Speculation, Embedding and Food Prices

A Cointegration Analysis

A. Jason Windawi
Adapted from a Quantitative Methods in the Social Sciences Masters Thesis

Speculation, Embedding and Food Prices:
A Cointegration Analysis

A. Jason Windawi

February 2012

Abstract: *The disparity between massive volatility in food prices and relatively slow changes in agricultural supply and demand since the beginning of the food crisis in 2007 has focused attention on the potential effects of financial speculators in food markets. The challenge of identifying the effects of such speculators has been complicated by a number of factors, key among which has been the criteria used to define speculative activity. This paper provides a more targeted analysis of one particular kind of speculator, and builds on a combination of sociological and econometric analysis to identify their presence in commodity markets during the food crisis.*

Table of Contents:

Section I: Introduction

The ongoing food crisis that began in 2007 has marked a significant departure from prior crises. Famines have historically been largely regional events driven by disruptions to food production such as weather, crop failures and armed conflict (Eicher, 1982). By contrast, in the current crisis the effects of price inflation were transmitted globally in a way that simultaneously harmed vulnerable populations whose misfortunes had previously been unrelated (Economist, 2008). The violent movements in price also ensnared a broad range of commodities that had previously traded more or less heterogeneously. The result has been a series of food riots around the world beginning in 2007, with some accounts even linking recent food price volatility to the Arab Spring and other political revolts (Arezki and Bruckner, 2011).

Two aspects of the price movements have made the analysis of root causes particularly difficult. The first of these has been the extraordinary volatility in food prices, which have undergone drastic reversals that have rendered directional arguments ineffective. After rising steadily but slowly from 2002 to 2006, food prices exploded in the second half of 2007 and through the first half of 2008, leading to the first wave of protests and food riots around the world (Economist, 2008). They subsequently fell nearly as rapidly through the end of 2008, only to soar once again in 2010. After falling slightly, prices have remained stubbornly high since. The second aspect is the fact that volatility in prices has far exceeded changes in underlying fundamentals such as production and demand (Timmer, 2010, Ghosh, 2010). The latter factor in particular has led to a small but growing body of research on the potential drivers of this divergence, much of which has centered on the role of speculative activity in commodity markets as a potential source of price distortions.

Much of the earliest analysis on the impact of speculation has focused on the influx of new cash in the form of passive index investments in commodities, which accelerated rapidly in the period immediately preceding the first spike in prices (see e.g. Ghosh, 2010, Masters, 2008). As I discuss in Section III below, their analyses have met with mixed acceptance in the literature (for a critical review of this debate, see Irwin and Sanders, 2011). Although it is rarely discussed, one of the key limitations of their analysis is the fact that this behavior is typically treated as "speculation," even though passive index investment tends to be long-term and strategic rather than the short-term activity implied by the term "speculator." This focus on index investment as the sole form speculation has resulted in a lacuna in the analysis of the role of financial investors which this paper seeks to fill. Using a behavioral framework that draws from sociology and financial economics, I demonstrate that trading activity in food commodities has become increasingly embedded into broader speculative trading activity across purely financial markets. In doing so, I seek to contribute a novel approach to quantifying embedding in the sociological literature while also complementing and building on existing work on the role of speculation in the ongoing food crisis.

The paper is organized as follows. The following section lays out the analytical framework, and is followed by a section on the changing structure of the commodity markets. The fourth section examines the literature on price formation in commodity markets. The fifth section outlines the two hypotheses which I test using the data set described in the sixth, and models described in the seventh. The complexity and importance of specification and lag selection for these models necessitates a separate treatment, which is incorporated into section eight. Section nine presents the results, and the paper closes with a discussion of substantive and methodological questions for future analysis.

<u>Section II. Theoretical Framework</u>

Economic analysis of finance-related crises often focuses on concepts of contagion and spillover of information and risk across financial markets (see e.g. Khalid and Kawai, 2003). While the two terms are often used interchangeably, Masson (1999) defines them more precisely. A spillover results from the transmission of price behavior from one market to another across explicit structural linkages. Eatwell & Taylor (2000) point to the interconnections of the global financial system as a primary mechanism of spillover between capital markets and banking systems. By contrast, contagion is the transmission of price or economic effects across seemingly unrelated markets in the absence of obvious connections.[1] The movement of risk from purely financial markets into food prices falls into the latter camp, and is the pattern on which I base this study.

The notion of contagion is a useful starting point, but begs questions about both the nature of linkages between markets as well as the agents whose behavior results in the movement of risk across them. The sociological concept of embeddedness partially fills this gap by providing a framework for the analysis of linkages (Granovetter, 1985). Embeddedness asserts that economic actors do not operate in isolation, but are rather embedded in larger networks of relations that inform (but do not determine) their actions. White (2002) extends this idea to markets by treating the embedding of a given market as an aggregate function of the embeddings of its constituent firms and individual traders. By implication, a change in the population of the traders within a market should (all things equal) trigger a change in the embedding of that market.

---

[1] Technically, Masson defines this as an unexplained, non-linear jump from one equilibrium to another. Dungey et al. (2005) note that this empirically usually ends up appearing as an unexplained residual.

The agents of interest for this study are financial speculators, a group that has historically played a minor role in agricultural futures markets (Peck, 1985) but has recently become far more active, as I show below. For clarity, I define financial speculators as traders whose interests are short-term, and whose behavior is driven by the observations and expectations of other traders rather than the underlying fundamentals of agricultural commodities (Keynes, 1936, Harrison and Kreps, 1978). Recent work in the social studies of finance provides evidence that such traders are cognitively embedded in a global "micro-structure" (Knorr Cetina and Bruegger, 2002) in which their attention is focused on the information visible through their screens (Beunza and Stark, 2011). To the extent that traders are invested in multiple assets, their "relational attention" (Prato and Stark, 2011) makes them prone to base their analysis of individual investments on information and analysis from other portfolio holdings, a key behavioral mechanism of spillover in financial markets (UNCTAD, 2011). The behavior of these investors is thus embedded in the broader range of markets in which they trade.

These characteristics imply that the entry of financial speculators into commodity markets would embed commodities into broader networks of speculative activity. The final question is how to identify such a change in embedding. Both economics and (increasingly) economic sociology point to market prices as providing such evidence. Since the prices produced in markets are social objects (Beckert, 2011, Beunza, Hardie and McKenzie, 2006, Knorr Cetina, 1997), it is reasonable to expect that they will contain evidence of the changes in the ecology of the agents producing them. Beja (1976) describes the information efficiency of financial market prices as being a function of both the extent to which they supply evidence, as well as the type of evidence they supply. Taken together, the economics and sociology of financial markets support

the analysis of market prices as indicators of changes in both the nature and the extent of changes of the embedding of commodity markets.

My tests for these effects are based on the econometric concept of cointegration, which is appealing for both empirical and theoretical reasons. The method was first developed by Granger and colleagues in a series of papers (Granger and Newbold, 1974, Engle and Granger, 1987) to address the behavior of economic and financial time series in modeling. These series tend to be non-stationary, meaning their mean and particularly their variance change over time, making traditional regression methods inappropriate. If a linear combination of two or more non-stationary time series is itself stationary, then the series are said to be cointegrated. This is defined in the economic literature as a form of equilibrium relationship linking the variables in a given equation or system of equations. This system-level behavior is key, as it allows for the analysis of prices in the context of larger groupings of indicators. For this study, I use this concept of cointegration among seemingly unrelated price series as an empirical indicator of embeddedness.

Finally, a word on causality. Many of the ideas for this study come from papers by Ghosh (2010) and Timmer (2009), each of whom argues convincingly that speculation played a role in the food crisis. Although this paper provides some evidence to support their causal arguments, my methodological approach is to use the information content of prices as containing signals of the presence of speculators. While these signals can in turn be interpreted as indications of a causal role in price formation, this is distinct from attributing the crisis itself to these speculators.

Testing for variable embeddings within this framework require an understanding of the nature and behavior of the speculators involved in commodity markets, as well as the dynamics of commodity price formation. Each is discussed further in the following sections.

Section III. Empirical Setting: The Changing Structure of Food Commodity Markets

There have historically been two types of market for agricultural commodities. The first of these are physical or spot markets, where trading in physical quantities of grain, pork bellies, etc. takes place. The agents in these markets include a mixture of farmers, purchasing companies and their intermediaries. As Çaliskan (2010) demonstrated in his study of the global markets for cotton, there is no single, global spot market but rather a branching network of regional, national and local markets where various commodities are traded in direct transactions. The spot markets are thus directly embedded into both the production and the consumption of agricultural commodities.

The modern commodity futures market grew out the centuries-old practice of hedging price risk through dyadic commitments between producers and buyers, in which each side attempts to lock in a price in the present for a transaction to take place in the future. Beginning in the second half of the 19th century, a series of steps moved away from this practice and toward futures. These involved the decoupling of direct relational commitments and a re-embedding of those commitments in a central clearinghouse, as well as a decoupling from the need to take delivery (Peck, 1985). The final stage of the process was the standardization of these commitments into contracts that could be sold to third parties. These practices evolved into the modern futures market in which millions of standardized futures contracts trade daily on a series of regulated exchanges in major financial and agricultural centers. The agents trading in these markets have historically been a combination of hedgers seeking to manage their future price risk, balanced by speculators seeking to assume future price risk for an expected profit. Importantly, these agents were until recently specialists in agricultural commodities and thus

driven by the logic of agricultural production. Moreover, the joint involvement by hedgers in both spot and futures markets created the tight linkages between the two types of market.

Swaps and the Financialization of Agricultural Futures

The Commodity Futures Modernization Act of 2000 was enacted in a period of intense support for financialization in the U.S., and included measures that effectively barred government oversight of over-the-counter (OTC) derivatives transactions for all but agricultural commodities. The Act specified that the Commodities and Futures Trading Corporation (CFTC) would retain oversight of derivatives in agricultural markets given their social importance. Although then-chair of the CFTC Brooksley Born argued strongly (and presciently) against the exemptions for OTC derivatives, she was overruled by stronger voices in the executive branch who pushed successfully for the bill's nearly unanimous passage in large part on arguments for the anticipated gains in efficiency for financial (as opposed to commodity) portfolio management (Schmitt, 2009). The passage of the bill resulted in an explosion of volume in the swap market, effectively all of which occurred off of regulated exchanges, and thus outside of the view of regulators as well as other market participants.

The mainstreaming of swaps in the financial industry had a range of unintended consequences, key among which was an innovation that opened the agricultural commodity markets to large institutions such as pensions just as they began seeking to diversify away from volatile equity markets. Although diversified commodity indexes had existed for decades, the logistics of investing across so many different commodity markets had made them more a source of data than an investment strategy (much as the S&P 500 Index was before Vanguard introduced the stock index mutual fund). With swaps, it became possible for an investor to buy an index fund from a vendor offering passive, diversified commodity investment. The vendor

would then enter into a swap arrangement with a bank, which would commit to deliver the vendor return of the index. The bank would in turn hedge its exposure by taking direct positions in the various futures comprising the index, allowing the bank to deliver an unregulated OTC swap while also conforming with the 2000 Act by limiting its trading of commodities to traditional futures contracts on regulated exchanges. The rapid growth in the market for index swaps created a complex set of linkages between investors, investment banks and swap markets, as well as a direct linkage through hedging activity to individual futures markets.

The concurrence of rapid growth in index fund assets and the first wave of the food crisis led to intense media and Congressional scrutiny of the role of index investments in triggering the spike in food prices. A 2009 Senate committee report indicated that the rapid increase in the use of index swaps had driven from one third to one half of all wheat futures activity from 2006 to 2009 (U.S. Senate, 2009). An article from 2008 asserted that commodity index funds held futures controlling the equivalent of 50% of the physical wheat, corn and soybeans in the U.S. as of March of that year (Wilson, 2008). In widely publicized testimony to Congress, hedge fund manager Seth Masters asserted that 39% of activity in commodity futures markets in the prior year had been the result of index speculation, based on his own calculations relating the timing of the influx of assets to the timing of the price increases (Masters, 2008).

While these statistics appear damning, efforts to prove a casual role for index investment on prices have produced an unconvincing mix of results. The lack of transparency in the swaps market has limited econometric analyses of the effect of index investment on commodity prices to using data on weekly changes in trader positions as a proxy for index investment, making their models dependent on self-reported and unconfirmed data (for a critical review, see Irwin and Saunders, 2011). While some have identified a causal role (e.g. Gilbert, 2010), in many cases the

findings were like those of Masters (2008), and were based on correlation in timing rather than rigorous causal proof.

Perhaps the biggest problem with most of these studies is that they only partially describe speculation in the commodity markets. The institutional roles governing the futures market assign all participants to the categories of "speculator" or "hedger," which has resulted in the categorization of all financial activity as speculation. While this categorization is true to the institutional roles of the futures market, it elides the distinctions between fundamentally different approaches to investment in commodities by large institutional investors. Passive index investment is generally done with the objective of diversifying a long-term asset allocation by capitalizing on the fundamentally divergent dynamics of financial and commodity markets (see e.g. Idzorek, 2006). This sort of strategic investment is the antithesis of short-term speculative activity. It is also not consistent with the full pattern of food price behavior over the course of the crisis. Given the basic dynamics of supply and demand, an influx of long-term "long" (meaning positions that benefit from rising prices) index investors would be entirely consistent with the enormous spike in prices in 2007 and 2008. That said, the long-term nature of these investments means that such an influx would make little sense as an ongoing driver of volatility, particularly the equally rapid drop in prices over much of 2008. A more complete analysis of the role of financial speculators requires a fuller understanding of truly speculative activity in commodity markets, as I describe below.

Wall Street, Hedge Funds and Commodity Speculation

The combination of increased commodity prices and rising profitability from creating swaps led to a significant increase in the involvement of Wall Street firms in the food futures markets, an increase that intensified with the collapse of the housing market. The period of 2006

and 2007 was an especially intense period of hiring by investment banks, many of which doubled

the size of their commodity trading desks even as they were laying off thousands of employees in

other areas (Kishan, 2007). Proprietary trading desks have several characteristics that align them

closely with this study's working definition of speculation. First, they operate across all major

asset classes, seeking profits purely from trading (rather than production) activity. Second, their

trades tend to be short-term in nature (GAO, 2011). Finally, they take both long positions

designed to benefit from rising prices (as index investors do) and short positions that allow them

to benefit from falling prices.

Wall Street's competition for trading talent came from hedge funds, which were enjoying

their own surge in demand due to a shift in demand from institutional investors. With

correlations between commodities and traditional assets rising, reducing the diversification

advantage of passive index positions, pensions and other institutions began to shift from passive

commodity index investments and into actively managed hedge funds able to balance risks

between both long and short positions (UNCTAD, 2011). Like Wall Street proprietary desks,

these funds are designed to capitalize on the liquidity of futures markets by trading more

aggressively both within and across markets, and in some cases across multiple asset classes. A

series of client surveys by investment bank Barclays Capital details the rapid growth in investor

interest in these funds.[2] The first survey was conducted in 2005, and indicated that the majority

of surveyed investors were primarily interested in the diversification provided by passive

investments. By 2007, however, survey participants' primary objective for their commodity

investments had shifted to active management and the pursuit of the sort of "absolute" returns

---

[2] Sourced from press releases available at http://www.barcap.com/About+Barclays+Capital/Press+Office/ News+releases

promised by hedge funds. By the 2011 survey, 60% of those surveyed expected to hire an actively managed commodity fund, up from the prior record of 43% in the prior year.

A recent study of the effects of financialization on commodity markets by the United Nations Commission on Trade and Development (UNCTAD, 2011) provided some evidence of the effects of this change on commodity markets. The authors compared the correlations between select commodity prices and the passive index investment flows discussed above, as well as between commodity prices and the investment positions of active managers (a category that includes hedge funds). Although the data likely suffers from the same self-reporting issues as the index data, the analysis did indicate that correlations between index investment flows and commodity prices fell sharply in 2009, while those between active manager positions and commodity prices were far higher. By implication, active managers appear to have played a larger role in commodity markets than prior analyses have taken into account.

Section IV: Price Dynamics in the Commodities Literature

In a widely cited chapter, Peck (1985) makes both a logical and an empirical case for the leading role of futures markets in price discovery for spot markets, meaning that the information in prices appears first in futures markets before it is reflected in spot prices. Such a pattern is typically described as the futures price "dominating" the spot price. This is true primarily for storable commodities, and less so for non-storable commodities such as cattle. Peck's conclusions confirm those of Garbade and Silber (1983), who found that futures markets dominate cash markets for storable commodities, with more than 75% of price discovery for wheat and corn occurring in futures markets. Their specification is based on the timing of information flows, so that in cases where the cash market gets information earlier, price discovery will happen there. These findings are echoed in several other studies (see e.g. Gorton

and Grouwenhorst, 2006, and Hernandes and Torero, 2010), and imply that the futures markets

are the appropriate point of departure for the study of price dynamics.

The price effects of linkages between commodity futures and other financial markets

have been well established in the economic literature on commodity price formation. In a widely

cited study, Bessembinder and Chan (1992) found that futures market prices can be forecast

using the same sorts of common factors as traditional equity and bond prices (in their case,

equity dividend yield, the three-month Treasury yield and the "junk bond premium" or the yield

of BAA less the yield of AAA- rated debt). By contrast, they found that the risk premia in each

asset class stemmed from different sources, indicating that commodity and traditional financial

markets are distinct but linked through the price mechanism. Their results were confirmed by

Bjornson and Carter (1997).

More recent studies have found a wider range of factors reflected in commodities prices,

key among which are signs of changes in speculative risk preferences. Etula (2009) examined the

effect of changes in Wall Street bank balance sheets on a range of commodities on the theory

that such changes would trigger changes in risk appetite leading to changes in the flow of money

into commodity markets. Etula found a statistically significant impact primarily for energy, but

also for wheat futures and spot prices (though not corn), equity market volatility and credit

spreads. Hong and Yogo (2009) also find evidence of risk appetite as a causal factor in price

formation. In addition to common market factors like those used by Bessembinder and Chan, the

authors incorporate a measure they call "aggregate basis" that captures relative appetite for

financial futures relative to physical assets traded in the spot markets, and thus captures shifts in

general preferences within the futures markets. Hong and Yogo find that this measure (when

aggregated across an equally weighted basket of commodity sectors) accounts for just as much of

the variance in commodity returns as the common factors, and that the impact of basis on prices has increased in recent years.

Several studies have also found that the effects of these speculative factors have been dynamic, and have generally grown stronger in recent years. In a study that partially motivated my use of Granger tests, Timmer (2009) tested a series of financial and non-agricultural indicators as predictors of rice prices, and found that these indicators Granger caused rice prices more frequently since the early years of the past decade. Tang & Xiong (2010) find an increasing correlation between agricultural commodities and oil in the years following 2004, well in advance of the financial crisis. They also determined that the pattern of increased correlation across commodities was markedly different than in past crises, indicating that different factors have been at work in more recent years. In a similar vein, Philips and Yu (2009) analyzed the returns of financial markets, commodity markets and currency markets, and found evidence of a bubble that appeared first in equity markets from 1995 to 2000, then migrated to real estate from 2001 to 2007 before manifesting in select commodities. Etula (2009) also noted that that the strong predictive power of his model broke down during the first commodity price spike in the second and third quarters of 2008, but recovered when prices fell later in the year.

A recent review of the evidence of financialization in commodity markets by the United Nations Commission on Trade and Development found consistent signs of increased correlations between individual commodities and commonly used portfolio trades (e.g. long positions in the Brazilian Real), as well as between futures markets and shifts in unrelated economic data (UNCTAD, 2011). Moreover, the report presented evidence from other studies that the recent price movements in commodity markets had many of the characteristics of information cascades and herding behavior by speculators. The authors took these patterns (which became prevalent in

the final years of the past decade) as evidence of a change in the logic driving price discovery in

the futures markets, which they determined had moved away from their traditional role of

transparent price formation to one driven by the logic of finance and speculation.

Section V. Hypotheses

Based on this information, I test the following two hypotheses:

H_1: *The <u>degree</u> of embedding of agricultural commodity markets into speculative networks of*

activity has increased since the entrance of speculators into futures markets.

More specifically, the rapid growth of Wall Street commodity trading and the turning point

in demand for commodity hedge funds noted in the Barclays Capital surveys both occurred in

roughly 2007, indicating that the shift in the embedding of commodity markets should be

evident from that time forward.

H_2: *Due to the behavior of short-term traders, the <u>nature</u> of the embedding should also*

change dynamically during the same period.

Since speculative traders tend to work across multiple markets, the linkages their behavior

creates should also vary over time. This should in turn produce a varying set of influences on

commodity prices.

Section VI. Data

Given the identification strategy, the non-commodity time series will need to proxy the

trading strategies of speculators. The challenge is that these strategies are proprietary

information. In the absence of direct knowledge, I use a combination of currency, risk and asset

class exposures that have been identified by academic finance research on the feasibility of

hedge fund replication as providing reasonably effective proxies for the trading behavior of

speculative portfolios (Amenc et al, 2010, Fung and Hsieh, 2001, Hasanhodzic and Lo, 2007),

along with several other measures that capture purely financial effects far removed from agriculture. All of the price series below are publicly available through the Bloomberg system, and are grouped by their functions within diversified portfolios.

Commodity Prices

The three most widely traded agricultural commodities globally are wheat, corn and rice. While it would seem optimal to test for financialization effects in all three, there are several factors which argue against including rice in the analysis. First, rice is among the most thinly traded of commodity markets, with estimates of only 7% to 8% of all production traded on markets (Timmer, 2009). This means that responses to changes in other markets are likely to be distorted by the relatively small trading volume. More important, the central role of rice as a staple of diets in Asia means that the bulk of trade is direct, rather than on markets. This pattern of trade makes rice particularly vulnerable to state-level interventions in the market. Slayton (2009) documents the impact of policy decisions during the food crisis by exporters to impose export controls, as well as by importers to accelerate purchases, as a major factor in the first wave of the food crisis. Given the possibility for such interventions to overwhelm other price effects, this study focuses solely on wheat and corn.

For the variable *Wheat*, the study uses daily settlement prices of the Kansas City Board of Trade Generic First-Month Contract (Bloomberg Ticker KW1). The U.S. is the world's largest exporter of wheat, accounting for 27% of the global market (Stroade, Taylor & Boland, 2010). Winter wheat accounts for just under half of U.S. wheat production, and is by far the largest variety produced domestically (ibid). Among the variety of maturities available, the study uses data from the contract closest to expiration, meaning a contract with anywhere from three months to one month remaining. This segment of the wheat futures market has historically been

the most active in terms of open interest (JPMorgan, 2011), indicating a level of liquidity that would likely appeal to more speculative, short-term hedge fund and proprietary desk traders. The front end of the market is also commonly used in tests involving commodity prices (see e.g. Etula, 2009, Bessembinder and Chan, 1992, Tang and Xiong, 2010).

For the variable *Corn*, I use the Chicago Board of Trade Generic First-Month Contract (Bloomberg Ticker C 1). Like the wheat contract, the C 1 contract captures the first three months of the corn market, which is the most active segment (JPMorgan, 2007). Also like the generic wheat contract, it has the added benefit of adjusting for the "roll" or the need to adjust to the price of a new contract every three months when the current contract expires. This feature obviates the need to calculate rolled returns for the full 12-year period as papers that follow the Gorton and Rouwenhorst (2006) methodology do. A preliminary test comparing the Bloomberg default rolled prices for cotton and wheat against manually computed prices (not included in this paper) indicated that the latter incorporated unnecessary volatility around roll dates, confirming the attractiveness of the pre-calculated Bloomberg series.

Competing Portfolio Allocations

Unlike commodity specialists, speculative traders typically manage portfolios that are diversified across multiple asset classes. As a result, these asset classes can be seen as competing with commodities in terms of asset allocation, so that changes in the prices of competing asset classes will be related to changes in the prices for commodities due to the micro-, meso- and macro-level linkages discussed above.

In the case of equities, I incorporate this effect through two series. The first tracks the daily performance of the S&P 500 Index, which is the most widely followed benchmark for U.S. equities. It is captured by variable *SPX*. Increasing prices in *SPX* can be interpreted as rising risk

tolerance in the broader markets since they would be consistent with investors buying equities as opposed to less volatile bonds. The test also incorporates an even more volatile time series, in this case one that tracks the daily performance of the MSCI Emerging Markets Index, coded *EM*. Emerging markets have historically produced higher returns than U.S. equities, but with more volatility. As a result, they serve in this study as an indicator of speculator preferences for significant equity risk. These and other index definitions are incorporated in Appendix A.

Rather than asset-class returns, the tests for contagion from credit markets are based on the approach traders use to these asset classes. Quotes for investment grade bonds are typically discussed in terms of incremental spread above the Treasury yields, given that the yield of bonds consists of the risk-free rate (typically the Treasury with the nearest maturity) plus a risk-based spread above the Treasury yield. The study disaggregates corporate yields into a Treasury component and a corporate spread component to capture this effect, and to avoid overlapping factors between Treasury and other securities. For the Treasury yield, variable *TSY* uses daily futures prices for the 10-year U.S. Treasury note. The corporate credit spread is captured by the variable *BAA*, which uses daily index prices from the U.S. Corporate 10 Year BAA Spread Index. This index measures the yield spread between the Moody's BAA corporate index yield and the yield of the 10-year TSY. The yield spread is both a tradable asset as well as an indicator of investors' perceptions of credit conditions. Those conditions are in turn a function of a combination of factors including interest rates, the economic prospects for indebted companies and other factors that drive both prices and traders' decisions about those prices.

The final competing allocation is Gold, for which I use the daily spot price to create the variable *Gold*. Gold is among the oldest of asset classes as well as a hedge against inflation.

Currency Indicators of Risk Preference

Relative currency levels serve two functions in financial markets. Within speculative portfolios, they offer an arbitrage opportunity for "carry trade" returns by which investors borrow (or go short) in the currency of a market with very low interest rates and invest (or go long) in securities in a market with higher interest rates. In many cases, investors involved in this trade will also use the proceeds to take highly speculative, short-term positions in riskier markets. As a result, the carry trade directly reflects the attractiveness of the sort of cross-border speculative activity this study seeks to identify. This effect is proxied by the variable *BRL*, which tracks the daily price of the Brazilian Real (a high-yielding currency) relative to the Yen (a very low-yielding currency).

In contrast to the Brazilian Real, a small group of currencies are commonly viewed as safe harbor in times of economic, political and market volatility. Increasing prices of such "safe haven" currencies can thus be interpreted a sign of investor preference for perceived safety. The Swiss Franc is one such currency, and its returns are incorporated by the variable *CHF*, the daily closing price of the Swiss Franc (or CHF) relative to the U.S. dollar.

Liquidity and Systemic Risk

Speculative traders typically run portfolios that rely on borrowed funds to control significantly larger assets than their actual cash holdings. As demonstrated by Etula (2009), changes in the cost of funding can have a significant impact on traders' risk appetite, and thus on speculative trading. Certain funding costs also act as proxies for the broader health of the financial system, which is comprised largely of the large banking institutions whose trading desks are of interest. I capture both of these effects by using the TED Spread, which is both a measure of perceived risk in the financial system as well as a proxy for the funding cost for

banks seeking to finance their own trading activity and, by extension, the ability of their hedge fund clients to secure the funding they also rely on from the banks (Brunnermeier, 2009). A higher TED Spread (incorporated as the variable *TED*) indicates more stringent liquidity conditions for banks, as well as a perception of increased risk in the financial system.

Volatility

The final variable in the study captures volatility in the U.S. equity market by use of the CBOE VIX Index, whose daily prices are incorporated in the variable *VIX*. The VIX index captures the "implied" volatility of U.S. equities as derived from trading in S&P 500 options. Those options are also, however, tradable instruments that are frequently used by hedge fund managers seeking to express a view on the U.S. equity market. As a result, the VIX is both a tradable time series as well as a key indicator of the sort of market dynamics that drive portfolio decisions.

Adjustments

To address non-normal distributions in several of the time series, I log transform the five variables with the most significantly skewed distributions: Wheat, Corn, EM, BAA and TED.

Descriptives

Although it would be unwise to draw strong conclusions about a single data set spanning several market regimes, the table of cross correlations below provides some support for the study. In most cases, the correlations appear to support the thesis of integration between the commodity futures and the indicators of speculative activity. For example, the corporate yield spread or BAA is correlated with the same sign as the commodities, indicating that higher yield spreads (a signal of declining risk tolerance in the bond market) are correlated with higher commodity prices (a signal of increasing risk tolerance in the commodity markets).

Table 1: Cross Correlations

	Wheat	Corn	SPX	EM	TSY	BAA	Gold	TED	BRL	CHF	VIX
Wheat	1.000										
Corn	0.919	1.000									
SPX	0.135	0.101	1.000								
EM	0.822	0.765	0.442	1.0000							
TSY	-0.642	-0.656	0.506	-0.419	1.000						
BAA	0.246	0.307	-0.637	-0.178	-0.506	1.000					
Gold	0.829	0.883	0.023	0.806	-0.733	0.251	1.000				
TED	0.483	0.297	0.237	0.371	-0.113	0.212	0.146	1.000			
BRL	0.264	0.229	0.769	0.478	0.375	-0.225	0.148	0.419	1.000		
CHF	0.827	0.850	-0.020	0.802	-0.783	0.126	0.922	0.187	-0.013	1.000	
VIX	0.131	0.174	-0.498	-0.236	-0.261	0.852	0.126	0.274	-0.118	-0.032	1.0000

This pattern is consistent with the thesis that the asset classes are being treated as substitutes in diversified portfolios. The negative TSY correlations with the commodities indicates that rising Treasury yields are correlated with lower commodity prices, which implies that risk aversion was expressed in similar ways across the Treasury and commodity markets during the period. The relationships between the BRL/JPY pair and the commodities were less strong but were consistent with the expression of risk appetite through simultaneous investment in the carry trade and in food commodities. The most surprising result was the high correlation between the TED spread and Wheat.

Section VII. Models

The tests for the two hypotheses each draw from the cointegration literature, though each draws on a different method.

Model 1: Johansen Cointegration Rank

The first hypothesis addresses the degree, rather than the specific nature, of cointegration across all of the time series in my data set. To test this hypothesis, I use a model developed by Johansen (1988, 1991, 1995) which estimates the following difference equation:

$$\Delta \boldsymbol{y}_t = \sum_{t=1}^{p-1} \Gamma_i \, \Delta \boldsymbol{y}_{t-1} + \Pi \boldsymbol{y}_{t-1} + \mu + \varepsilon_t \qquad\qquad (2)$$

In this model, $\boldsymbol{y}_t$ is a k x 1 vector of prices for all 11 variables on day t, and $\Delta \boldsymbol{y}_t$ is the first difference of those prices. The form includes a time-invariant constant μ and is conditioned on the errors ε_t being normally distributed and serially uncorrelated, though it does assume contemporaneous correlation. The parameter of interest is the coefficient matrix Π for the first lagged set of observations, which Johansen (1988) disaggregates into two components:

$$\Pi = \alpha \beta'$$

The β matrix is called the cointegrating matrix, and is a set of r cointegrating vectors, each with k coefficients, that describe the long-term equilibrium relationships linking the k variables in the system. Mathematically,this set of vectors is the basis of the space spanned by the columns of the β matrix, meaning the smallest number of linearly independent — and thus distinct – vectors that describe the equations linking all of the variables. Put another way, the cointegrating space is of dimension or rank r, and as a result, the r statistic is often referred to as the Johansen rank I test for r using Johansen's maximum likelihood test, which uses an iterative approach that repeats until it reaches a statistically significant value for the trace statistic, which is in turn based on the number of eigenvalues in the β matrix (Johansen, 1995). The test begins with the null hypothesis that the rank is less than or equal to 0, and iterates upward until it reaches a trace statistic that fails to reject the null.

In the context of this study, a higher r (or Johansen rank) indicates greater degree of cointegration among the 11 price series, and by extension a more intensive level of embedding of commodities into speculative activity. Similarly, changes in r would indicate changes in the level of embedding, consistent with my hypothesis that embedding is a dynamic process.

Model 2: Granger Causality

My second hypothesis concerns the effect of short-term trading horizons on embedding, and is intended to test for short-run variation in the types of cointegrating relationships between commodity prices and speculative activity in unrelated markets. Analysis of variation in the coefficients of the β matrix over time would seem logical. However, such analysis is highly complex in cases when the matrix includes $r > 1$ cointegrating vectors, as it requires both structural assumptions and calculations across both the cointegrating vectors and the short-term adjustments in the α matrix to arrive at a single normalized vector (Johansen, 1988).

Instead, I test for Granger causality (Granger, 1969). Although not itself a cointegration test, rigorous identification using Granger tests is conditioned in part on the presence of cointegration between the variables being tested. As a result, based on the presence of cointegration identified in Model 1, I use Granger tests to analyze the changes in relationships between the cointegrated variable pairs as a sign of changes in the nature of the embedding of each commodity.

The Granger test determines whether the addition of lagged values of a given variable x_t to a regression of another variable z_t on its own lagged values makes that regression more precise. Mathematically, the test identifies this effect as a reduction in the variance of the estimate of z_t in the regression including x_t relative to the variance of the estimate including only lagged values of z. Since the test is based on an improvement in prediction based on past values, it is often referred to as a test of "temporal relations" (Granger and Newbold, 1977) rather than of pure causality. Granger testing has been used widely in agricultural economics (see e.g. Thurman and Fisher, 1988, Torero and Hernandez, 2010), as well as more broadly to test the causal role of oil in macroeconomic stability (Hamilton, 1983) and the interaction of money

supply and income (Sims, 1972). In these studies, the test is used as an indicator of the flow of information from one market or time series to another, an interpretation I use below.

Rather than use the traditional bivariate approach used in these papers, I follow a recent paper on the Asian currency crisis of 1998 (Khalid and Kawai, 2003) in using a multivariable Granger test. I first fit a multivariable vector autoregression (VAR) as follows:

$$\boldsymbol{y}_t = \Gamma_1 \boldsymbol{y}_{t-1} + \ldots + \Gamma_p \boldsymbol{y}_{t-p} + \mu + \varepsilon_t \qquad (3)$$

As in the Johansen test above, $\boldsymbol{y}_t$ is a k x 1 vector of observations of the variables at time t, the errors are assumed to follow a normal distribution with no serial correlation, and p is the number of lags. Each Γ_i in the model is a k x k (or 11 x 11) matrix of VAR coefficients describing the cross-series relationships at a given lag. The formal Granger test determines whether the p coefficients (one for each lag) for a given independent variable are jointly 0 in the predictions of the variable of interest during a given time period. If the test statistic is sufficiently large, I reject the null that variable x does not Granger cause z based on a Wald statistic that follows a χ^2 distribution. As noted in Greene (2003:590), using a Wald test statistic in this case relaxes the need for strict normality of the error terms.

The value of the multivariate approach in this context lies in the ability to Granger test each of the k-1 variables against the variable of interest, and to do so simultaneously. In addition to being more efficient, it also allows for the identification of the joint marginal contributions across all of the time series simultaneously. I test my hypothesis by looking for variation in the patterns of significant predictors of each commodity over time.

Section VIII. Specification Tests and Lag Selection

The tests underlying the two models impose significant demands in implementation, each of which I describe further below.

Orders of Integration

Cointegration analysis is predicated on the variables being used having the same order of integration, which Engle and Granger (1987) define as the number of differences needed for a given time series to become stationary, or to have no unit root in its error terms. One of the most widely used tests to identify the order of integration of time series is the Augmented Dickey-Fuller (ADF) test. The ADF test estimates the following equation:

$$\Delta y_t = \alpha + \beta y_{t-1} + \sum_{j=1}^{p} \theta \Delta y_{t-j} + e_t \qquad (4)$$

The null hypothesis for the test is $\beta = 0$, which is to say that there is a unit root in the time series. A rejection of the null implies that there is no unit root, and that the data are stationary.

Implementing an ADF test requires specification of the p term, which captures the number of lags over which new information continues to have an effect on the data.[3] It is standard practice to select the lag based on information criteria such as Aikake's Information Criteria (or AIC) or Schwarz's Bayesian criteria (SBIC). Ng and Perron (1995), however, demonstrated that these approaches (which don't take into account the characteristics of the data) tend to underestimate the optimal lag, and that rules-based approaches in general are not efficient and can yield widely varying results. Instead, they propose a "general to specific" method of lag selection that uses iterated ADF tests on the data. I followed this approach, and used Schwert's (1989) rule to establish the maximum lag for the ADF tests. For confirmation, I used a generalized least squares version of the estimator proposed by Elliott, Rothenberg and Stock (1996), which transforms the data in order to identify the optimal lag selection following Ng and Perron (1995).

---

[3] The test often involves a trend term as well, though given the need to test the variables over a 12-year period marked by multiple market cycles, a single trend was highly unlikely. The ADF tests thus do not include a trend term.

The lags selected through this process are listed in the second row of Table 2, and the

ADF test statistics using this lag are reported in the third. As confirmation of these results, I

include a second unit root test with the opposite null hypothesis, namely that there is no unit root.

The test statistics for this test (the KPSS) are reported in the third row of Table 2. The final row

includes the results of an ADF test using the first-differenced version of each series. If the ADF

and KPSS tests indicate a unit root in the levels of a series, while the ADF test for a unit root in

the first difference finds none, then a series is integrated of order one, or I(1).

Table 2: Orders of Integration
Parentheses contain critical values at 95% confidence

	Wheat	Corn	SPX	EM	TSY	BAA	Gold	TED	BRL	CHF	VIX
Lags	23	23	28	26	12	24	28	27	27	20	16
ADF	-1.380 (-2.860)	-1.042 (-2.860)	-2.027 (-2.860)	-1.089 (-2.860)	-1.596 (-2.860)	-1.931 (-2.860)	2.156 (-2.860)	-2.484 (-2.860)	-2.126 (-2.860)	-0.835 (-2.860)	-2.851 (-2.860)
KPSS	0.499 ‡ (0.146)	0.904‡ (0.146)	0.716‡ (0.146)	0.834‡ (0.146)	1.530‡ (0.146)	1.240‡ (0.146)	2.110‡ (0.146)	0.709‡ (0.146)	1.060‡ (0.146)	0.542‡ (0.146)	1.920‡ (0.146)
Diff ADF	-11.169‡ (-2.860)	-10.996‡ (-2.860)	-10.172‡ (-2.860)	-9.021‡ (-2.860)	-14.901‡ (-2.860)	-8.910‡ (-2.860)	-10.468‡ (-2.860)	-13.101‡ (-2.860)	-9.360‡ (-2.860)	-10.873‡ (-2.860)	-13.730‡ (-2.860)

‡ p<0.01

In each case, the ADF test for the variable failed to reject the null hypothesis, while the

KPSS test rejected the null, indicating the presence of a unit root (and thus non-stationarity) in

the levels. However, ADF tests of the first-differenced variables all rejected the null at 99%

confidence, indicating that the series are all I(1) and thus appropriate for use in cointegration

analysis.

Time Periods and Specification Tests

Constructing the tests involved two related decisions, each of which had a significant

impact on the form I ultimately chose. First, both the Johansen and Granger analyses require the

specification of a lag, as well more or less well-behaved error terms. Second, for the Johansen

tests, cointegrating relationships can be disrupted by unseen breaks in the cointegration vectors, leading to potentially spurious results if not identified properly (Hansen, 1992).

My initial approach to these issues was to break the 12-year period into three regimes, each of which began with a shift in price behavior. The first of these precedes the beginning of increasing prices, and thus provides a sort of control. The second regime preceded the food crisis, but was marked by a slow, sustained rise in prices as well as the beginning of the financialization patterns discussed above. The third regime began with the first spike in food prices in June 2007 and continued through September 2011, the end of the test data. It is also the period in which speculative behavior in commodity markets has been most prevalent.

Trial runs of the two tests using these three regimes made clear, however, that they were not appropriate given that the errors from trials for each did not conform, no matter what lag length I specified. This was likely due to a combination of noise from daily observations as well as the often dramatic changes in price behavior within the three regimes. I adjusted for these factors by breaking each of the three periods into several subperiods, and selected the subperiods based (wherever possible) on changes in price movements to minimize the impact of unseen cointegration breaks. The final structure for the tests is based on 12 subperiods, with two in the pre-financialization regime, four in the second regime of slowly rising prices and increasing financialization, and six in the regime since June 2007. I selected the subperiods in the final regime to coincide with the dramatic spikes and drops in prices in order to isolate potentially interesting relationships, as shown in Figure 1 below.

Figure 1: Identification of Testing Subperiods
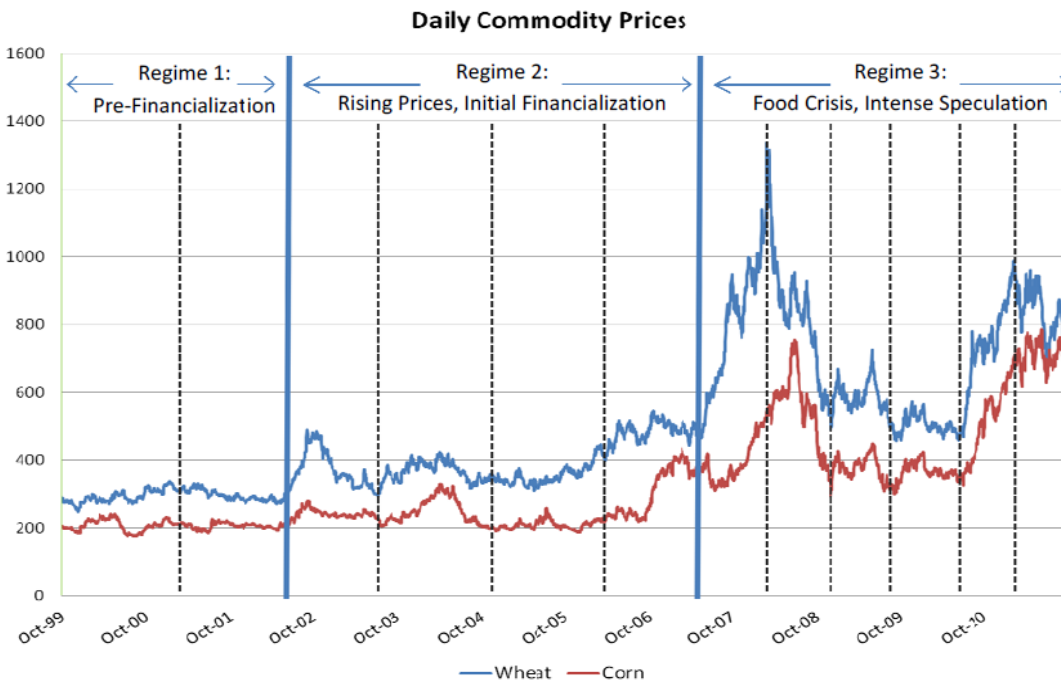
Data source: Bloomberg

Lag Selection for Modeling

In keeping with the spirit of Ng and Perron (1995), I based my lag selection on a theory about the data first, and then ran specification tests of both models across the time periods as described above using that lag to determine whether it was appropriate. A recently updated Federal Reserve Bank research paper exploited a natural experiment in the equity market to determine how many trading days are required for information to pass through the system, and determined that the timeframe was roughly five days (Carvalho et al., 2009). I chose to use five days as the initial lag based on this information. Fortunately, a five-day lag specification produced reasonable results in terms of the behavior of the error terms for both models.

Although the process of lag selection is typically treated as a necessary step toward more informative testing, the process yielded some preliminary insights into the data. In both the Johansen and Granger specification tests, the tests for normality of errors showed a clear shift in

the transition from the end of the second regime into the third. This shift is echoed in Figure 1 above, which shows that the third regime required a larger number of shorter time periods than did the other two regimes. The reasons for this pattern remain to be determined, but they were a prelude to the results of the formal tests discussed in the following section. Appendix B contains a more detailed discussion of the specification tests used and their findings.

Section IX. Results

The results of the Johansen cointegration tests for the various subperiods are presented in Table 3 below. The first row includes the Johansen rank, or the r statistic, which measures the degree of cointegration between the various indicators. The second row specifies the lag, and the third and fourth provide background information on the trace statistics that resulted from the test.

Table 3: Johansen Test Results

	Pre-Financialization		Rising Prices, Initial Financialization				Food Crisis, Intensified Speculation					
							Spike	*Drop*			*Spike*	
	10/99 – 3/01	3/01 – 6/02	6/02- 9/03	9/03 – 12/04	12/04- 3/06	3/06- 6/07	6/07- 3/08	3/08- 12/08	12/08– 9/09	9/09– 6/10	6/10– 1/11	1/11- 9/11
Rank	0°	2°	2	2	1	2	4	5	5	5	4	2
Lag	5	5	5	5	5	5	5	5	5	5	5	5
Trace Statistic	223.80	144.15	173.61	180.60	220.62	186.11	115.21	92.71	87.55	86.80	117.81	184.96
Critical Value	233.13	156.00	192.89	192.89	233.13	192.89	124.24	94.15	94.15	94.15	124.24	192.89

° Due to data limitations, neither of the first two subperiods includes the TED spread.

The numbers can be volatile and are highly sensitive to lag selections, so it would be unwise to read too much into any single number. That said, the results support the first hypothesis of increased embedding in speculative activity. After spending most of the first two regimes at 2, the cointegration rank doubled to 4 at the outset of the third regime, which is the period I categorize as including the most intensive speculative activity, and remained at 4 or 5 through early 2011. This sustained increase in cointegration indicates that (all things equal) food

markets in the period since the first wave of the food crisis have been more embedded in speculative flows of information than they have in the recent past.

The results from the final subperiods are more difficult to interpret. The test results for the final months of the 12-year data set showed a drop in cointegration rank from 5 to 2, returning to the rank of earlier regimes. Although this result could have been a fluke of the data, it was confirmed in both of the Granger tests below. I discuss possible reasons for this pattern in the Discussion section that follows.

Figure 2 below provides a more intuitive perspective on the Johansen tests by relating the cointegration rank to the evolution of commodity prices. The chart plots daily wheat and corn futures prices over the measurement period, along with the cointegration results (each diamond represents the cointegration result tested at the end of that period, as in the table above). The commodity prices are plotted on the left axis, and the cointegration rank on the right.

Figure 2: Commodity Prices and Cointegration Rank
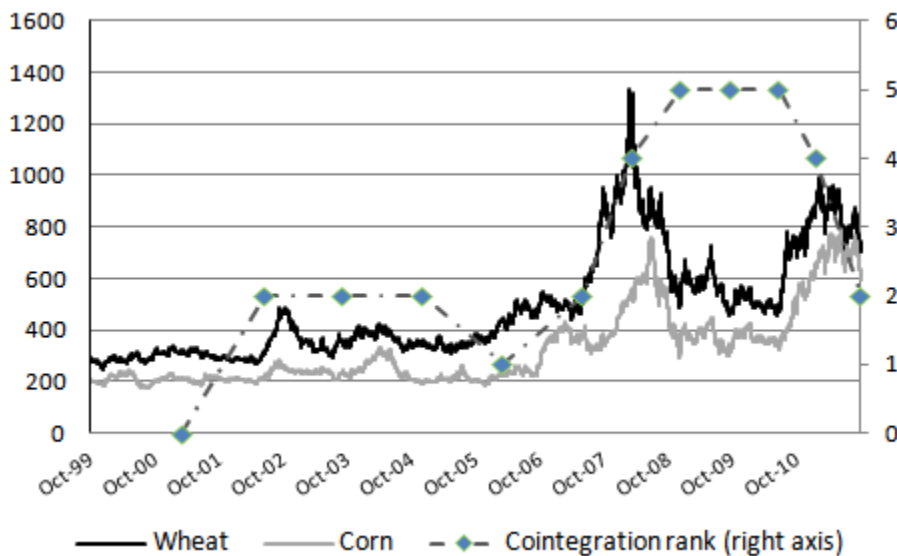
Data source: Bloomberg

The chart shows that the cointegration rank climbed sharply with the first spike in food prices, then climbed to its peak in the ensuing drop in prices. The sustained high level of

cointegration implies that the embedding of food prices into speculative activity was at its greatest when prices were falling as well as during the volatile period between the two spikes. Such a pattern would be inconsistent with the definition of "speculators" as including only index investors given their long-term buying activity. It is, however, entirely consistent with the entrance of investors able to profit from both falling and volatile prices.

Granger Tests

The following two tables show the results of the Granger tests for which Wheat and Corn, respectively, were the dependent variables. Since the variable of interest is simply the χ^2 statistic for the Wald test, I omit the statistics (which are all positive by definition) in favor of simple indicators of statistical significance.

Table 4: Wheat Granger Analysis

	Pre-Financialization		Rising Prices, Initial Financialization				Food Crisis, Intensified Speculation					
							Spike	*Drop*			*Spike*	
	10/99 –3/01	3/01 – 6/02	6/02-9/03	9/03 –12/04	12/04-3/06	3/06-6/07	6/07-3/08	3/08-12/08	12/08–9/09	9/09–6/10	6/10-1/11	1/11-9/11
Wheat												
Corn		**						***		***		
SPX					***				**			
EM				*	***	*	*			***		
TSY						***	**	***	***		*	
BAA					***		***		**			*
Gold								***	**			
TED					**			***	**	***	**	**
BRL			***				*	**	*			
CHF									**	**		
VIX					**			***	*			*
Rank	0°	2°	2	2	1	2	4	5	5	5	4	2
Lag	5	5	5	5	5	5	5	5	5	5	5	5

***, ** and * represent p< 1%, 5% and 10%, respectively
° Due to data limitations, neither of the first two subperiods includes the TED spread.

The Wheat Granger test results show a clustering of speculative financial influences on wheat prices in the period from early 2006 through June of 2010, with a particularly strong

increase in the four subperiods beginning with the first drop in prices. The strongest support for my hypothesis of increased speculative embedding is the peak of cross-market influences beginning with the first drop in food prices in late 2008, and ending just before the second spike in prices in 2010. This behavior is consistent with the entry of speculative investors able to take both long and short positions, rather than the static long exposures taken by passive index investors. It is also consistent with the pattern of increasing hedge fund and proprietary desk involvement over these subperiods. Like the Johansen tests, however, the Granger tests for Wheat (and Corn, as shown below) showed a steep drop in the information flow from other markets into the wheat market in the final subperiods.

The variation in the significant predictor variables across the subperiods also provides support for my hypothesis of dynamic embedding. There were no variables that appeared as significant in all time periods, indicating that the traders involved in the wheat market were also involved in a varying range of other asset classes over the measurement period. Among the competing portfolio allocations, emerging markets equities (EM) and Treasury yields (TSY) were the most consistently predictive of wheat prices, with the latter generally attaining higher levels of significance. There is no fundamental reason for the yield of U.S. sovereign debt to be reflected so strongly in wheat prices, which implies that the financial logic of speculative traders rather than the production logic of agricultural specialists was the link between the two markets. The same was true, albeit less frequently, of corporate bond yield spreads (BAA).

The indicators of financial risk preferences provided even stronger evidence of the presence of financial traders in food futures markets. The most consistently significant predictor of wheat prices across the 12 subperiods was the TED spread (TED), an indicator of bank liquidity as well as systemic financial risk. Together with Treasury yields, this is the most

compelling evidence of the increased integration of food markets into speculative financial activity, especially given the sustained significance TED across the entire third regime. The tests also indicated that the Brazilian Real carry trade (BRL) and the VIX (VIX) were each relatively frequent predictors of wheat prices. The latter is particularly interesting given that the VIX is a direct measure of investors' expectations for future volatility in the S&P 500. The latter was only a significant predictor of wheat prices in two subperiods, while expected equity volatility predicted wheat prices in four.

Like the wheat tests, the Granger results for Corn (shown in Table 5 below) were clustered around the first wave of the food crisis, though the peak in cross-market information flow was more tightly concentrated in the 18 months beginning with the rapid drop in prices that began in March 2008. The results also differed from those of the wheat tests in that the range of effects spanned more subperiods, with a varying array of significant predictors in each one.

Table 5: Corn Granger Analysis

	Pre-Financialization		Rising Prices, Initial Financialization				Food Crisis, Intensified Speculation					
							Spike	*Drop*			*Spike*	
	10/99 – 3/01	3/01 – 6/02	6/02- 9/03	9/03 – 12/04	12/04- 3/06	3/06- 6/07	6/07- 3/08	3/08- 12/08	12/08– 9/09	9/09– 6/10	6/10– 1/11	1/11- 9/11
Wheat			***		*	**			**	***		**
Corn												
SPX						***			*			
EM			**				**			***		
TSY					**	**	*	***	**			
BAA			***					***	*			
Gold		***			**	**	*	***				
TED							*	***	**			**
BRL				*				*	***			
CHF	*								**			
VIX						**	***	**	***			
Rank	0°	2°	2	2	1	2	4	5	5	5	4	2
Lag	5	5	5	5	5	5	5	5	5	5	5	5

***, ** and * represent p< 1%, 5% and 10%, respectively
° Due to data limitations, neither of the first two subperiods includes the TED spread.

Because of this span, there were no single predictors that were as consistently significant as was the case with the wheat tests. Among competing portfolio allocations, the S&P 500 (SPX) and emerging markets equities (EM) were each significant in a relatively small number of periods. The lack of relationship between Corn and EM was a marked change from the wheat results. Corporate credit spreads (BAA) were also only significant in three of the 12 subperiods, though Treasury yields (TSY) were more frequently predictive of corn prices. The price of gold was also strongly related to the price of corn, and like Treasury yields, its significance was largely clustered around the first wave of the food crisis.

As with the wheat tests, the behavior of the risk measures in the corn tests indicated a tighter integration with speculative financial sector activity in the period of increased speculation. The behavior of the VIX was unusually concentrated during the four subperiods of the most intensive cross-market information flows, where it was the only predictor that was significant at at least 5% across all four subperiods. The TED spread was less consistently significant, but was also the only speculative indicator reflected in corn prices in the final subperiod.

Section X. Discussion

The fact that both tests gave consistent results from different perspectives provides confirmation of both the model selection as well as the two related hypotheses. Substantively, the two tests identify different patterns, so it is conceivable that they would produce different output. The Johansen test does not say anything about the actual relationships between specific variables beyond their linearity, so there is no way to know whether a given coefficient is statistically significant without further analysis of the β matrix. By contrast, the Granger test looks specifically at whether the inclusion of a given variable reduces the variance of the estimates of

another variable based on its own lagged values, and gives a direct measure of statistical significance in that relationship. The differences in structure between the two mean that there is no reason for the Granger test to identify the same number of statistically significant relationships *between* variables as the Johansen test finds *across* them.

The two tests were equally consistent in their divergence from the hypothesis of increased cointegration in the final two subperiods, which were marked by even greater investment in commodity hedge funds than earlier subperiods. One possible empirical driver for this divergence is the passage of the Dodd-Frank financial regulation, which included measures that led most Wall Street banks to sell or spin off their proprietary trading operations, particularly those involving commodities. Many of these teams have taken advantage of strong demand for commodity hedge funds by either starting their own firms or moving to larger, more established hedge funds. It is not clear how this would affect the embeddings given the lack of more than anecdotal data, but there is a possibility that this shift in the market structure has had an impact.

Another possible reason is the impact of high-frequency trading (HFT). This strategy involves algorithmic trading by extremely powerful computers that can execute thousands of transactions per second. The banks and hedge funds using HFT have historically operated primarily in the equity and bond markets, but have recently been reported by some industry experts as moving into the liquid commodity markets (Sheppard and Spicer, 2011). Although there are no data to support these reports, it is conceivable that the entry of these firms could disrupt existing cross-market relationships by reducing the lag time for information flow from days to as little as minutes or even seconds.

Threats to Validity

The primary threat to construct validity in my models is my interpretation of the Johansen cointegration rank. This statistic is typically interpreted in binary terms as indicating whether a set of time series are cointegrated or not given that most econometric tests are done in order to identify the more specific information I analyze using the Granger tests. It may be that this is the more valid approach, but given my interest in embedding as a form of integration into larger systems, using an increase in the dimension of the cointegrating space as an indicator of increasing cointegration is both mathematically and empirically motivated.

My approach to controlling for confounding threats to internal validity was to be as rigorous as possible in ensuring that the model and tests I used were statistically sound, while also recognizing the realities of empirical work. My original intent was to expand on Timmer (2009), who conducted a series of two-variable Granger tests of the effect of various non-commodity factors on rice prices over the 2000 to 2009 period, using rolling six-month windows based on daily observations. Timmer's paper provided the core idea for this study. Further work will replicate his tests for wheat and corn, but my interest in the cross-linkages between the commodity prices and the other indicators made this approach of testing two series at a time less efficient. The challenge of testing for the behavior of error distributions across so many time periods was also formidable.

The approach I ultimately used allowed for more direct control over testing parameters, but introduced a separate set of risks in terms of the surprisingly unstructured process of lag selection. Although I do not include the results in this draft, I tested several alternate lag specifications to measure the effect of using only lags that strictly delivered conforming errors. The results were unpalatable, in that they tended to result in very different specifications for the

Johansen and Granger tests. The best solution was to return to the Ng and Perron (1995)

approach of testing a lag selection driven by theories about the data rather than adherence to

objective rules. This produced the specification tests I discuss in greater detail in Appendix B.

While the resulting errors were not perfect, they were sufficiently conforming to support the

results I present in the prior section. More important, they allowed me to compare results across

the two tests since each used the same information.

Directions for Future Work

Having confirmed the viability of the two models, it would be interesting to expand the

approach to incorporate other types of variables in order to test for related effects. In particular,

both oil and housing prices have played significant roles in financial market dynamics in recent

years, albeit in different ways. Incorporating measures of underlying fundamentals could provide

a form of control for non-financial effects, though the challenge would be to identify reliable

sources of such data. It would also be advisable to incorporate a measure of investor demand for

commodities distinct from prices, perhaps in a modified form of Hong and Yogo's (2009)

orthogonalized "aggregate bias" measure of relative demand for futures and spot prices.

It would also likely be productive to look across other agricultural commodities with

active futures markets, such as soybeans, sugar, coffee, tea and orange juice. Many of these other

commodities have had far more significant volatility in the most recent wave of rising prices,

indicating that speculators may be rotating across commodities in addition to other speculative

markets. Testing for changes in the relationships between these commodities could also provide

insight into the effects of the movement of commodity trading out of Wall Street banks and into

dedicated hedge funds in the wake of the Dodd-Frank legislation.

Conclusion

The embedding of food prices in broader speculative activity calls into question the long-term viability of food systems with financialized markets at their core. As the collapse of commodity broker MF Global has recently shown, commodity markets can be just as vulnerable to misconduct and instability as the more widely followed debt and equity markets. This instability only confirms the implicit warnings of Karl Polanyi, who first used the term "embedding" to refer to the macro-level enmeshing of economic activity into the social (1957). In writing about the absence of exchange markets in pre-modern societies, Polanyi pointed out that these cultures had strictly enforced a separation between competitive exchange markets and the trading of food in order to maintain social stability. While it is difficult to imagine the global food system of today working without such markets, it is also clear that we ignore Polanyi at our peril.

REFERENCES

Amenc, N., Martellini, L., Meyfredi, J.C., and Ziemann, V. (2001). Passive hedge fund replication – beyond the linear case. *European Financial Management, 16*(2), 191-210.

Arezki, R. and Bruckner, M. (2011). Food prices and political instability. *IMF Working Paper 11/62*,

Beckert, J. (2011). Where do prices come from? Sociological approaches to price formation. *Socioeconomic Review, 9*(4), 757-786.

Beja, A. (1976). The limited information efficiency of market processes. Institute of Business and Economic Research Working Paper No. 43, University of California, Berkeley.

Bessembinder, H. and Chan, K. (1992). Time-varying risk premia and forecastable returns in the futures market. *Journal of Financial Economics, 32*(2), 169-193.

Beunza, D., Hardie, I., and MacKenzie, D. (2006). A price is a social thing: Towards a material sociology of arbitrage. *Organization Studies, 27*(5), 721-745.

Beunza, D. and Stark, D. (2011). From dissonance to resonance: Cognitive interdependence in quantitative finance. Available at SSRN: http://ssrn.com/abstract=1285054. Accessed September 18, 2011.

Bjornson, B. and Carter, C.A. (1997). New evidence on agricultural commodity performance under time-varying risk. *American Journal of Agricultural Economics, 79*(3), 918-930.

Brunnermeier, M.K. (2009). Deciphering the liquidity and credit crunch 2007-2008. Journal of Economic Perspectives, 23(1), 77-100

Çalişkan, K. (2010). *Market threads: How cotton farmers and traders create a global economy*. Princeton: Princeton University Press.

Carvalho, C., Klagge, N., and Moench, E. (2009). The persistent effects of a false news shock. Federal Reserve Bank of New York Staff Report No. 374, updated version of June 2011. Accessed at: http://www.newyorkfed.org/research/staff_reports/sr374.pdf, on October 1, 2011.

Dungey, M., Fry, R., Gonzalez-Hermosillo, B. and Martin, V. L.(2005). Empirical modeling of contagion: a review of methodologies. *Quantitative finance, 5*(1), 9-24.

Eatwell, J. and Taylor, L. (2000). *Global finance at risk*. New York: The New Press.

The Economist. (2008). The silent tsunami. Print edition of April 17, 2008. Accessed at http://www.economist.com/node/11050146?story_id=11050146, December 10, 2010.

Eicher, C. K. (1982). Facing up to Africa's food crisis. *Foreign Affairs, 61*(1), 151-174.

Elliott, G., Rothenberg, T.J. and Stock, J.H. (1996). Efficient tests for an autoregressive root. *Econometrica, 64*(4), 813-836.

Engle, R., and Granger, C.W.J. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica, 55*(2), 251-276.

Etula, E. (2009). Broker-dealer risk appetite and commodity returns. Federal Reserve Bank of New York Staff Report No. 406, November.

Fung, W. and Hsieh, D. (2001). The risk in hedge fund strategies: evidence from trend followers. *The Review of Financial Studies*, *14*(2), 313-341.

Garbade, K. D., and Silber, W. L. (1983). Price movements and price discovery in futures and cash markets. *The Review of Economics and Statistics, 65*(2), 289-297.

Ghosh, J. (2010). The unnatural coupling: Food and global finance. *Journal of Agrarian Change*, *10*(1), 441-454.

Gilbert, C.L. (2010). Speculative influences on commodity prices 2006-2008. UNCTAD Discussion Paper No. 197, March.

Gorton, G., and Rouwenhorst, K. G. (2006). Facts and fantasies about commodity futures. *Financial Analysts Journal, 62*(2), 47-68.

Government Accountability Office (2011). *Proprietary trading: Regulators will need more comprehensive information to fully monitor compliance with new restrictions when implemented.* GAO Report 11-529. Accessed at http://www.gao.gov/htext/d11529.html on November 5, 2011.

Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral

methods. *Econometrica, 37*(3), 424-438.

Granger, C.W.J and Newbold, P. (1974). Spurious regressions in econometrics. *Journal of Econometrics, 2*(1974), 111-120.

Greene, W.G. (2003). *Econometric analysis*. Upper Saddle River, New Jersey: Pearson Education.

Hansen, B.E. (1992). Tests for parameter instability in regressions with I(1) processes. *Journal of Business and Economics Statistics, 70*(1), 99-126.

Hamilton, J.D. (1983). Oil and the macroeconomy since World War II. *Journal of Political Economy, 91*(2), 228-248.

Hamilton, J.D. (1994). *Time series analysis*. Princeton, New Jersey: Princeton University Press

Harrison, J.M. and Kreps D.M. (1978). Speculative investor behavior in a stock market with rational expectations. *The Quarterly Journal of Economics, 92*(2), 323-336.

Hasanhodzic, J. & Lo, A. (2007). Can hedge fund returns be replicated? The linear case. *Journal of Investment Management, 10, 321-335*.

Hernandez, M. and Maximilian Torero (2010). Examining the dynamic relationship between spot and future prices of agricultural commodities. IFPRI Discussion Paper 00988, International Food Policy Research Institute, Washington D.C.

Hong, H. and M. Yogo. (2009). .Digging into Commodities..Working Paper.

Idzorek, T.M. (2006). *Strategic asset allocation and commodities*. Ibbotson Associates, commissioned by PIMCO. Accessed at: http://corporate.morningstar.com/ib/documents/ MethodologyDocuments/IBBAssociates/Commodities.pdf on June 3, 2011.

Irwin, S.F. and Sanders, D.R. (2011). Index funds, financialization, and commodity futures markets. *Applied Economics Perspectives and Policy*, *2011*, 1-31.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control, 12*(2), 231-254.

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica,59*(6), 551-580.

Johansen, S. (1995). *Likelihood-based inference in cointegrated vector autoregressive models*. Oxford: Oxford University Press.

J.P. Morgan Global Commodity Research (2007). *Introducing the JPMorgan Commodity Curve Index*. Accessed at: http\\www.jpmorgan.com\directdocs\CCI_Introduction.pdf on October 7, 2011.

Keynes, J.M. (1936). *The general theory of employment, interest, and money*. Amherst, New York: Prometheus Books, 1997 paperback edition.

Khalid, A.M. and Kawai, M. (2003). Was financial market contagion the source of economic crisis in Asia? Evidence using a multivariate VAR model. *Journal of Asian Economics, 14*(2003), 131-156.

Kishan, S. (2007, October 17). Commodity traders drive hiring amid credit shakeout, Bloomberg News, accessed at http://www.bloomberg.com/apps/news?pid=newsarchive&sid=ausWiwNk8kWY on November 20, 2011.

Knorr Cetina, K. (1997). Sociality with objects: Social relations in postsocial knowledge societies. *Theory, Culture & Society, 14*(4), 1-30.

Knorr Cetina, K., and Bruegger, U. (2002). Global microstructures: the virtual societies of financial markets. *American Journal of Sociology, 107*(4), 905-950.

Masson, P. (1999). Contagion: monsoonal effects, spillovers and jumps between multiple equilibria. In P.R. Agenor, M. Miller, D. Vines & A. Weber (Eds.), *The Asian financial crisis: causes, contagion and consequences* (pp. 265-283). Cambridge: Cambridge University Press.

Masters, S. (2008). *Financial speculation in commodity markets: are institutional investors and hedge funds contributing to food and energy price inflation?*, Testimony to Committee on Homeland Security and Governmental Affairs, U.S. Senate, 110th Sess.

Ng, S. and Perron, P. (1995). Unit root tests in ARMA models with data-dependent methods for the selection of truncation lag. *Journal of the American Statistical Association, 90*(429), 268-281.

Peck, A.E. (1985). The economic role of traditional commodity futures markets, in A.E. Peck (Ed.),

Futures markets: their economic role (pp. 1-81). Washington, DC: American Enterprise Institute.

Phillips, P.C.B. and Yu, J. (2010). Dating the timeline of financial bubbles during the subprime crisis. Cowles Foundation Discussion Paper No. 1770, Cowles Foundation for Research in Economics, Accessed at http://cowles.econ.yale.edu/P/cd/d17b/d1770.pdf on September 14, 2011

Piesse, J. and Thirtle, C. (2009). Three bubbles and a panic: an explanatory view of recent food commodity price events. *Food Policy*, *34*(2009), 119-129.

Polanyi, K (1957). The economy as instituted process, reprinted in *The sociology of economic life* (pp. 29-51). Boulder: Westview Press.

Prato, M. and Stark, D. (2011). Attention structures and valuation models: Cognitive networks among security analysts. Working paper.

Schneeweis, T. and Spurgin, R.B. (1998). Multifactor analysis of hedge fund, managed futures, and mutual fund return and risk characteristics. *Journal of Alternative Investments, 1*(2), 1-24.

Schwert, G.W., (1989). Testing for unit roots: A Monte Carlo investigation. *Journal of Business & Economic Statistics, 7*(2), 5-17.

Sheppard, D. and Spicer, J. (2011). Analysis: High-frequency trade fires up commodities. Bloomberg Online, June 17, 2011. Accessed at http://www.reuters.com/article/2011/06/17/us-commodities-highfrequency-idUSTRE75G0MT20110617 on November 10, 2011.

Sims, C.A. (1972). Money, income and causality. *American Economic Review, 62*(4), 540-552.

Stroade, J., Taylor, M. and M. Boland (2010). Hard red wheat profile, Kansas State University Agricultural Marketing Resource Center. Accessed at: http://www.agmrc.org/ commodities_products/ grains_oilseeds/wheat/ hard_red_wheat_profile.cfm on October 7, 2011.

Thurman, W. N. and Fisher, M. E. (1988). Chickens, Eggs, and Causality, or Which Came First? *American Journal of Agricultural Economics, 70*(2), 237-238.

Timmer, C. P. (2009). Rice price formation in the short run and the long run: the role of market structure in explaining volatility. Center for Global Development Working Paper Number 172, May 2009, Center for Global Development, Washington DC.

Timmer, C. P. (2010). Reflections on food crises past. *Food Policy, 35*(2010), 1-11.

United Nations Commission on Trade and Development. (2011). *Price fluctuations in financialized commodity markets: the role of information*. New York: United Nations.

U. S. Senate (2009). *Excessive speculation in the wheat market*. Permanent Subcommittee on Investigations, Committee on Homeland Security and Governmental Affairs, June 24, 2009. Accessed at http://hsgac.senate.gov/public/_files/ on November 20, 2010.

White, H.C. (2002). *Markets from networks: Socioeconomic models of production.* Princeton: Princeton University Press.

Appendix A: Index Definitions

Variable   Definition

BAA   **U.S. Corporate 10 Year BAA Spread**, from Bloomberg Industries, measures the spread between the Moody's BAA corporate yield and the yield of the 10-year U.S. Treasury note. *(Bloomberg: BICLB10Y)*

EM   **Morgan Stanley Capital International Emerging Markets Index** tracks the performance of 21 emerging markets globally. *(Bloomberg: MXEF)*

SPX   **Standard & Poor's (S&P) 500 Index**   is a capitalization-weighted index that tracks the performance of roughly 500 large-capitalization stocks trading in the United States. It is widely used as a proxy for U.S. equities. *(Bloomberg: SPX)*

TED   **TED Spread** captures the difference between three-month LIBOR and the three-month Treasury note. It is produced by the British Bankers' Association, or BBA. *(Bloomberg: BAPTSTP)*

VIX   **Chicago Board Options Exchange (CBOE) VIX Index** uses price quotes for options on the S&P 500 Index to create a real-time index of implied equity volatility. *(Bloomberg: VIX)*

Appendix B: Specification Tests

As noted in the text above, strict adherence with the conditions of the Johansen test requires that the errors of the underlying vector error correction model be normally distributed, and that they not exhibit serial correlation. Standard practice also requires testing the cointegration matrix for stability over the time period being measured. The following specification tests examine each of these factors within the subperiods being tested. The autocorrelation result includes the p-value for the χ^2 test statistic at two lag specifications, with a null hypothesis of no autocorrelation. The results show that the tests generally failed to reject the null in at least one of the specifications for each subperiod, though the tests were generally weaker prior to the subperiod beginning 6/07, which marked the beginning of Regime 3.

The test for normality of the error terms is called the Jarque-Bera test, and is calculated by STATA as the sum of tests for skewness and kurtosis. The test statistic also follows a χ^2. Because this test examines the errors from the vector error correction models for each individual variable regressed against all of the others (plus its own lagged values), the test reports normality for each equation by the dependent variable. I omit those in the table below in favor of noting how many equations failed to reject the null hypothesis of normality. Like the autocorrelation tests, the Jarque-Bera tests indicated a clear change in behavior at the transition into the third regime. While the results were generally much weaker prior to that, the combination of strong autocorrelation results and uniform stability made these results acceptable in my view.

Table 6: Johansen Specification Tests

Period	Lag	Autocorrelation p		Jarque-Bera Test	Stability
		1	2		
10/1/99 – 3/1/01	5	0.199	0.542	3 normal at 0.001	Stable
3/2/01 – 6/18/02	5	0.030	0.516	6 normal at 0.001	Stable
6/19/02 – 9/4/03	5	0.995	0.916	3 normal at 0.001	Stable
9/5/03 – 12/2/04	5	0.037	0.543	8 normal at 0.001	Stable
12/3/04 – 3/2/06	5	0.181	0.163	4 normal at 0.001	Stable
3/3/06 – 5/31/07	5	0.217	0.017	4 normal at 0.001	Stable
6/1/07 – 3/6/08	5	0.836	0.596	8 normal at 0.001	Stable
3/7/08 – 12/11/08	5	0.042	0.149	7 normal at 0.001	Stable
12/12/08 – 9/17/09	5	0.893	0.246	8 normal at 0.001	Stable
9/18/09 – 6/24/10	5	0.299	0.709	9 normal at 0.001	Stable
6/25/10 – 1/20/11	5	0.992	0.853	10 normal at 0.001	Stable
1/21/11 – 9/30/11	5	0.452	0.549	9 normal at 0.001	Stable

The specification tests for the vector autoregression model underlying the Granger test were similar to those for the Johansen test, with some adjustment. First, although I present the results for tests of normality in the error terms, that condition is not strictly required (Greene, 2003). Second, because I present only the results for the wheat and corn equations in the body of the paper, I show the p-values of the tests for each commodity's equation. Like the Johansen specification tests, the Granger specification tests showed a significant break in behavior at the boundary between the second and third regimes.

Table 7: Granger Specification Tests

Period	Lag	Autocorrelation p		Jarque-Bera Test p		Stability
		1	2	Wheat	Corn	
10/1/99 – 3/1/01	5	0.232	0.204	0.001	0.000	Stable
3/2/01 – 6/18/02	5	0.002	0.304	0.003	0.000	Stable
6/19/02 – 9/4/03	5	0.698	0.713	0.000	0.000	Stable
9/5/03 – 12/2/04	5	0.029	0.409	0.009	0.031	Not stable
12/3/04 – 3/2/06	5	0.099	0.212	0.000	0.000	Stable
3/3/06 – 5/31/07	5	0.290	0.254	0.000	0.058	Not stable
6/1/07 – 3/6/08	5	0.711	0.039	0.192	0.184	Stable
3/7/08 – 12/11/08	5	0.124	0.435	0.218	0.789	Not stable
12/12/08 – 9/17/09	5	0.686	0.290	0.199	0.000	Stable
9/18/09 – 6/24/10	5	0.063	0.008	0.052	0.266	Stable
6/25/10 – 1/20/11	5	0.697	0.485	0.137	0.349	Stable
1/21/11 – 9/30/11	5	0.450	0.596	0.142	0.123	Stable

Institute for Social and Economic Research and Policy
Columbia University in the City of New York
420 West 118th Street
8th Floor, Mail Code 3355
New York, NY 10027
Tel: 212-854-3081
Fax: 212-854-8925
Email: iserp@columbia.edu
iserp.columbia.edu

Administration

Peter Bearman, Director
Nancy Davenport, Associate Director
Shelley J. Klein, Assistant Director

FEBRUARY 2012