**ARE THERE NONLINEAR SPECULATIVE BUBBLES IN COMMODITIES PRICES?**

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 Abstract

 Daily price movements of 17 commodities are tested for the possible presence of nonlinear speculative bubbles during 1991-2012. A VAR model for logarithmic first differences of each is estimated with one year Treasury bill rates, US dollar value, a world stock market index, and an overall commodities price index using Hamilton regime switching and Hurst rescaled range tests. Residuals after removing ARCH for all 17 commodity price series are tested for remaining nonlinearity using the BDS test. These tests fail to reject the presence of bubble-like trends and nonlinearity beyond ARCH for all 17 commodity series.

**Introduction**

 While it has long been argued that stock and real estate markets are sometimes subject to speculative bubbles, such were only rarely thought to happen in commodities markets (Kindleberger, 2000, Appendix B). Those that happened in grains were usually triggered by some extraordinary supply restriction, such as the British blockade of Continental Europe during the Napoleonic wars or a very extreme weather event. While suspected bubbles may have been more likely to happen with metals, with the gold and silver bubbles of the late 1970s and early 1980s perhaps classic examples, it has been widely argued that futures markets in commodities in general along with the use of these goods in production for final sale in markets have led to greater efficiency in the markets for such goods with clear linkages to storage costs (Working, 1933).

 However, in the past decade there has been increased concern that there may have emerged rising volatility in commodities markets. Some of this may be due to exogenous events, such as global warming leading to greater volatility of weather patterns that has negatively shocked agricultural production or the possible nearing to the point of global peak oil production as various sources of oil become depleted combined with wars in the Middle East. Others may be tied to rising broader volatility of macroeconomic activity, particularly with the arrival of the Great Recession and the great speculative bubble and crash in housing that preceded it. The behavior of metals prices, particularly for gold, may well have been destabilized by these developments. Nevertheless, many observers fear that at least some of this apparently heightened volatility may reflect a greater role of speculative bubbles and crashes in many of these markets during this period as well, with rise in oil price to an all-time nominal peak only to be followed by a spectacular decline in 2008 a particularly dramatic example. That this apparently heightened volatility might be due to speculative bubbles is the subject of this paper.

 We consider the markets for 17 commodities since 2001, including various metals and agricultural commodities as well as oil, using a method previously used by Ahmed et al (2010) to study the behavior of stock markets in emerging markets. Daily price series from January 1, 1991 to February 22, 2012 are transformed into logarithmic first differences. For each series a vector autoregressive (VAR) model is estimated with movements of US 1–year Treasury bill rates, a measure of the value of the US dollar, an overall world stock market price index, and an overall commodity price index. This is assumed to estimate a measure of the fundamental series for each commodity. Unusual trends in the residuals for each series are tested for using Hamilton regime switching and Hurst rescaled range coefficients. After removing ARCH effects, BDS tests are also made to test for the presence of remaining nonlinearities in each series. We find that we are unable to reject the presence of such trends in prices or nonlinear effects in any of the price series, thus suggesting that there may have been nonlinear speculative bubbles in these series during the past decade.

**Literature Review on Commodity Market Dynamics**

 The study of agricultural commodities and the determination of their prices has long been a central concern of many classical political economists and early neoclassical economists, ranging from William Petty, Thomas Robert Malthus, and David Ricardo to Alfred Marshall. This reflected both the much more central place that agriculture played in the economies of earlier eras as well as the central role played by agricultural production in the basic welfare of most of the population of those societies. When the price of bread rose, the standard of living of large numbers of people declined sharply. However, the general focus of this older literature was more on the determination of the equilibriurm prices of agricultural goods and their relationship to such larger scale issues as the size of population and the availability of land rather than the determination or nature of shorter term price dynamics, with an occasional exception such as discussion of the tulipmania of the 1630s, which was generally dismissed as a manifestation of culpability and the “madness of crowds” (MacKay, 1842). While most view that episode as an early example of a speculative bubble, some have argued that it may not have been, or only part of it was (Garber, 1989). There was generally little discussion of the determination of the prices of other commodities such as metals, except for discussions of gold, which usually involved its role as a form of money.

 Eventually a line of discussion of price dynamics emerged in the early 20th century, although it had a prelude with Émile Cheysson (1887), regarding season to seasons in prices and production. This would develop along two lines. One involved interrelationships between related agricultural commodities, particularly corn and hogs (Wright, 1925). The other focused more on the reactions of farmers to prices in making production decisions in the cobweb literature (Ezekiel, 1938). This latter literature would eventually culminate in the development of the rational expectations hypothesis (Muth, 1961), but in fact the corn-hog cycle literature also involved the matter of expectations, if in a somewhat more complicated way, although Wright firmly took the view that farmers were backward looking in forming their expectations. As it is, whatever one thinks of the adaptive versus rational expectations issue, at least cycles in cattle numbers seem to have existed until recently (Rosen et al, 1994). None of this literature involved speculation or the development of bubbles.

 Yet another strand developed more formal models capable of being econometrically tested of price fundamentals. A literature for dynamics of prices of nonrenewable depletable natural resources, which fits many medals, with Hotelling (1931) showing in an equililbrium with all sources known and no technological change that the price should rise at the real rate of interest, a result applicable to oil. Working (1933) developed a model for grain prices tied to storage costs, which was extended by Scheinkman and Schechtman (1983) and Bobenfrieth et al (2002).

 Most of the empirical study of commodity price dynamics has avoided the question of speculative bubbles, focusing more on possible excess volatility. While a few studies have found the standard competitive model to be fully supported, such as Wright (2011) for a set of grain prices, many more studies have found some degree of excess volatility.

A much cited example is by Pindyck and Rotemberg (1990), in which they first find strong evidence of co-movements of prices across a heterogeneous set of commodities: wheat, cotton, copper, gold, crude oil, lumber, and cocoa. Furthermore, they estimate monthly price equations for each of the commodities using various macroeconomic variables, including industrial production, a general price index, various exchange rates, the three month interest rate on US Treasury bills, the S&P stock market index, and the M1 measure of the money supply. They find that these variables only explain a fairly small amount of the price variability of these commodity prices, which is much greater than their variation would explain, even after accounting for the co-movements among the commodity prices. They suggest that this excess volatility may reflect “herding behavior,” but avoid the provocative words “bubble” or “speculative.” They say that “by herd behavior we mean that traders are alternatively bullish and bearish on *all* for no plausible economic reason” (ibid, pp. 1174-1175).

Many subsequent studies have also found excess volatility as well for various samples during various periods of time. Hudson et al (1987) found the presence of leptokurtosis, aka “fat tails,” for wheat, soybeans, and cattle prices. Using a STAR-GARCH approach, Westerhoff and Reitz (2005) found booms and slumps in US corn prices. Also using a STAR-GARCH technique, Reitz and Slopek (2009) found cycles in oil prices. Ahmed et al (2011) find non-normal distributions for gold, silver, and copper prices, using a GARCH model, although using integrated volatility Fourier transforms can move these distributions closer to normality. Padungsakawasdi and Daigler (2013) find unexplained volatility for a set of commodity ETFs.

Some of these and other recent studies have more directly considered the role of speculation, particularly in the presence of heterogeneous traders. Thus in their study, Westerhoff and Reitz (2005) posited the presence of technical traders as an explanation for their results. Likewise, Reitz and Slopek (2009) argued that their results regarding oil prices could be explained by the nonlinear interaction of different categories of traders. This issue is approached theoretically by He and Westerhoff (2005) who focus on the interactions of consumers, producers, and a heterogeneous group of speculators, with the interactions of fundamentalists and chartists or technical traders determining the dynamics. They show that setting price minima or maxima can eliminate chaotic dynamics, but when these are in place price limiters can aggravate clustering. The matter of the possibility of chaotic bubbles in the face of heterogeneous agents was first shown by Day and Huang (1990), who showed this outcome for a model with fundamentalists, trend chasers, and market makers. As it is, in these models it is the trend chasers who herd who destabilize dynamics and introduce the volatility we associate with speculative bubbles.

**Theoretical Issues Regarding Speculative Bubbles**

 While there is certainly a historical literature arguing for the existence of speculative bubbles in at least some commodities going back even as far as the 17th century tuipmania (MacKay, 1852; Garber, 1989; Kindleberger, 2000), the literature on such bubbles more recently has been relatively scarce, as the above review should indicate, with indeed most studies that might suggest such bubbles emphasizing rather “excess volatility” and non-normal distributions of returns and other such phenomena that might suggest the presence of bubbles, but do not really come right and say so. There are some serious questions about whether it is even possible to econometrically observe such speculative bubbles, so let us consider what is involved with these, although for the general nature of such bubbles, the literature is both vast and well-worn, with Kindleberger (2000) providing an excellent overview, albeit without getting into the more theoretical issues involved.

 Underlying most studies of speculative bubbles is the following simple model, where *b* is the amount of the bubble, *p* is the commodity (or asset, more generally) price, *f* is the fundamental price of the commodity, and *ε* is an exogenous stochastic value, with all of these varying over time:

 *b*(t) = *p*(t) – *f*(t) + *ε*(t). (1)

This apparently simple equation contains within it the main problems involved in both the theoretical discussions and attempted empirical estimations of bubbles, with only the price variable being more or less straightforward (although one can worry about whether this should be in real terms or nominal or whatever). The stochastic process term hides some potentially serious issues. While it is conventional to assume that it is Gaussian normal, it may not necessarily be so. If not, and if it contains skewness or fat tailed leptokurtosis, then the sorts of evidence observed in many studies of commodity price series showing supposedly excess volatility in the form of such fat tails may well not indicate any presence of bubbles at all, but simply rather represent observations of the non-normality of the exogenous stochastic process. There is no way to resolve this issue.

 Needless to say, these problems spill over onto the problem of identifying the fundamental. In some models, this is assumed not to vary with time, but to be a constant representing some discounted value of a future discounted stream of real returns consistent with some broad general equilibrium of the economy, which in turn are rationally expected. However, as we know, rational expectations may never be fulfilled and in turn depend as well on the nature of the random error process. However, more generally it is recognized that this fundamental is likely to vary over time as new information arrives, with or without the stochastic error process.

 A very basic issue is whether or not such bubbles can even exist, with any price changes simply being entirely due to the exogenous price process and the evolution of the fundamental over time. This issue is especially sharp for the case of rational agents. Indeed, Tirole (1982) has shown that when agents are infinitely lived with rational expectations, bubbles cannot exist. This is due to backward induction, with the transversality condition in effect saying that in the infinite time horizon whatever bubbles might have existed must cease. This sets up the backward induction argument in that if the bubbles must come to an end, then rational agents will not be willing to buy the asset prior to the end of a bubble as there will be nobody to sell the bubbly asset to. This argument works backwards to the present, implying that rational agents will never even get into a bubble at the beginning, which therefore means that the bubble will never even start.

 At the time that Tirole established this result, many took it seriously as a description of real markets that ruled out the existence of speculative bubbles at all, particular as this was the heyday of widespread belief in the reality of rational expectations. However, even before this naïve period came to an end with the 1986 paper by Fischer Black (1986) on noise traders and the crash of the stock market in 1987, Tirole (1985) showed that at least stationary bubbles could exist in overlapping generations models, even with rational expectations. In effect, the finiteness of life of agents allows them to avoid facing the transversality condition and thus backward induction, passing on the “hot potato” of the bubbly asset to a succeeding generation, with the stationarity avoiding the problem of the price potentially going to infinity in finite time.

 The problem of rational bubbles in the face of prices possibly exploding to infinity in finite time was confronted by Blanchard and Watson (1982) with their model of stochastically crashing rational bubbles. In this model, stochastic processes are allowed, and risk averse agents know that indeed the bubble will end in a crash in finite time and furthermore at any moment know the probability of such a crash occurring, with this probability rising as the bubble rises above the fundamental further. To attract risk averse rational agents to continue buying the asset and therefore continuing to drive the bubble upwards in a self-fulfilling prophecy, the bubble must rise in an accelerating manner to properly compensate the agents for the rising probability of the crash. This accelerating rise indeed guarantees that the price will crash in finite time.

 While empirical efforts have been made to observe such rationally crashing stochastic bubbles (Elwood et al, 1999; Sornette and Zhou, 2005), all these efforts face the conundrum in practice of the misspecified fundamental problem, originally identified clearly by Flood and Garber (1980). This amounts to arguing that any effort to identify a fundamental will be fatally flawed in that what may look like a bubble and crash ex post may from the ex ante perspective of rational agents have simply been an outcome within the expected probability distribution of the rational agents. Rational expectations are not always fulfilled, and the agents may well have had econometrically unobservable expectations about what the future returns would look like that simply were not fulfilled. While there may be some limited exceptions to this problem, such as the case of closed-end funds that have net asset values for their underlying assets that presumably are not too far off from the true fundamental of the fund as long as there is an ability for agents to buy and sell the underlying assets (Ahmed et al, 1997), this problem dogs the vast majority of efforts to estimate fundamentals for any price time-series, and we must admit that this problem applies to our efforts here.

 Needless to say, with the weakening of belief in rational expectations and the widely observed appearance of apparent bubbles in the dotcom boom and bust of the 1990s and afterwards and the housing bubble that peaked in 2006 to be followed by a decline generally accepted to have triggered the financial collapse of 2008 and the subsequent Great Recession, many observers have been much more willing to eschew the earlier approaches that assumed homogeneity of rational agents. Quite aside from leading to people to take more seriously the arguments of Kindleberger (2000) as well as Minsky (1972) whose arguments he drew upon, or others such as Shiller (2005) who documented the mounting housing bubble even prior to its peak and crash, the door was opened to more formal modeling of heterogeneous agent models such as those mentioned in the final paragraph of the previous section, with bubbles emerging when trend chasing agents would come to dominate fundamentalist traders in a model . Indeed, this argument had been made prior to the coming to dominance of the rational expectations revolution (Baumol, 1957; Zeeman, 1974). Even while it was still strong, DeLong et al (1991) showed that it was not necessarily irrational to be trend chasers as they could not only survive, contrary to many arguments (Friedman, 1953), but could even thrive.

 As it is, in this paper we shall not attempt to impose any assumption regarding whether markets that may appear to contain speculative bubbles are being driven by either rational agents anticipating possible crashes or more simply by irrational trend chasing agents who come to dominate the market. However, we recognize that our efforts to estimate fundamentals and thus bubbles, will not escape from the critique that we may not know for sure whether we have succeeded in identifying true fundamentals or not. In this, we shall share the same problem that the vast majority of empirical efforts to test for bubbles also face.

**Methods and Data**

 We follow Ahmed et al (2006) and Ahmed et al (2010) in our approach. This involves estimating fundamentals series for 17 commodities by means of Vector Autoregressions (VARs) with the resulting residuals then being studied using regime switching tests, rescaled range analysis, and BDS tests. The idea of using VARs to estimate fundamentals for price series was originated by Canova and Ito (1991).

 More precisely, we tracked daily price series from 1/1/91 through 2/22/12 for corn, cotton, gold, aluminum, copper, lead, zinc, natural gas, nickel, Brent crude oil, palladium, palm oil, rice, soya oil, tin, wheat, and silver. Figures 1-17 show the time series for these commodity prices respectively. These are then transformed into first log differences as ln(Indext) – ln(Indext-1) that are modeled in Vector Autoregressions with the log differences of the daily series for the middle rate of 1-Year U.S. Treasury bills, the U.S. World Currency Index of the Federal Reserved, the MSCI World Stock Price Index, and the TR Equal Weight CCI Commodity Price Index. The MSCI Index is calculated by Morgan Stanley International, and the other series come from Datastream International.

**Regime Switching Tests**

 Hamilton (1989) introduced an approach to regime switching tests that can be used to test for trends in time series and switches in trends, as used in Engel and Hamilton (1990) and van Norden and Schaller (1993). We use this approach as our main test for the null of no bubbles on the residual series derived above which is given by

 ∈t = nt + zt (2)

where

 nt = μ1 + μ2st (3)

and

 zt - zt-1 = 1(zt-1 - zt-2) +…+r (zt-r - zt-r-1) + t (4)

with s = 1 being a positive trend, s = 0 being a negative trend, and I ≠ 0 indicating the possible existence of a trend element beyond the VAR process. Furthermore, let

 Prob [st = 1 st-1 = 1] = p, Prob [st = 0 st-1 = 1] = 1 - p (5)

 Prob [st = 0 st-1 = 0] = q, Prob [st = 1 st-1 = 0] = 1 - q. (6)

 Following Engel and Hamilton (1990) a "no bubbles" test proposes a null hypothesis of no trends given by p = 1 - q. This is tested by with a Wald test statistic given by

 [p - (1 - q)]/[var(p) + var(1 - q) + covar(p, 1 - q)]. (7)

The critical value for rejecting the null of no trends is χ2 = 3.84. Results are reported in Table 1. Clearly, the null of no trends is strongly rejected for all commodities, with the highest value for aluminum at 13,128 and the lowest for palm oil at 69.. However, we caution that this does not definitively prove the presence of a bubble due to the misspecified fundamental problem.

**Hurst Persistence Tests**

 Hurst (1951) developed a test to study persistence of Nile River annual flows, which was first applied to economic data by Mandelbrot (1972). For a series xt with n observations, mean of x\*m and a max and a min value, the range R(n) is

 k k

 R(n) = [max 1 ≤ k ≤ n Σ (xj - x\*) - min 1 ≤ k ≤ n Σ (xj - x\*)]. (8)

 j=1 j=1

The scale factor, S(n, q) is the square root of a consistent estimator for spectral density at frequency zero, with q < n,

 q

 S(n, q)2 = g0 + 2Σwj(q)gj, wj(q) = 1 - [j/(q-1)], (9)

 j=1

with g's autocovariances and w's weights based on the truncation parameter, q, which is a period of short-term dependence. Lo (1991) has criticized the used of the classical Hurst coefficient for studying long-term persistence due to this presence of short-term dependence in it, but this is not a problem for us. The classical Hurst case has q = 0, which reduces the scaling factor to a simple standard deviation.

 Feller (1951) showed that if xt is a Gaussian i.i.d. series then

 R(n)/S(n) ∝ nH, (10)

with H = 1/2, which implies integer integrodifferentiation and thus standard Brownian motion, the "random walk." H is the Hurst coefficient, which can vary from zero to one with a value of 1/2 implying no persistence in a process, a value significantly less than 1/2 implying "anti-persistence" and a value significantly greater than 1/2 implying positive persistence. The significance test involves breaking the sample into sub-samples (namely, pre-bubble, during-bubble and post-bubble period) and then estimating a Chow test on the null that the subperiods possess identical slopes. This technique is also called *rescaled range analysis*.

 Table 2 presents the results of this test. For each sample H (Hurst) coefficient is estimated. Computed F values for the Chow tests of the significance of this coefficient are reported. For a test of a model with both slope and intercept the computed F-values are substantially above the critical value showing a significant rejection of the null hypothesis that the coefficient is equal to 0.50 (thus indicating no persistence). Results are reported for a test of a model with the intercept suppressed, the computed F values are all far above the critical value of 6.4, leading to the rejection of the null that there is no persistence. The highest F-value was for cotton at 24,732, while the lowest was for wheat at just under 1016, although both gold and oil were just over this number. As before, this test remains subject to the caveat that we may not have properly estimated the true fundamental.

**Nonlinearity Tests**

 We test for nonlinearity of the VAR residual series in two stages. The first is to remove ARCH effects. Engle (1982) the nonlinear variance dependence measure of autoregressive conditional heteroskedasticity (ARCH) as

 xt = δtμt (11)

 n

 δt2 = α0 + Σ αixI-i2 (12)

 i=0

with μ i.i.d. and the αI's different lags. We use a three period lag and, as expected, found significant ARCH effects in all series, available on request from the authors.

 The second stage involves removing variability attributable to the estimated ARCH effects from the VAR residual series for both models. The remaining residual series is run through the BDS test due to Brock, Dechert, LeBaron, and Scheinkman (1997), with useful guidance on certain aspects in Brock, Hsieh, and LeBaron (1991). This statistic tests for generalized nonlinear structure but does not test for any specific form such as alternative ARCH forms or chaos.

 The correlation integral for a data series xt, t = 1, …, T results from forming m-histories such that x = [xt, xt+1, …, xt+m+1] for any embedding dimension m. It is

 cmT(ε) = Σ Iε(xtm, xsm)[2/Tm(Tm-1)] (13)

 t<s

with a tolerance distance of ε, conventionally measured by the standard deviation divided by the spread of the data, Iε(xtm, xsm) is an indicator function equaling 1 if Iixtm - xsmII < ε and equaling zero otherwise, and Tm = T - (m - 1).

 The BDS statistic comes from the correlation integral as

 BDS (m, ε) = T1/2{cm(ε) - [c1(ε)]m}/bm (14)

\where bm is the standard deviation of the BDS statistic dependent on the embedding dimension m. The null hypothesis is that the series is i.i.d., meaning that for a given ε and an m > 1, cm(ε) - [c1(ε)]m equals zero. Thus, sufficiently large values of the BDS statistic indicate nonlinear structure in the remaining series. This test is subject to severe small sample bias with a cutoff of 500 observations sufficient to overcome this, a minimum both of our daily series easily achieve.

 Table 3 present the results of this test for embedding dimensions, m = 2 to 4 (m = 3 is conventional). The critical value for rejecting the null of i.i.d. is approximately 6. Based on the estimated BDS statistics null is rejected. The highest BDS statistic is for palladium at over 23, while the lowest is for soya oil at just under 9. Thus, there appears to be remaining nonlinearity beyond basic ARCH in the VAR residual series.

 Of course, just as our earlier tests are subject to the validity of our original VAR specifications and the broader misspecified fundamental problem, likewise so is this test. We also emphasize that the nature of the remaining nonlinearity remains unknown.

**Discussion**

 While our results strongly find the presence of trends and persistence in the residuals of the estimated VAR series, which is strongly suggestive of the presence of speculative bubbles in the markets for these commodities, we remain fully aware of the power of the misspecified fundamental problem here. Quite aside that for certain commodities such as grains we have left out variables that many would argue should enter into determining the fundamental, such as storage costs and stockpiles as modeled by Working, there have clearly been some dramatic shocks to both supply and demand for many of these commodities that are not modeled by the variables we have used in our VARs and that could easily be responsible for these outcomes in the form of rapidly changing fundamentals. In particular for the agricultural commodities, the outbreak of major droughts and other weather anomalies in the past decade has provided supply shocks for various of the commodities we have considered. Likewise, the prices of nearly all of the commodities dropped sharply with the appearance of the Great Recession in 2007 and 2008, although this is at least partly picked up by at least our global stock market index.

 Indeed, we should note that in terms of journalistic accounts and widespread discussion there have been considerably different views about what has gone in these different markets, even though our tests have strongly rejected the null of no trends or persistence for all of them. In particular, there has been little discussion of speculative bubbles in grain markets in particular traditionally. Volume is high, and there are definite limits on how long grain can be stored. The widely held perception is that grain markets are highly competitive and highly responsive to news, particularly weather reports. Volatility is clearly high, but it may well be indeed that weather-induced shocks to supply lie behind the outcomes that we observe here.

 On the other hand, markets for metals, particularly for gold and silver, have had histories of claims of speculative bubbles, with some of them coming from only particular sources, and also subject in some cases to monopolistic or oligopolistic control that may trigger speculation. Regarding gold and silver, it has long been argued that the spectacular runups on their prices at the end of the 1970s and early 1980s, followed by rapid declines (particularly rapid for silver) represented speculative bubbles. However, even in those cases, particularly for gold, some would argue that the runups of their prices represented not irrational expectations regarding inflation that came not to be fulfilled. As long as the inflationary expectations remained high, it was fully rational and arguably within bounds as a fundamental, for their prices to be high. The same issue arises in recent years for gold again, even though there has been far less actual inflation than there was in the late 1970s and early 1980s. However, now many argue that fear of a more global systemic economic breakdown explains the demand for gold.

 The case of oil is more peculiar and also receives a lot of attention due to its greater macroeconomic impact. This is a market long characterized by alternations over time between periods of competition and periods of cartelization or monopolization, thereby aggravating the volatility of this market. For much of the period of our sample, the oil market has been quite competitive, although many think that it may have become less so in more recent years. In any case, the runup in oil prices in 2007 and up to the July, 2008 peak of $147 per barrel, followed by a severe crash, has been argued by many to be a speculative bubble (Rosser, et al, 2012), although this has remained a matter of unresolved contention and debate. However, it must be noted also that many think this market has become more subject to speculative bubbles than it was in the past.

 Regarding policy, we make no suggestions. Certainly high volatility, whether due to bubbles or not, can disrupt economies, and policymakers thus often wish to reduce it. But efforts to do so always threaten to disturb the market mechanism in inefficient ways. As it is, most governments intervene in agricultural markets to some extent, although more often than not they do so in order to keep prices from going below certain levels rather than to keep them from going too high, which is often associated with some supply shock anyway. More generally, buffer stocks are the obvious policy tool for attempting to stabilize commodity prices, and the United States does maintain the Strategic Petroleum Reserve precisely in order to control overly great price increases for oil, although it is used for this somewhat infrequently and often more for political show than for any actual impact on the markets. By and large, there seem to be few efforts by governments to control prices for metals, although when gold played an official role in the world monetary system its price was strictly controlled for long periods of time (and even now, the US government still officially values the gold it owns at the old official price of $35 per ounce for its own accounting purposes).

**Conclusion**

 This paper has considered the possible existence of speculative bubbles in the markets for 17 commodity markets. Few past studies of commodity market dynamics have specifically addressed this question, although many have found that such markets often appear to exhibit greater volatility than can easily be explained by obvious supposedly underlying supply and demand dynamics. The few papers that have modeled speculative bubbles have done so by modeling dynamics of heterogeneous groups of traders interacting nonlinearly with each other. But few of these studies have set out to establish whether or not speculative bubbles per se have been involved.

 As it is, our work strongly supports the widely observed phenomenon of unexplained volatility in these markets, indeed in all of them we studied, which include both metals as well as agricultural commodities and oil. Indeed, we can go further and say that there appear to be strongly persistent trends in all of these markets, which would be consistent with speculative bubbles. Nevertheless, we cannot say definitely that these trends represent speculative bubbles because they might represent strong movements in fundamentals not captured by the variables that we have used to model the fundamentals.

 We used interest rates, exchange rates, and stock market prices, along with the overall commodity price index itself, as the variables to model the fundamentals for each of the specific commodities. Use of this latter variable means that presumably we are capturing the individual dynamics of each commodity rather than just some co-movement of all of them, something found to exist in past studies. We estimated fundamentals by constructing VARs from the log differences of the price series for each commodity with the log differences of these explanatory variables. Using regime switching tests and rescaled range analysis we rejected with high significance the null hypotheses of no trends and no persistence in the residuals off of these estimated fundamentals. We also tested for nonlinearity beyond ARCH by use of the BDS statistic on the residuals on these residual series after ARCH effects were removed, and also rejected the null hypothesis of no further such nonlinearity, although we have not determined the form this nonlinearity takes.

 We make no policy recommendation on this, partly because the misspecified fundamental problem means that we cannot clearly say these trends and high volatility represent speculative bubbles, and even if they do any efforts by governments to intervene may simply induce greater inefficiencies or instabilities. Nevertheless, governments do use a variety of schemes, such as buffer stocks and subsidies and controls, to try to influence the prices of many commodities, although often these are to prevent agricultural commodity prices from falling too low rather than to restrain them from going too high. For metals markets and oil markets, while some efforts have been made, particularly for gold when it was a form of legal money, these markets largely remain unregulated and international, even if some are subject to varying degrees of cartelization or monopolization at times. In any case, the apparently increased volatility in these markets attracts concern that this may be due to increasingly unstable speculative effects.

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Table 1

Wald Tests for Bubbles

|  |  |  |
| --- | --- | --- |
| Commodities | Sample Dates  | H0: P=P1-P2χ2 |
| Cornus2Corn No.2 YellowCents/Bushel | 01/01/1991-2/22/2012 | 4812.3112 |
| CottonmCotton,1 1/16Str Low –Midl,Memph C/Lb | 01/01/1991-2/22/2012 | 4502.9603 |
| GoldblnGold Bullion LBMU$/Troy Ounce | 01/01/1991-2/22/2012 | 7320.1032 |
| LahcashLME-Aluminum 99.7% CashU$/MT | 01/01/1991-2/22/2012 | 13127.5881 |
| LcpcashLME-Copper, Grade A CashU$/MT | 01/01/1991-2/22/2012 | 10939.0341 |
| LedcashLME-Lead CashU$/MT | 01/01/1991-2/22/2012 | 8489.7809 |
| LzzcashLME-SHG Zinc 99.995% Cash U$/MT | 01/01/1991-2/22/2012 | 37069.2777 |
| NatlgasNatural Gas-Henry Hub$/MMBTU | 01/01/1991-2/22/2012 | 859.1073 |
| LnicashLME-Nickel CashU$/MT | 01/01/1991-2/22/2012 | 3886.2363 |
| OilbrenCrude Oil-Brent Cur. Month FOB U$/BBL | 01/01/1991-2/22/2012 | 2234.0642 |
| PalladmPalladiumU$/Troy Ounce | 01/01/1991-2/22/2012 | 3451.7503 |
| PmomyrbPalm Oil-Malaysian RBD FOB $/MT | 01/01/1991-2/22/2012 | 69.3220 |
| RcetilgRice,Thai L/Grn 100% B Grade FOB, $/MT | 01/01/1991-2/22/2012 | 186.3171 |
| SoyaoilSoya Oil, Crude DecaturCents/lb | 01/01/1991-2/22/2012 | 1887.3437 |

|  |  |  |
| --- | --- | --- |
| TinusnyTin (New York) USCts/lb | 01/01/1991-2/22/2012 | 273.0581 |
| WheatmpWheat,Spring,14%-Pro (Minn.) C/Bushel | 01/01/1991-2/22/2012 | 937.9161 |
| SlvcashSilver Fix LBM CashCents/Troy ounce | 01/01/1991-2/22/2012 | 1768.4835 |

Critical value χ2 = 3.84.

Steps involved in Wald test:

1. Each commodity series was transformed into logarithmic first difference and used in VAR procedure (with 8 lags) as an endogenous variable along with the following five variables:
2. FRTCM1Y=U.S. Treasury Const Mat 1 Year (D) Middle Rate
3. US$CWMN=US $ Major Currency March 1973=100 (FED-Exchange Index)
4. MSWRLDL=MSCI World-Price Index
5. NYFECRB=TR Equal Weight CCI-Price Index
6. VAR Residuals related to the each commodity were then used to run the Wald tests.

Table 2

Hurst Coefficient and F Values for Chow Test (Slope No Intercept)

|  |  |  |
| --- | --- | --- |
| Commodities | Sample size for the final run | Hurst Coefficient and F Values for Chow Test (Slope and intercept) |
| Cornus2Corn No.2 YellowCents/Bushel | 2748 | Estimated Hurst Coefficient=0.75Computed F Value=1545.75 |
| CottonmCotton,1 1/16Str Low –Midl,Memph C/Lb | 2748 | Estimated Hurst Coefficient=0.55Computed F Value=24732 |
| GoldblnGold Bullion LBMU$/Troy Ounce | 2748 | Estimated Hurst Coefficient= 0.75Computed F Value=1016.75 |
| LahcashLME-Aluminum 99.7% CashU$/MT | 2416 | Estimated Hurst Coefficient=0.76Computed F Value=1544.01 |
| LcpcashLME-Copper, Grade A CashU$/MT | 2421 | Estimated Hurst Coefficient=0.76Computed F Value=16133.33 |
| LedcashLME-Lead CashU$/MT | 2421 | Estimated Hurst Coefficient= 0.75Computed F Value=1247.18 |
| LzzcashLME-SHG Zinc 99.995% Cash U$/MT | 2419 | Estimated Hurst Coefficient=0.76Computed F Value=1360.68 |
| NatlgasNatural Gas-Henry Hub$/MMBTU | 2379 | Estimated Hurst Coefficient=0.78Computed F Value=2121.81 |
| LnicashLME-Nickel CashU$/MT | 2423 | Estimated Hurst Coefficient=0.76Computed F Value=1286.15 |
| OilbrenCrude Oil-Brent Cur. Month FOB U$/BBL | 2746 | Estimated Hurst Coefficient=0.75Computed F Value=1016.38 |
| PalladmPalladiumU$/Troy Ounce | 2746 | Estimated Hurst Coefficient=0.75Computed F Value=1544.62 |
| PmomyrbPalm Oil-Malaysian RBD FOB $/MT | 2746 | Estimated Hurst Coefficient=0.76Computed F Value=1233.71 |
| RcetilgRice,Thai L/Grn 100% B Grade FOB, $/MT | 2746 | Estimated Hurst Coefficient=0.72Computed F Value=1067.88 |
| SoyaoilSoya Oil, Crude DecaturCents/lb | 2746 | Estimated Hurst Coefficient=0.75Computed F Value=1292.23 |
| TinusnyTin (New York) USCts/lb | 2746 | Estimated Hurst Coefficient=0.75Computed F Value=1612.73 |
| WheatmpWheat,Spring,14%-Pro (Minn.) C/Bushel | 2746 | Estimated Hurst Coefficient=0.75Computed F Value=1015.64 |
| SlvcashSilver Fix LBM CashCents/Troy ounce | 2746 | Estimated Hurst Coefficient=0.76Computed F Value=1067.88 |

Critical value of F = 6.40

Steps involved in Obtaining the Hurst Coefficients and related Chow Tests.

1. Each commodity series was transformed into logarithmic first difference and used in VAR procedure (with 8 lags) as an endogenous variable along with the following four variables:
2. FRTCM1Y=U.S. Treasury Const. Mat 1 Year (D) Middle Rate
3. US$CWMN=US $ Major Currency March 1973=100 (FED-Exchange Index)
4. MSWRLDL=MSCI World-Price Index
5. NYFECRB=TR Equal Weight CCI-Price Index
6. VAR Residuals related to the each commodity were then used to obtain Hurst Coefficients and related Chow test F Values.

Table 3

BDS/SD Results

|  |  |  |
| --- | --- | --- |
| Commodities | Sample Size | Estimated BDS/SD Statistics |
| Cornus2Corn No.2 YellowCents/Bushel | 5506 | 15.27 |
| CottonmCotton,1 1/16Str Low –Midl,Memph C/Lb | 5505 | 10.64 |
| GoldblnGold Bullion LBMU$/Troy Ounce | 5506 | 16.56 |
| LahcashLME-Aluminum 99.7% CashU$/MT | 4845 | 14.0 |
| LcpcashLME-Copper, Grade A CashU$/MT | 4852 | 15.23 |
| LedcashLME-Lead CashU$/MT | 4852 | 19.7 |
| LzzcashLME-SHG Zinc 99.995% Cash U$/MT | 4847 | 22.6 |
| NatlgasNatural Gas-Henry Hub$/MMBTU | 4767 | 22.6 |
| LnicashLME-Nickel CashU$/MT | 4852 | 15.11 |
| OilbrenCrude Oil-Brent Cur. Month FOB U$/BBL | 5506 | 9.35 |
| PalladmPalladiumU$/Troy Ounce | 5506 | 23.49 |
| PmomyrbPalm Oil-Malaysian RBD FOB $/MT | 5505 | 12.20 |
| RcetilgRice,Thai L/Grn 100% B Grade FOB, $/MT | 5505 | 12.20 |
| SoyaoilSoya Oil, Crude DecaturCents/lb | 5506 | 8.89 |
| TinusnyTin (New York) USCts/lb | 5506 | 16.19 |
| WheatmpWheat,Spring,14%-Pro (Minn.) C/Bushel | 5506 | 18.56 |
| SlvcashSilver Fix LBM CashCents/Troy ounce | 5506 | 18.56 |

Critical value (for sample>1000, with m=2 is approximately 4.70-6.92. Results from m=3 are reported in this table.

Steps involved in estimating BDS/SD:

1. Each commodity series was transformed into logarithmic first difference and used in VAR procedure (with 8 lags) as an endogenous variable along with the following four variables:
2. FRTCM1Y=U.S. Treasury Const. Mat 1 Year (D) Middle Rate
3. US$CWMN=US $ Major Currency March 1973=100 (FED-Exchange Index)
4. MSWRLDL=MSCI World-Price Index
5. NYFECRB=TR Equal Weight CCI-Price Index
6. VAR Residuals related to the each commodity were then used to conduct ARCH (degree 3). Residuals from each ARCH test were used to obtained BDS/SD statistics.