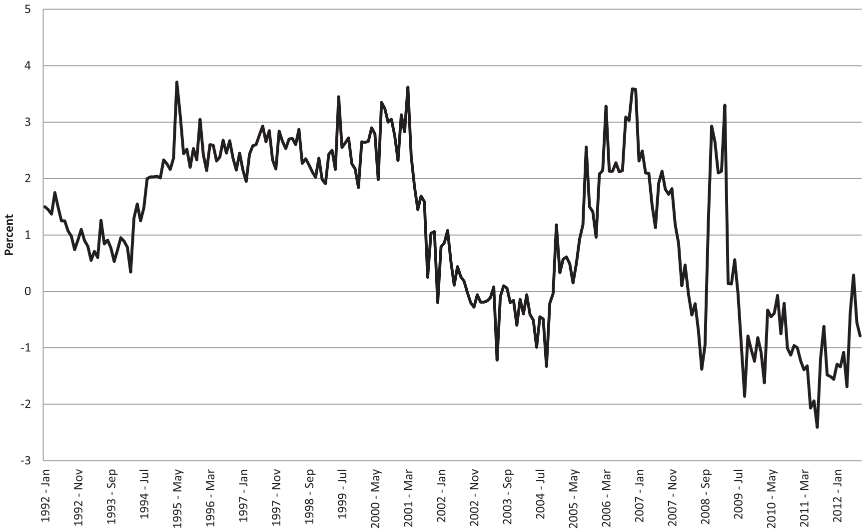

FIGURE 4. One-year real interest rate. *Source*: Federal Reserve Bank of Cleveland as described in Haubrich, Pennacchi, and Ritchken (2011).

Seemingly in contradiction to the hypothesis that lower interest rates should lower price volatility, this apparent increase in volatility occurred against a backdrop of sharply lower real interest rates. As shown in Figure 4, notwithstanding spikes in 2007 and late 2008/early 2009, the real interest rate was on average lower post-2002 than in the prior decade.[9]

However, notwithstanding the increased volatility of prices over the past decade, lower interest rates could still be promoting the inventory smoothing of transitory shocks. For example, the increase in price volatility over the past decade despite lower interest rates could reflect an increase in the volatility of the underlying shocks driving commodity prices or a shift toward persistent shocks away from transitory shocks. However, since shocks are observed only through movements in the price, it is difficult to disentangle changes in volatility due to changes in the underlying shock process and changes that arise from lower interest rates.

One decomposition that can help alleviate the identification problem introduced by possible changes in the distribution of shocks is to separate shocks into persistent and transitory components. The standard model presented in Deaton and Laroque (1992, 1996) predicts that a decrease in interest rates will decrease price volatility emanating from transitory shocks, but have little impact on the volatility associated with persistent shocks. As such, a preferred testing methodology would decompose movements in commodity prices into those due to either persistent or transitory shocks, and then examine the impact of interest rates on the volatility from transitory shocks alone.

Our methodology for identifying transitory versus persistent shocks is similar to that of Schwartz and Smith (2000). We assume that front month commodity prices are affected by transitory and persistent shocks, whereas year-ahead prices move only in response to persistent shocks.[10] Under these assumptions, transitory shocks are responsible for movements in the price difference between the front-month futures contract and the year-ahead futures contract (i.e., the time spread of the futures curve).[11] Testing the model then relates to examining the volatility of commodity time spreads relative to the level of the interest rate.

Before formally examining the relationship between interest rates and price volatility, we first compare the volatility of persistent and transitory shocks across the 1992–2002 and 2003–mid-2012 subsamples discussed earlier. As shown in Table 1, year-ahead futures prices (columns 4 and 5) are generally less volatile than the front month futures (columns 1 and 2). However, as shown in column 6, there was a large increase in the volatility of year-ahead futures prices post-2003, with the volatility of year-ahead crude oil contracts increasing over 80% over 2003–2012 relative to 1992–2002. In contrast, as shown in column 9, the volatility of the time spread declined for many commodities in the latter period. Thus, for most commodities, the increase in the volatility of front-month contracts (shown in column 3) is more than fully explained by an increase in the volatility of persistent shocks, as the volatility of transitory shocks declined.

Next, we estimate the following GARCH (1,1) model for each commodity:

$$\Delta \log P_t = \mu + \varepsilon_t, \tag{1}$$

$$\sigma_t^2 = a + b * \varepsilon_{t-1}^2 + c * \sigma_{t-1}^2 + d * r_t, \tag{2}$$

where μ is the constant, r_t is the real interest rate, and σ_t^2 is the conditional variance of shock ε_t. Testing the theoretical model is equivalent to testing whether $d > 0$ such that an increase in the interest rate increases the volatility of prices.[12]

Our estimation results are reported in Table 2, with column 1 showing results for the front-month contract, column 3 for the year-ahead contract (persistent shock), and column 5 for the time spread (transitory shock). For the year-ahead contracts, the coefficient on the real interest rate is largely insignificant such that the interest rate appears to have no effect on the volatility of prices in response to persistent shocks. The coefficients for the front-month contracts are also insignificant, perhaps reflecting the relative importance of persistent shocks in explaining movements in front-month prices. However, for many commodities, the coefficients are significant and positive in regard to the volatility of the time spread (column 5). This pattern of significance and insignificance aligns with the predictions of the model in that interest rates should impact the response only to transitory (and not to persistent) shocks.

The model tends to work better for metals than for agricultural commodities, where the coefficients in column 5 are insignificant and often of the wrong sign. A potential explanation for this lack of significance is based on the observation that agricultural commodities have much lower value per ton than metals do, and therefore could reasonably be expected to have higher associated inventory costs than metals. For example, the average price per ton of corn, wheat, and soybeans

Table 2. Price volatility and the interest rate coefficent on real interest rate in the variance equation in GARCH(1,1) model equation (2)

		1	2	3	4	5	6
		Front month price (St)		Year ahead futures price (Ft)		Time spread (F_t/S_t)	
		Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Energy	Crude Oil	−0.46	1.10	−0.30	0.29	**1.55***	0.58
	Heating Oil	0.23	0.95	−0.31	0.33	**0.98***	0.33
	Natural Gas	2.42	3.72	−0.46	0.44	3.03	2.14
Foods and beverages	Cocoa	−0.83	0.89	−0.78	0.67	−0.75	0.49
	Corn	0.46	0.34	0.09	0.21	−0.57	0.28
	Live hogs	0.69	0.52	−0.13	0.71	0.18	2.02
	Orange juice	−2.80	2.69	−0.89	0.80	−0.17	0.34
	Soybeans	−0.47	0.43	−0.18	0.35	−0.18	0.10
	Soybean meal	−0.37	0.36	0.00	0.26	−0.20	0.15
	Soybean oil	−1.05	1.16	−0.60	0.78	0.01	0.01
	Wheat	0.18	0.38	−0.08	0.31	**−1.07****	0.45
Raw materials	Cotton	−3.63	2.49	−1.78	1.17	−0.60	0.48
Metals	Aluminum	−0.01	0.40	−0.17	0.22	**0.19****	0.09
	Copper	2.18	1.72	−0.34	0.91	0.01	0.02
	Nickel	−0.13	0.88	−0.04	0.66	**0.03***	0.01
	Zinc	−0.12	0.40	**−4.96***	0.80	**0.15****	0.07

Note: For aluminum, copper, nickel, and zinc, year-ahead futures price is the 15-month contract. Estimated on monthly data from 1992 to 2012. The boldface indicates significance of at least 10 percent, with the * and ** denoting actual thresholds.

*denotes significance at the 1% level. **denotes significance at the 5% level.

over the 2003–12 period was about a tenth of the price per ton of aluminum or zinc and even less for higher valued metals like copper or nickel. Consistent with this finding, Cafiero et al. (2011) report that marginal storage costs for metals are about a tenth of the marginal storage costs for agricultural commodities. As a result, a given decline in the financial cost of inventories is likely less meaningful for agricultural commodities and less likely to have an effect on price dynamics.

3. PRICE CORRELATION

The higher level and increased volatility of commodity prices from 2003 to 2012 was associated with an increase in commodity price correlation (as shown in Figure 3).

As discussed earlier, the effect of interest rates on the correlation of commodity prices is dependent on the structure of shocks impacting commodity markets, in particular, on the relative persistence of common versus idiosyncratic shocks. It

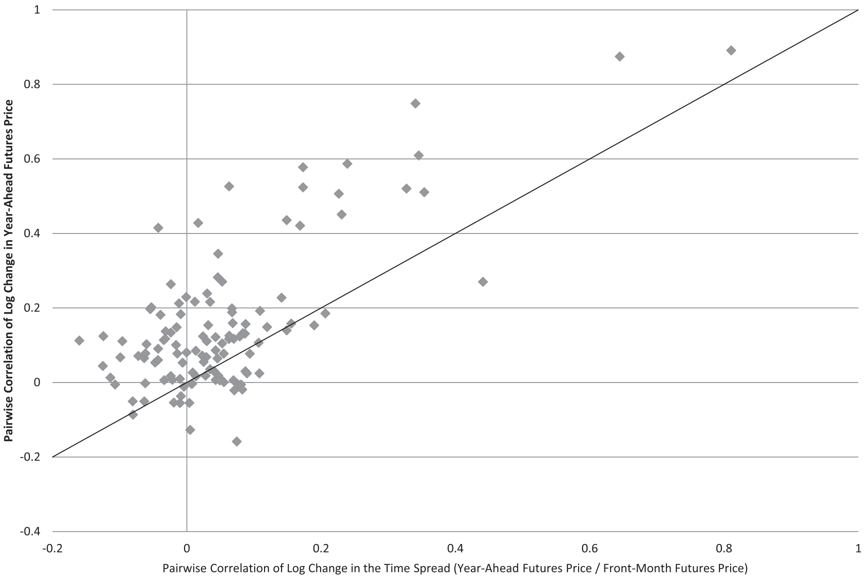

FIGURE 5. Pairwise correlation of log price changes 1992:1 to 2012:7. Pairwise correlations for commodities listed in the appendix.

is only when idiosyncratic shocks are relatively less persistent that lower interest rates should increase price correlation.

Are idiosyncratic shocks less persistent than common shocks? We start by addressing a slightly different question: Are persistent shocks more correlated than transitory shocks? Figure 5 reports the pairwise correlation of year-ahead futures prices (which reflect persistent shocks) against the correlation of time-spreads (which reflect transitory shocks) computed over the entire 1992–2012 sample. An observation above the 45° line indicates that persistent shocks are more correlated than transitory shocks for a particular commodity pair. As shown in Figure 5, for about 75% of commodity pairs, persistent shocks (captured by year-ahead futures prices) were more correlated than transitory shocks (embodied in time spreads).

3.1. Dynamic Factor Model

To assess directly whether idiosyncratic shocks are less persistent than common shocks, we turn to a dynamic factor model.[13] We estimate the following specification, which allows for both common and commodity-specific shocks to the price level, and these shocks can be either permanent or temporary:

$$\log P_{it} = a_i f_t + b_i f_t^{\tau} + f_{i,t} + f_{i,t}^{\tau}, \tag{3}$$

$$f_t = f_{t-1} + v_t, \tag{4a}$$

Table 3. Dynamic factor model

	Persistence of temporary factors	Contribution to variance of price changes			
	1	2	3	4	5
		Common (ρ)		Idiosyncratic (ρ_i)	
	Idiosyncratic (ρ_i)	Permanent	Transitory	Permanent	Transitory
Crude oil	0.78	0.18	0.65	0	0.17
Heating oil	0.88	0.22	0.69	0	0.11
Natural gas	0.88	0.03	0.1	0.29	0.58
Corn	0.94	0.46	0.06	0	0.49
Cocoa	0.97	0.02	0	0	0.98
Live hogs	0.92	0.01	0	0.01	0.98
Orange juice	0.98	0.03	0	0	0.96
Soybeans	0.96	0.67	0.08	0	0.25
Soybean oil	0.95	0.68	0.08	0	0.25
Wheat	0.93	0.28	0.02	0.02	0.68
Cotton	0.96	0.17	0	0	0.83
Aluminum	0.97	0.19	0.07	0	0.74
Copper	0.52	0.23	0.06	0.71	0
Nickel	0.98	0.16	0.03	0	0.81
Zinc	0.98	0.13	0.02	0	0.85
	Common (ρ)				
	0.98				

Notes: As described in the text, each commodity price is modeled as responding to both common and idioscyncratic shocks, which are either be permanent or transitory. The transitory shocks are modeled as an AR(1), with an autoregressive term parameterized by ρ.

$$f_t^\tau = \rho f_{t-1}^\tau + v_t^\tau, \tag{4b}$$

$$f_{i,t} = f_{i,t-1} + v_{i,t}, \tag{5a}$$

$$f_{i,t}^\tau = \rho_i f_{i,t-1}^\tau + v_{i,t}^\tau, \tag{5b}$$

where f_t and f_t^τ are common factors for all commodity prices and $f_{i,t}$ and $f_{i,t}^\tau$ are specific to commodity i. Shocks to f_t and $f_{i,t}$ are permanent shocks to the price level, whereas shocks to f_t^τ and $f_{i,t}^\tau$ are temporary shocks. Shocks' standard deviation is denoted by σ, σ_τ, σ_i, and $\sigma_{i,\tau}$.

Table 3 reports statistics on the importance and persistence of the shocks. As shown in the first column, although the effects of idiosyncratic shocks are quite persistent, the persistence of the common temporary shock is greater than the persistence of most idiosyncratic shocks. Columns 2–5 report contributions to the variance of log price changes, using the formula

$$\text{var}\,(\Delta \log P_{it}) = {a_i}^2\sigma^2 + b_i^2\left[\frac{2(1-\rho)}{1-\rho^2}\right]\sigma_\tau^2 + \sigma_i^2 + \left[\frac{2(1-\rho_i)}{1-{\rho_i}^2}\right]\sigma_{i,\tau}^2. \tag{6}$$

For most commodities (13 out of 15), the variance contribution from the common permanent shock (column 2) is greater than the variance contribution from the permanent commodity-specific shock (column 4). In contrast, the contribution from the commodity-specific temporary shock is frequently greater than the contribution from the common temporary shock. All told the evidence is that common shocks are more persistent than idiosyncratic shocks.

3.2. Panel GARCH

Similar to our earlier test for the effect of the interest rate on volatility using a univariate GARCH specification, we now estimate a panel GARCH model to examine the impact of the interest rate on price correlation. The model is set up as follows:

$$\Delta \log P_{it} = \mu_i + \varepsilon_{it}, \tag{7}$$

$$\sigma_{it}^2 = a_i + b_i * \varepsilon_{i(t-1)}{}^2 + c_i * \sigma_{i(t-1)}^2 + d_i * r_t, \tag{8}$$

$$\text{cov}_{ijt} = a_{ij} + b_{ij} * \varepsilon_{i(t-1)} * \varepsilon_{j(t-1)} + c_{ij} * \text{cov}_{ij(t-1)} + d_{ij} * r_t. \tag{9}$$

In particular, we are interested in examining the coefficient on the interest rate in the covariance equations and testing whether $d_{ij} < 0$. A negative and significant coefficient d_{ij} indicates that price correlation increases as the interest rate declines.

Estimating the unconstrained model for the entire panel of commodities would require estimating 560 parameters across 3,920 observations and proved infeasible in practice.[14] In order to cut down on the number of estimated parameters, we pursued two alternative approaches. First, we estimated the model using the entire panel, but constrained the coefficient on the interest rate in the covariance equations to be identical across all commodity pairs. Second, we estimated separate two-commodity panels for each of the 120 possible commodity pairings, while allowing the coefficient on the interest rate to vary with each regression.

Table 4 reports the coefficient estimates for d_{ij} as well as the associated standard errors from our first approach, with d_{ij} constrained to be equal across all i and j. When the panel consists of all commodities (or only food prices), the coefficient on the interest rate is negative, in line with the theory, though insignificant. However, if the panel includes only metals prices or metals and oil prices, the coefficient is negative and significant. One interpretation of these results, as with our volatility estimates, is that the relatively low physical storage costs for metals increases the importance of interest rate movements for explaining price dynamics. In contrast, where financial inventory costs may be small relative to physical costs (such as with foods), interest rates appear to be less important.

The results of our second approach are reported in Table 5, which shows the coefficients on the interest rate in the covariance equation for each of the separate 120 two-commodity panels. The majority of the coefficients are negative but insignificant, with the lack of significance likely reflecting the low power of the test due to the small size of the samples. The solid black line in Figure 6 presents

TABLE 4. Price correlation and the interest rate; coefficient on interest rate in covariance equation of panel GARCH model [equation (9)]

	Coefficent	S.E.
All commodities	−0.03	0.08
Metals	**−0.40***	0.22
Foods	−0.02	0.02
Crude oil and metals	**−0.48***	0.27
Energy and metals	−0.41	0.27

Note: Coefficients have been multiplied by 10,000. Esimated on monthly data from 1992 to 2012. The boldface indicates significance of at least 10 percent, with the * and ** denoting actual thresholds.
*denotes significance at the 10% level. Energy includes crude oil, heating oil, and natural gas. Foods includes cotton, cocoa, corn, live hogs, orange juice, soybeans, soybean meal, soybean oil, and wheat. Metals includes aluminium, copper, nickel, and zinc.

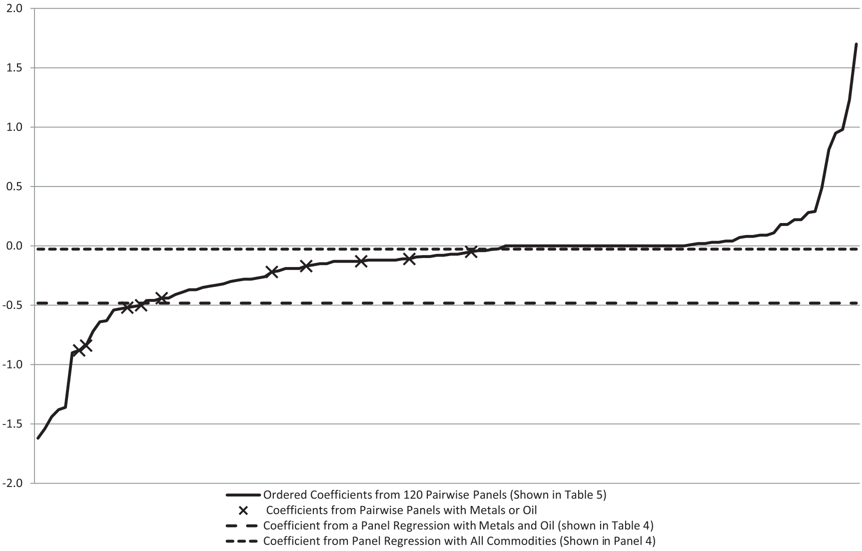

FIGURE 6. Coefficients on the interest rate in covariance equation from panel GARCH models.

an ordering (from most negative to most positive) of all 120 coefficients and shows that just over half of the coefficients are negative. In particular, as indicated by the large Xs in Figure 6, all pairings between metals and between oil and metals are negative. Furthermore, from these results, it is apparent that many pairings that do not include metals also have large negative coefficients. The dashed line in Figure 6 is the coefficient estimate from a panel including all metals and oil (as reported in Table 4) and lies at about the average for two-commodity estimates with those same commodities. The dotted line in Figure 6 depicts the coefficient estimate from the panel with all commodities (also reported in Table 4).

TABLE 5. Price correlation and the interest rate (two-commodity panels) coefficient on interest rate in covariance equation of panel GARCH models

	Crude oil	Heating oil	Natural gas	Cotton	Cocoa	Corn	Hogs	Orange juice	Soybeans	Soybean meal	Soybean oil	Wheat	Alum.	Copper	Nickel
Heating oil	−0.03														
(s.e.)	0.06														
Natural gas	−0.09	0.98													
(s.e.)	0.95	0.99													
Cotton	0.00	−0.03	0.81												
(s.e.)	1.03	0.36	0.88												
Cocoa	−0.33	−0.34	−1.36	0.00											
(s.e.)	0.97	0.27	1.28	0.73											
Corn	−0.32	−0.53	**0.95***	−0.37	−0.12										
(s.e.)	0.52	0.37	0.52	0.25	0.44										
Hogs	−0.13	−0.46	−1.62	−0.13	−0.13	0.29									
(s.e.)	0.89	0.51	1.41	0.42	0.25	0.29									
Orange juice	0.00	−0.37	0.11	0.00	0.00	0.09	−0.46								
(s.e.)	0.99	0.82	0.95	1.13	0.77	0.62	0.45								
Soybeans	0.00	−0.08	0.22	0.00	0.00	0.02	0.08	0.00							
(s.e.)	0.49	0.34	1.14	0.97	0.34	0.32	0.39	0.56							

Table 5. Continued

	Crude oil	Heating oil	Natural gas	Cotton	Cocoa	Corn	Hogs	Orange juice	Soybeans	Soybean meal	Soybean oil	Wheat	Alum.	Copper	Nickel
Soybean meal	0.00	0.04	0.28	0.00	−0.08	0.03	0.07	0.00	0.00						
(s.e.)	0.70	0.44	1.61	1.34	0.18	0.28	0.39	0.80	0.16						
Soybean oil	−0.13	**−0.44****	0.22	**−0.41***	0.00	−0.19	0.18	0.00	−0.12	−0.19					
(s.e.)	0.33	0.26	0.96	0.21	0.38	0.25	0.44	0.53	0.13	0.21					
Wheat	0.00	−0.06	0.49	−0.15	0.00	0.18	0.00	0.01	0.03	0.09	0.08				
(s.e.)	0.78	0.35	0.67	0.32	0.44	0.53	0.33	0.75	0.42	0.37	0.50				
Alum.	−0.22	−0.21	0.02	−0.04	−0.16	−0.28	−0.30	−0.19	−0.04	0.00	−0.12	−0.12			
(s.e.)	0.24	0.23	0.36	0.40	0.15	0.21	0.27	0.87	0.19	0.27	0.18	0.15			
Copper	−0.88	**−1.44***	1.70	−0.35	−0.51	**−1.38***	**1.23***	−0.54	**−0.90***	−0.63	**−1.54***	−0.72	−0.11		
(s.e.)	0.74	0.54	1.62	1.34	0.83	0.49	0.57	1.17	0.57	0.70	0.70	0.69	0.55		
Nickel	−0.05	−0.27	0.04	0.00	−0.07	−0.12	−0.11	0.00	0.00	0.00	0.00	−0.07	**−0.50***	**−0.84****	
(s.e.)	0.82	0.37	0.87	1.25	0.19	0.38	0.34	0.86	0.35	0.34	0.35	0.53	0.11	0.49	
Zinc	−0.44	−0.39	−0.64	0.00	−0.09	−0.28	−0.26	0.00	−0.09	0.00	−0.29	−0.15	−0.13	**−0.52***	−0.17
(s.e.)	0.37	0.26	0.54	0.78	0.17	0.19	0.32	0.56	0.22	0.17	0.26	0.19	0.09	0.13	0.14

Note: Coefficients have been multiplied by 10,000. Estimated on monthly data over 1992–2012 period. The boldface indicates significance of at least 10 percent, with the * and ** denoting actual thresholds.

*denotes significance at the 5% level. **denotes significance at the 10% level.

3.3. Decomposing the Increase in Commodity Price Correlation

As a final exercise, we look at the relative importance of changes in the correlation of permanent shocks (measured by year ahead prices) versus changes in correlation of temporary shocks (time spreads) in explaining the observed increase in correlation in front month commodity prices. If our hypothesis is correct, and a portion of the increased price correlation is due to lower interest rates, we would expect to see that most of the increased correlation is attributable to permanent shocks.

The correlation of changes in front month prices, $\mathrm{cor}(\Delta \log P_{it}, \Delta \log P_{jt})$, can be decomposed into the correlation of changes in year ahead prices and changes in time spreads:

$$\begin{aligned}
&\mathrm{cor}\left(\Delta \log P_{it}, \Delta \log P_{jt}\right)\\
&= \sqrt{\frac{\mathrm{var}\left(\Delta \log F_{it}\right) \mathrm{var}\left(\Delta \log F_{jt}\right)}{\mathrm{var}\left(\Delta \log P_{it}\right) \mathrm{var}\left(\Delta \log P_{jt}\right)}}\,\mathrm{cor}\left(\Delta \log F_{it}, \Delta \log F_{jt}\right)\\
&\quad + \sqrt{\frac{\mathrm{var}\left(\Delta \log \frac{P_{it}}{F_{it}}\right) \mathrm{var}\left(\Delta \log \frac{P_{jt}}{F_{jt}}\right)}{\mathrm{var}\left(\Delta \log P_{it}\right) \mathrm{var}\left(\Delta \log P_{jt}\right)}}\,\mathrm{cor}\left(\Delta \log \frac{P_{it}}{F_{it}}, \Delta \log \frac{P_{jt}}{F_{jt}}\right)\\
&\quad + \text{cross terms,}
\end{aligned} \qquad \mathbf{(10)}$$

where the cross terms are the correlations between one commodity's time spread and the other commodity's year ahead price.

Given this formula, we can determine what factors have driven the change in the correlation of spot prices. The top left panel of Figure 7 reports the distributions for the change in pairwise correlations of front month prices (the blue bars), of year ahead prices (the red starts), and of spreads (the black squares). The front month and year ahead prices both had large increases in correlation. In contrast, the spread did not see a large increase.

Likewise, as reported in the top right panel, the distribution of the variance of the year ahead prices relative to the front month price,

$$\sqrt{\frac{\mathrm{var}\left(\Delta \log F_{it}\right) \mathrm{var}\left(\Delta \log F_{jt}\right)}{\mathrm{var}\left(\Delta \log P_{it}\right) \mathrm{var}\left(\Delta \log P_{jt}\right)}},$$

which in equation (10) determines the weight on the correlation of year ahead prices, saw a large shift toward higher values. In contrast, the distribution of the relative weight on the correlation of spreads,

$$\sqrt{\frac{\mathrm{var}\left(\Delta \log \frac{P_{it}}{F_{it}}\right) \mathrm{var}\left(\Delta \log \frac{P_{jt}}{F_{jt}}\right)}{\mathrm{var}\left(\Delta \log P_{it}\right) \mathrm{var}\left(\Delta \log P_{jt}\right)}},$$

shifted lower, consistent with the theory that lower interest rates decrease the contribution of transitory shocks to front month price correlation.

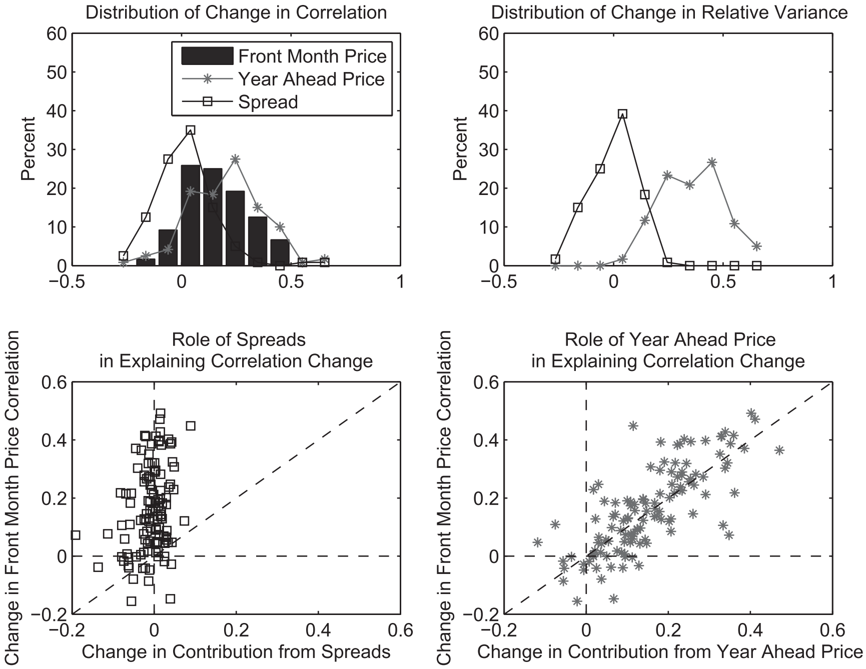

FIGURE 7. Decomposing the increase in commodity price correlation.

These changes in distribution are summarized by the bottom two panels. The bottom left panel shows that temporary shocks (as measured by the spread) played very little role in explaining the increased correlation of front month prices. In contrast, as shown in the bottom right panel, permanent shocks (as measured by futures) played an important role in the increased correlation of front month prices, not only because permanent shocks were more correlated, but also because the relative weight on temporary shocks decreased.

4. CONCLUSION

We examine the effect of interest rates on the volatility and correlation of commodity prices. An established literature posits that lower interest rates raise the level of commodity prices by lowering inventory carrying costs and increasing inventory demand. In the framework of Deaton and Laroque (1992), lower interest rates should also decrease the volatility of commodity prices, as lower inventory-carrying costs increase incentives to smooth prices in response to transient shocks. Also, lower interest rates could lead to an increase in commodity price correlation under the additional assumption that shocks common to all commodities are more persistent than idiosyncratic shocks. With idiosyncratic shocks that are relatively more transient, lower interest rates decrease the volatility of prices due to idiosyncratic shocks but have little effect on the volatility resulting from (relatively more persistent) common shocks, thereby increasing the measured correlation of prices across commodities.

First, to analyze the impact of interest rates on commodity price volatility, we empirically identify transient shocks via variation in the time spread of the futures curve, under the assumption that persistent shocks affect both front-month and year-ahead futures prices, whereas transient shocks affect only front-month prices. Using a GARCH model, we show that for a number of commodities the volatility of the time spread falls as the real interest rate declines, in line with the theory. Our results suggest that the observed increase in commodity price volatility primarily reflects an increase in the volatility of persistent shocks.

Second, in order to understand the impact on commodity price correlation, we examine a panel of commodity prices. Disentangling common versus idiosyncratic shocks via a dynamic factor model, we find that common shocks are more persistent than idiosyncratic shocks. Using a panel GARCH model, we show that as the interest rate decreases, correlation increases, most significantly for the prices of highly storable metals. In this regard, we have provided evidence of a theoretical channel based on physical supply and demand fundamentals to explain the increase in commodity price correlation observed since 2003, in contrast to theories that rely on financial market factors. Although our results do not rule out the importance of financial market developments in explaining the correlation of prices, they do suggest that the increase in correlation cannot be taken as prima facie evidence in favor of financial factors determining commodity prices. As such, our work increases the demand for a theoretical model relating financial markets to commodity price correlation such that the effect of financial factors can be distinguished from the fundamental channels that we have identified.

NOTES

1. As detailed in the appendix, our commodity sample includes crude oil, heating oil, natural gas, aluminum, copper, nickel, zinc, cocoa, corn, live hogs, orange juice, soybeans, soybean meal, soybean oil, wheat, and cotton.

2. In the Hoteling-based model of Barsky and Kilian (2002), lower interest rates also cause commodity prices to increase.

3. The link between the level of commodity prices and interest rates has been subject to a number of empirical tests, often with mixed results. Frankel found evidence of a negative relationship based on data from the 1970s. However, extending his analysis to more recent data can lead to an estimated positive relationship. Frankel and Rose (2010) find little evidence that real interest rates affect commodity prices. The endogenity of both interest rates and commodity prices to the business cycle complicates empirical analysis. Akram (2009) controls for endogenity using a VAR and finds a strong negative relationship between interest rates and commodity prices.

4. Most of the previous literature on storable commodities has held the interest rate constant. Exceptions are Arseneau and Leduc (2012) and Unalmis et al. (2012), both of which embed the storable commodity price model within a general equilibrium framework such that the interest rate is endogenous to the model.

5. Another implication is that as interest rates fall and transitory shocks are smoothed, movements in commodity prices will increasingly be driven by persistent shocks such that the level of any particular commodity price should approximate a random walk. This argument is similar to that presented by Engel and West (2005) in the context of financial assets and currencies in particular.

6. We examine prices at a monthly frequency for a diverse range of commodities (listed in the appendix). All prices are deflated by the U.S. headline CPI such that we consider movements in real prices.

7. Front month futures price for a given commodity is the current price quote of that commodity's futures contract that will next expire.

8. In examining changes in the standard deviation of prices, the conditional standard deviation from a GARCH model may be superior to other methodologies (including breaking the sample or rolling sample statistics) in that it allows for a more precise identification of the timing of changes in volatility as well as maintaining a common mean around which to compute the variance.

9. We use the Federal Reserve Bank of Cleveland's measure of the one-year real interest rate as described in Haubrich et al. (2011). Alternative calculations of the real interest rate, for example, subtracting lagging 12 month inflation from the constant maturity one-year Treasury Bill yield, are not markedly different. Although Figure 4 reports a measure of the real interest rate in the United States, global real rates likely followed a similar trajectory.

10. Analogous to the front month price, the year-ahead price is the current price quote for the futures contract that will expire next a year from the current date.

11. In Schwartz and Smith (2000), the long-run equilibrium price is estimated using a Kalman filter informed by long-dated futures prices. Our approach is to assume that the equilibrium price and the long-dated futures price are identical. This assumption abstracts from a convenience yield. However, since we are examining price changes rather than levels, our approach does not implicitly ignore the convenience yield, but rather assumes that it is constant. In the language of Schwartz and Smith (2000), our test would be equivalent to testing whether the volatility of their "deviation" process depends on the level of the interest rate. Additionally, in looking at price correlations, we speculate that the cross commodity covariance of Schwartz and Smith's "equilibrium" shocks is higher than the covariance of "deviation" shocks.

12. Although we explore how the level of the interest rate influences the variance of commodity price changes, understanding the relationship between the variance of interest rates and the variance of commodity prices would also be of interest. Hafner and Herwartz (2008) provide guidance on testing for statistical causality in variances.

13. Vansteenkiste (2009) also examines commodity prices via a dynamic factor model, showing that a common factor can explain a substantial portion of movements in commodities prices. She shows that prices became more correlated with the common factor through the 2000s. She does not do our exercise of studying the relative persistence of common versus idiosyncratic shocks.

14. Rather than a panel GARCH strategy, one might consider alternative estimation strategies such as DCC-GARCH of Engle (2001). Although it is beyond the scope of the current paper to determine whether a DCC-GARCH approach specification modified for covariates would make the full specification more feasible, this line of inquiry would be a promising direction for future work.

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APPENDIX

TABLE A.1. Commodity sample

	Market	Futures ticker	Comments
Energy			
Crude oil	NYMEX	CL	WTI (1,000 U.S. barrels)
Heating oil	NYMEX	HO	No. 2 fuel oil (1,000 U.S. barrels)
Natural gas	NYMEX	NG	Henry Hub delivery (10,000 mmBtu)
Metals			
Aluminum	LME	AH	Ingots, t-bars, and sows (25 metric tons)
Copper	LME	CA	Grade A cathodes (25 metric tons)
Nickel	LME	NI	99.80% purity cathodes (6 metric tons)
Zinc	LME	ZS	99.995% purity ingots (25 metric tons)
Agricultural			
Cocoa	ICE	CC	All origins (10 metric tons)
Corn	CBT	C	No. 2 yellow (5,000 bushels)
Live hogs	CME	LH	Also "lean hogs" (40,000 lb.)
Orange juice	ICE	JO	Frozen, concentrated (15,000 lb.)
Soybeans	CBT	S	No. 2 yellow (95,000 bushels)
Soybean meal	CBT	SM	Minimum protein 48% (100 short tons)
Soybean oil	CBT	BO	Crude (60,000 lb.)
Wheat	CBT	W	No. 1 and No. 2 varieties (5,000 bushels)
Raw materials			
Cotton	ICE	CT	No. 2 U.S. grown (50,000 lb.)

Sample monthly data from January 1992 to July 2012.