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Deconstructing Wheat Price Spikes: A Model of Supply and Demand, Financial Speculation, and Commodity Price Comovement

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Abstract

In 2008, wheat futures prices spiked and then crashed along with prices for other agricultural and nonagricultural commodities. Market observers offered several theories to explain this common movement, or comovement, in prices, and have proposed policies to address the perceived problem of excessive price volatility. The design of an appropriate policy response would benefit from a better understanding of the cause of the observed price movements. This study uses an econometric model to decompose observed wheat prices into a set of economic factors and measure the relative contribution of each factor to observed price changes. Findings show that market-specific shocks related to supply and demand for wheat were the dominant cause of price spikes in the three U.S. wheat futures markets. Fluctuations in the global macroeconomy associated with broadbased demand shocks were relatively less significant for wheat than for other commodities like crude oil and corn. Finally, little evidence suggests commodity index trading contributed to recent price spikes.

Keywords: Commodity prices, comovement, futures, index funds, speculation, wheat

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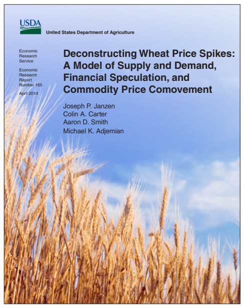

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Deconstructing Wheat Price Spikes: A Model of Supply and Demand, Financial Speculation, and Commodity Price Comovement

Joseph P. Janzen, Colin A. Carter, Aaron D. Smith, and Michael K. Adjemian

What Is the Issue?

Over the last 5 years, wheat futures prices spiked and then crashed along with prices for other agricultural and nonagricultural commodities. Market observers offered theories to explain this common movement, or comovement, in prices: macroeconomic shocks, correlated supply disruptions, and the influence of nontraditional speculative firms known as commodity index traders (CITs). The perceived role of speculators in the recent price spikes led market participants, policymakers, and economists to call for restrictions on the trading activity of CITs. This study examines the degree to which a comprehensive set of economic factors, including the trading behavior of CITs, contributed to recent dynamics in wheat futures prices.

More acreage is planted to wheat than any other commodity in the world, and wheat is used to make flour, bread products, cookies, cakes, and pasta. Wheat is also a significant source of animal feed. So, understanding wheat price spikes is an important step toward understanding food price spikes more generally. Since food in developed countries is heavily processed, wheat price shocks have only a small effect on U.S. consumers. However, these shocks can affect wheat producers everywhere, as well as consumers in developing countries who spend a large share of their household budgets on less processed cereals.

What Did the Study Find?

Supply-and-demand shocks specific to the wheat market were the dominant cause of price spikes between 1991 and 2011 in the three U.S. wheat futures markets (hard red winter, hard red spring, and soft red winter wheat). Focusing specifically on the February 2008 wheat price spike, the study finds that, depending on the market, wheat prices in that month would have been 40-62 percent lower in the absence of current crop year supply-and demand-shocks, such as unexpected weather events that lower wheat yields. Wheat prices would have been

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11-36 percent lower in the absence of precautionary demand shocks—which represent an anticipatory buildup of commodity inventories—associated with expectations about future prices.

To put these estimates in context, at the same time, per-bushel wheat prices increased by 300 percent on the Minneapolis Grain Exchange, from around $8 to $24. Alternative explanations for wheat price spikes had minimal impact in February 2008. Broadbased demand shocks associated with fluctuations in global economic activity had a 9- to 12-percent price impact. In contrast, similar studies have found that changes in real economic activity (inflation-adjusted production and consumption of goods and services) accounted for most of the recent price spikes for corn and crude oil. CITs contributed minimally to recent price spikes: the peak wheat price in February 2008 would have been only 1 percent lower in the absence of shocks attributable to financial speculators like CITs. Even at its maximum price impact between 2006 and 2011, financial speculation increased wheat prices by only 5-8 percent. These findings suggest that wheat futures markets have performed efficiently in the sense that wheat futures prices have reflected fundamental factors. Consequently, restrictions on commodity index trading are not likely to prevent future price spikes.

How Was the Study Conducted?

The study uses a structural vector autoregession (SVAR) econometric model to decompose observed wheat prices into a set of factors and to explain the relative contribution of each factor to observed price changes. These factors include: (1) real economic activity affecting the demand for all commodities, (2) passive or financial speculation by CITs based on a desire to hold baskets of commodities as part of a larger investment portfolio, (3) precautionary speculation related to expected prices in future periods and the incentive to hold wheat inventories, and (4) current crop-year supply-and-demand shocks specific to the wheat market. Structural shocks associated with each explanation represent the change in the wheat price caused by that factor, conditional on all past information about prices and other relevant economic variables. The model allows CIT-driven shocks to take precedence over wheat market-specific shocks; if the latter are found to drive more of the variation in prices, one can be confident that the CIT effect was given the best chance to reveal itself in the data.

Deconstructing Wheat Price Spikes: A Model of Supply and Demand, Financial Speculation, and Commodity Price Comovement

Introduction

Wheat futures prices spiked in early 2008 before rapidly crashing, though this hardly makes the wheat market unique; commodities such as crude oil, natural gas, corn, and cotton exhibited price spikes and crashes around the same time. But the magnitude of the wheat price spike combined with the coincidence of these other extreme price movements raises important questions. Were wheat prices driven by the same set of macroeconomic factors as the other commodities? Did wheat markets suffer from supply disruptions at the same time that the other commodities faced disruptions? Did the actions of futures market speculators and commodity index traders play a role? Past studies have provided divergent answers to these questions. For example, analysts at J.P. Morgan, an investment bank, suggest that wheat markets during this period "reflect(ed) unique fundamental storylines" and generated "rational and corresponding price signals": observed wheat price fluctuations were due to supply-and-demand factors specific to the wheat market (J.P. Morgan, 2010). In contrast, some observers claim that "excessive speculation" by large financial traders caused wheat futures prices to diverge from levels justified by supply-and-demand forces. This study provides new answers to these questions using an econometric model of price dynamics.

As part of the analysis, this study identifies economic mechanisms that could account for observed wheat futures price movement and quantifies their importance in explaining price behavior from 1991 to 2011, with particular emphasis on the 2008 period when prices for many commodities spiked. Price impacts are estimated for four factors: (1) macroeconomic influences on the demand for all commodities; (2) wheat-market-specific forces, such as the supply of wheat by farmers and demand from users such as millers and bakers; (3) the passive speculation associated with commodity index traders (CITs); and (4) more traditional speculation based on anticipation of future supply-and demand shocks in a single market. Macroeconomic shocks affecting all commodity markets could account for empirically observed common movement, or comovement, among agricultural and nonagricultural commodity prices. Some recent economic studies link comovement to speculative futures trading, particularly passive financial speculation, such as by CITs who trade simultaneously in many commodity markets. Unlike previous studies of commodity price comovement, this study distinguishes between two types of speculative demand for wheat and wheat futures contracts, one due to passive speculative trading associated with commodity index traders and one due to anticipation of future supply-and-demand shocks in a single market, in this case wheat.

Most recent criticism of the wheat futures price discovery process has focused on the impact of financial speculation and commodity index trading. Proposed policy interventions, including speculative position limits (Masters, 2011), virtual grain reserves (Von Braun and Torero, 2009), transaction taxes, and proprietary trading bans (UNCTAD, 2011), are motivated by the suggestion that price levels and price volatility in commodity futures markets did not reflect market-specific supply-and-demand conditions during the 2008 price spike due to the effects of commodity index trading. Identifying the causes of wheat price fluctuations and their relative importance is necessary to evaluate proposed policy interventions in commodity futures markets.

This study focuses on wheat for three reasons. First, more land is planted to wheat than any other crop in the world, and only corn and soybeans account for more acreage in the United States (USDA, Foreign Agricultural Service, 2011). So, understanding wheat price spikes is an important step in understanding food price spikes more generally. Second, the three major classes of wheat grown in the United States are traded on three separate futures markets (hard red winter, Kansas City; hard red spring, Minneapolis; and soft red winter, Chicago). These distinct but connected markets serve as a laboratory in which to analyze price volatility.[1] Third, the performance of these related futures markets has come under increasing scrutiny in the last decade. Price patterns in these markets have been very volatile and have not followed traditional relationships. In addition, expiring futures prices, particularly in Chicago and Kansas City, routinely far exceeded the prevailing cash price in their respective delivery markets, a phenomenon known as non-convergence. Some observers have linked non-convergence to the trading activities of large, passive speculators. Indeed, index trader holdings of Chicago wheat futures positions increased dramatically from 2004 to 2008 and accounted for more than 30 percent of open positions by 2008. But Garcia et al. (2012) and Adjemian et al. (2013) find that recent non-convergence can be attributed to storage market dynamics; they find no evidence linking index trader behavior to non-convergence. Still, the empirical question of commodity index trader impacts on wheat prices remains unanswered.

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[1]For example, the Chicago futures contract is much more widely traded and has much greater index trader participation than the other two contracts in Kansas City and Minneapolis.

Structural Factors Driving Wheat Price Variation

To construct a tractable econometric model, this study divides the structural or fundamental forces that drive wheat futures prices into four groups.[2] Descriptions follow for each structural factor and the likely sources of variation in these factors driving unexpected wheat price changes.

Global Real Economic Activity and Commodity Demand

Rapid economic growth and intense industrial activity tend to coincide, especially in less developed nations. This increased activity spurs demand for commodities and raises commodity prices.[3]

Clearly, prices of energy and industrial commodities, such as crude oil and copper, rise in response to economic growth and industrialization. Why would prices for agricultural commodities, such as wheat, respond similarly? First, higher energy prices imply higher costs of agricultural production and higher costs of transporting agricultural commodities. Second, greater real economic activity (measured production of goods and services adjusted for inflation) leads to rising incomes, which, along with population growth, constitute the standard set of demand shifters for food commodities like wheat (Antle et al., 1999). Rising incomes drive greater wheat consumption, particularly in developing countries where caloric intake is more responsive to income growth. Moreover, consumers in developing countries adjust their diets in response to newfound wealth, eating proportionately more meat and less grain. This change in diet diverts grain to animal feed use. Many pounds of grain are needed to produce a single pound of meat, so demand for feed grains increases and prices rise (Trostle, 2008). As large and developing countries, such as China and India, increase their consumption of wheat and meat, global economic activity, not just economic activity in wealthy nations, becomes the more appropriate price driver.

Other factors may also contribute to the link between global economic activity and wheat prices. Low interest rates make grain storage relatively inexpensive, which increases the incentive to hold wheat off the market, thereby raising prices. Frankel (1986) argues that, because the prices of grains such as wheat tend to be more flexible than retail prices, grain prices may overshoot in response to monetary stimulus. This phenomenon causes pronounced procyclicality in commodity prices, that is, prices may rise more than measured economic activity.

Wheat-Specific Supply-and-Demand Factors

Wheat-specific factors that contribute to price volatility may have either supply or demand origins, but consistent with price variation for most agricultural commodities, supply shocks appear to dominate shortrun variation in wheat prices. Once the crop is planted, supply is virtually perfectly inelastic, and shocks that shift the supply curve cause most price changes (Adjemian and Smith, 2012). In this light, wheat-specific supply-and-demand variation is termed a “net supply” shock.

Production is a function of acreage harvested and crop yield. Growth in global wheat production since 1960 has come from yield gains rather than acreage increases. Over the period, world wheat

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[2]We focus on major U.S. wheat classes: hard red winter, hard red spring, and soft red winter milling wheats; each of these has established U.S. benchmark futures prices (Antle and Smith, 1999).

[3]Carter et al. (2011) show that commodity price booms in both 1973-74 and 2007-08 were preceded by unusually high world economic growth, especially in emerging economies.

acreage has grown at an average annual rate of 0.04 percent, whereas yield has increased about 2 percent annually (table 1). Growth in world wheat yields rebounded in the last decade after falling in the 1990s when agricultural productivity dropped in Kazakhstan, Russia, and Ukraine. (For a review of the spatial and temporal distribution of world wheat supply, see box "Global Wheat Production.") Wheat yields in the United States have increased at a slower rate than global yields, leading to concerns about future productivity growth. Specifically, wheat-breeding efforts may have fallen behind the pace of genetic improvement for other crops (Carter, 2001).

Longrun trends in wheat production can be anticipated, so wheat prices remain volatile because of shortrun production variability. Weather, pests, and disease drive much of the variation in wheat yield, and their effects are difficult to anticipate, so prices adjust in response to quantity shocks (Adjemian and Smith, 2012). Both U.S. and world wheat supply vary considerably from year to year (see table 2). Production in a single country (like the United States) is more volatile than overall production worldwide. In the United States, planted acreage is particularly variable relative to yield. Globally, acreage and yield exhibit similar levels of year-to-year variation. Variability in acreage mainly reflects opportunities for substitution in production between wheat and other crops but also the potential for new land to be brought into production (Antle et al., 1999).

Wheat may be milled domestically for human consumption, used for animal feed, or exported to countries where demand exceeds production. In the 2011/12 marketing year, U.S. domestic wheat consumption was 32.1 million metric tons (mmt), of which just 14 percent was used for feed. In the same period, the United States exported 28.6 mmt of wheat. U.S. food use of wheat grew steadily from the 1960s until the late 1990s, leveling off at approximately 27 mmt annually, while world food use continued to increase (fig. 1). U.S. and world feed use of wheat exhibited a somewhat similar pattern during the period; world feed use, however, continues to grow though U.S. use has actually declined since the early 1990s (fig. 2). Annual growth rates in wheat consumption, both for feed and food, have been lower in the United States than in the rest of the world (see table 1). As noted earlier, population and income growth are the main drivers of global wheat consumption, and continued growth in global consumption has come from emerging economies where populations and incomes are rising the fastest (Carter, 2001; Alexandratos and Bruinsma, 2012).

Table 1

Growth in U.S. and world wheat production and consumption measures, 1960/61 to 2011/12 (average annual percentage change)

	United States				World			
Period	Area	Yield	Feed use	Food use	Area	Yield	Feed use	Food use
1960s	0.76	1.77	18.38	0.55	1.05	3.06	10.04	2.46
1970s	4.25	0.02	-7.71	2.00	1.20	2.07	1.47	3.05
1980s	-3.54	-0.27	6.28	2.05	-0.90	2.76	2.21	2.29
1990s	-1.28	1.30	-0.48	1.56	-0.41	1.07	-2.09	1.43
2000s	0.35	0.94	-9.45	-0.09	0.52	1.38	0.88	1.16
1960-2010	-0.02	1.10	2.15	1.46	0.04	2.01	2.29	2.04

Note: Growth rates are estimated using log-linear regressions of the form: ln(Y) = a + b*time, where the coefficient b represents a constant growth rate.

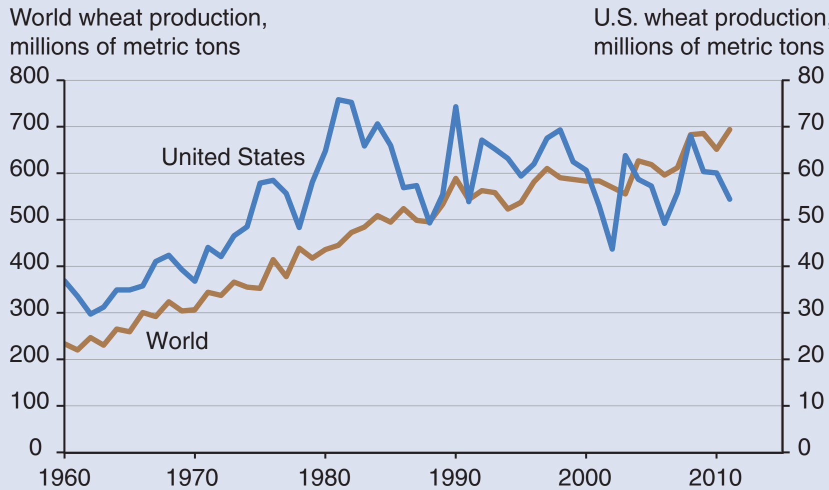
Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service (2011).

Global Wheat Production

For the 2011/12 marketing year, the global wheat harvest measured 697 million metric tons (mmt). Production in the United States was 8 percent of this total, or about 54.4 mmt (see box figure 1a). Since 1960, the global wheat supply has grown steadily, nearly tripling during the period. The U.S. share of global wheat production has shrunk over time, but the United States remains a major producer. The remainder of global production is concentrated in a number of countries; the European Union (EU), China, the former Soviet Union (mainly Kazakhstan, Russia, and Ukraine), India, Canada, Australia, Pakistan, and Argentina. On average, over the period 2002-11, these nations and the United States produced over 84 percent of the world's wheat. Production in most of these regions has remained relatively steady, with the notable exception of China, Kazakhstan, Russia, and Ukraine, where production has grown by approximately 25 percent in the last decade (USDA, Foreign Agricultural Service, 2011).

Box figure 1a

U.S. and world wheat production



Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service (2011), "Production, Supply, and Distribution Online," www.fas.usda.gov/psonline/

Regional production is specialized by class, both in the United States and abroad. The United States produces all classes of wheat, but production of each class is generally confined to specific U.S. regions. Hard red winter (HRW) wheat accounted for the largest share of production (39 percent) in the United States in 2011. U.S. production of HRW is concentrated in the Southern Great Plains. Soft red winter (SRW) wheat and hard red spring (HRS) wheat made up 23 and 20 percent of U.S. 2011 production, respectively. SRW is generally grown in States east of the Mississippi River and north of the Ohio River, but SRW production also occurs across the South from Arkansas to the Atlantic Coast. HRS is mainly grown in the Northern Great Plains (USDA, Economic Research Service, 2011). Canada primarily produces HRS. Most EU production is soft wheat; France, the United Kingdom, and Germany are the EU's largest producers. Australia grows winter wheat, much of it a white wheat with milling qualities similar to U.S. HRW. Argentina produces both hard and soft wheat (Taylor and Koo, 2011). Kazakhstan, Russia, and Ukraine grow both winter and spring red wheat, though wheat production and wheat quality are more variable in these countries than in North America (Liefert et al., 2010). China mainly produces white and red winter wheats, while in India, white wheats are predominant (Curtis, 2002).

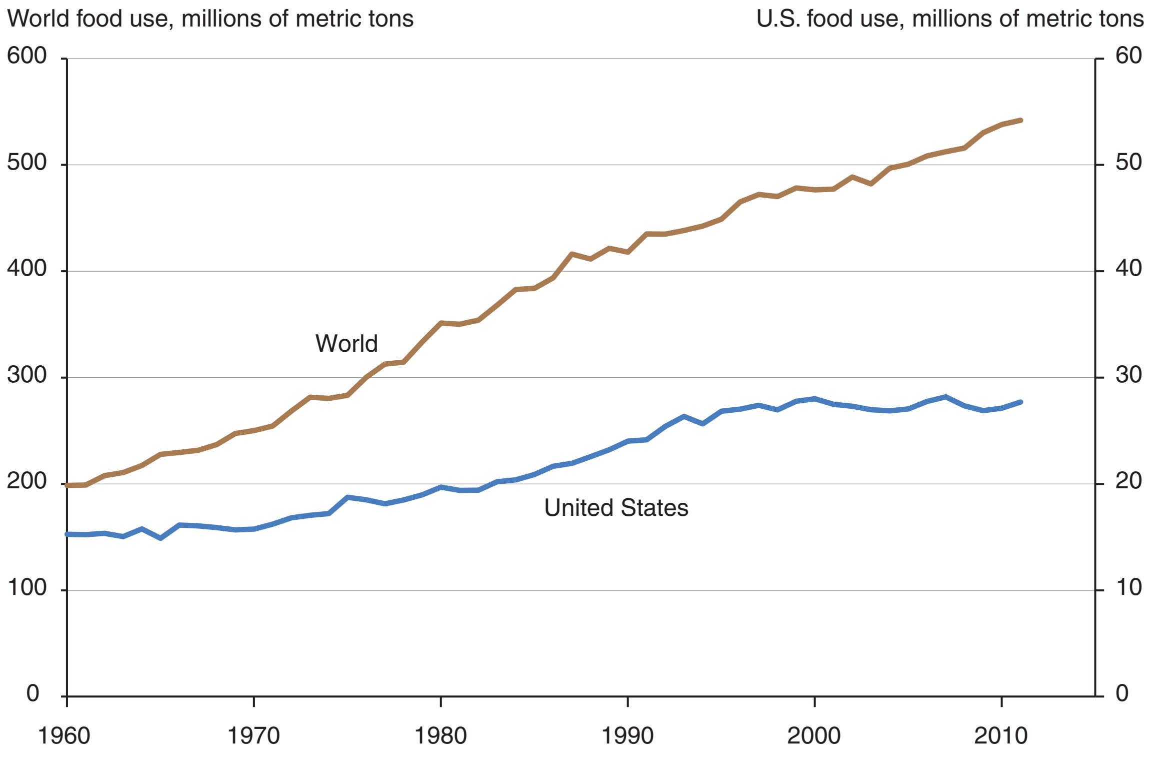
World regions also differ in planting and harvest timing. Regional price seasonality is dampened by global supply available throughout the year. Little wheat of any type is harvested globally in January or February, but wheat is harvested in significant quantity somewhere in every other month. India generally begins its harvest in March. U.S. and European winter wheat harvest generally begins in late May as Northern Hemisphere spring wheat planting is completed. Winter wheat harvest runs into the spring wheat harvest that begins in Canada and the United States in late July and continues through October. Harvest in major Southern Hemisphere producers Argentina and Australia occurs mainly in November and December. There, winter wheat crops are grown through the mild winters, with harvest occurring in the late spring and early summer (USDA, Office of the Chief Economist, 2011).

Table 2
Variability in U.S. and world wheat production and consumption measures, 1960/61 to 2011/12 (coefficient of variation (%) relative to linear trend)

	United States	World
Area	15.65	3.94
Yield	6.74	4.19
Production	17.66	6.36
Feed use	57.70	15.46
Food use	5.30	3.36
Exports	24.12	10.86

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service (2013).

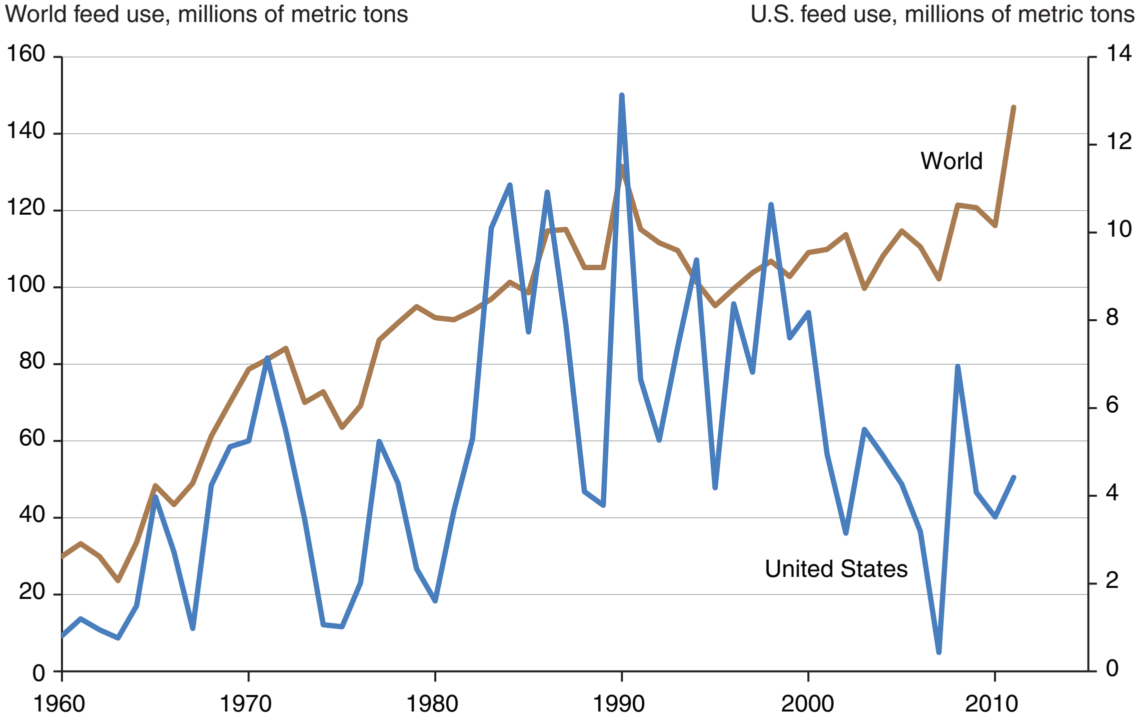
Figure 1
U.S. and world consumption of wheat for food use



Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service (2011), "Production, Supply, and Distribution Online," www.fas.usda.gov/psonline/

A comparison of figures 1 and 2 shows that wheat use for feed is smaller and more volatile from year to year than wheat use for human consumption. The proportion of the wheat crop used for animal feed depends on the quality of the wheat crop and the price of wheat relative to other feed grains, such as corn. Thus, wheat competes with other agricultural products both in production and consumption. The feed market is an outlet for lower quality wheat, and prices of other feed grains place a lower bound on potential wheat prices (Chambers, 2004). When wheat prices are high and

Figure 2
U.S. and world consumption of wheat for feed use



Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service (2011), "Production, Supply, and Distribution Online," www.fas.usda.gov/psonline/

crop quality is good, very little wheat is used for feed, as in the 2007-08 marketing year when wheat prices reached record-high levels. Crop quality issues may force wheat into the feed channel even when wheat prices are relatively high, as was the case in early 2011.

Supply fluctuations in exporting countries are particularly relevant to U.S. prices because these supplies represent direct competition for U.S. exports. Annually, U.S. wheat exports account for approximately 50 percent of U.S. wheat production and 25 percent of global wheat trade. For the world, trade accounts for approximately 20 percent of annual global consumption (USDA, Foreign Agricultural Service, 2011). The United States is therefore an integral player in the global wheat market and is the world's largest wheat exporter, competing with Canada, the European Union (EU), Australia, and Argentina. In addition, Kazakhstan, Russia, and Ukraine have also emerged as major wheat exporters. While their wheat production quality and their political climates are more volatile than those of other major exporters, their vast productive capacity gives them the potential to be major participants in wheat export markets (Liefert et al., 2010).

Table 2 shows the coefficient of variation for feed use, food use, and exports for both the United States and the world. Since 1960, U.S. feed use has been more variable than exports, which in turn have been more volatile than domestic food consumption. Variability in food use, which constitutes most of consumption, is lower than variability in production, so one might expect that price changes reflect supply variability more than demand variability.

Government intervention can be a source of unexpected variation in prices as policies alter the flow of wheat from production to end use. U.S. farm bill subsidy programs may affect wheat production and wheat prices, but the overall impact of current U.S. commodity subsidy programs on wheat prices is relatively small (Babcock, 2007). Trade controls by major wheat importing and exporting countries are more likely than farm subsidies to cause large, unanticipated commodity price fluctuations. Examples of trade controls include export taxes, restrictions, and bans on wheat imports in Argentina, Russia, Kazakhstan, Ukraine, Serbia, and India during the runup in wheat prices in 2007-08 (Trostle, 2008). Subsequently, Russia and other countries of the former Soviet Union continued to use export restrictions and state-trading enterprises to control domestic prices and the movement of wheat to export markets under a rationale of food security and economic nationalism (Wegren, 2011). In general, political objectives may supersede economic objectives in many major wheat-trading countries, with consequences for world prices. (For examples of economic activity and wheat-specific supply-and-demand driven price movements, see box "Recent Impacts of Global Economic Activity and Wheat-Specific Supply and Demand.")

Speculative or Precautionary Demand

When commodities are storable, as in the case of wheat, the contemporaneous fundamentals represented by the factors mentioned earlier do not fully explain price levels or price changes. Rather, storability implies that price volatility can be smoothed over time if speculative storers buy commodities when prices are low and bring inventories to market when prices are high. Merchants, users, governments, and other entities may hold such inventories based on their own expectations of future prices to provide a buffer against fluctuations in supply and demand.

Economists have formalized the relationship between current and expected future prices in rational expectations competitive storage models such as those described by Williams and Wright (1991). The competitive storage model essentially states that firms will hold inventories of storable commodities such that the current price equals the discounted value of the expected price in the future. This is a no-arbitrage condition. If discounted expected future prices exceed current prices, firms will add to current inventories and reduce the supply available for current consumption, raising the current price relative to the expected future price so that this condition holds. Thus, through stockholding behavior, expectations about future prices affect prices today.

The competitive storage model recognizes an important component of commodity demand related to expectations about prices in the future. Because this demand component is anticipatory in nature, it is referred to as "precautionary demand." In the presence of a futures market, the price of a futures contract normally represents the expected cash price in the delivery period for that contract.[4] Therefore, traders may profit from expectations about future supply-and-demand conditions by speculating on the price of futures contracts, in addition to adjusting inventories. (For a review of speculative trading in wheat futures markets, see box "Comparing the Three U.S. Wheat Futures Markets: Specifications and Trading Volume.") Futures trading motivated by precautionary demand is a form of speculative demand in the sense that "anyone buying not for current consumption but for future use is a speculator from an economic point of view" (Fattouh et al., 2012). However, informed speculation associated with precautionary demand is not the target of recent popular criticism, as

[4]Garcia et al. (2012) and Adjemian et al. (2013) point out that that for most domestic grain futures markets, the futures contract price actually represents the price of the delivery instrument used to satisfy the contract. Most of the time, this price is equal to the commodity cash price, but these prices can diverge under non-convergence.

discussed later in this section. That type of speculation is understood by economists as instrumental to the operation of a futures market (Working, 1970). Distinguishing the impact of precautionary demand on observed prices from current supply and demand and other speculative influences is the primary challenge in this study.

Two aspects of competitive storage models help to identify the effect of precautionary demand. The first relates to the physical limit restricting negative inventories. Inventories must be non-negative because future production cannot be brought forward to meet shortages in the present. Once inventories go to zero, demand for current consumption must equal current supply. If current supply is low, perhaps because of a poor crop, then prices for nearby delivery rise substantially to allocate the supplies to those users willing to pay the most. Price behavior in these low-inventory periods is quite different than that in high-inventory periods. When inventories are low, the spot price of the commodity may be much higher than the price for delivery after the next harvest has replenished stocks. In contrast, high inventories bring less volatile nearby prices and cause nearby prices to move in concert with distant prices because inventory management by speculative storage firms spreads the impact of supply-and-demand shocks over time (Wright, 2011). Of importance to this analysis, storable commodity prices are relatively more volatile during low inventory periods.

The second aspect of competitive storage models is an implied relationship between current prices, futures prices for deferred delivery, and the level of inventories. Suppose that the futures price in period t for delivery in some distant period T represents an unbiased estimate of the spot price at T. Then competitive storage behavior implies that the calendar spread (i.e., the difference between the price for deferred delivery in T and the price for delivery today) is positively related to the level of inventories. This relationship was empirically confirmed by Working (1933) and is accordingly known as the "Working curve." It is widely acknowledged as a stylized fact in storable commodity markets such as wheat (Carter and Revoredo-Giha, 2007). The non-negativity constraint and the Working curve help identify the econometric model of wheat futures markets.

Financial Speculation, Commodity Index Trading, and Comovement

Critics of futures market speculation generally are not concerned with traditional precautionary demand related to expectations about future prices. Instead, they suggest that alternative motives for speculative trading impede the ability of markets to discover the price levels justified by market fundamentals. The recent financialization of commodity futures markets and the presence of commodity index traders has been associated with these alternative motives for commodity market speculation. Financialization has been defined as the increased presence of "financial motives, financial markets, and financial actors in the operations of commodity markets" (UNCTAD, 2011) and the "increased acceptance of (commodity) derivatives as a financial asset" (Fattouh et al., 2012).

Many financial investors who participate in commodity markets do not have directional views on the prices of a specific commodity, such as wheat. Rather, they wish to gain exposure to the broad movement of commodity prices because of perceived portfolio diversification benefits. Influential studies such as Gorton and Rouwenhorst (2004) noted a negative correlation between returns from an index of commodity prices and equity or bond returns. Major indexes, such as the Standard and Poor's-Goldman Sachs Commodity Index (GSCI) and the Dow Jones-UBS Commodity Index (DJ-UBSCI), measure broad commodity price movement, and many managed funds and exchange-traded funds track these popular indexes. Energy commodity prices, especially crude oil prices, are heavily weighted in these indexes. Financial firms have developed exchange-traded funds, swap contracts, and other vehicles to allow individual and institutional investors to track these and similar

Recent Impacts of Global Economic Activity and Wheat-Specific Supply and Demand

In the model used in this study, two types of fundamental factors influence U.S. wheat prices: those that affect commodity markets generally through global real economic activity and factors specific to the wheat market.

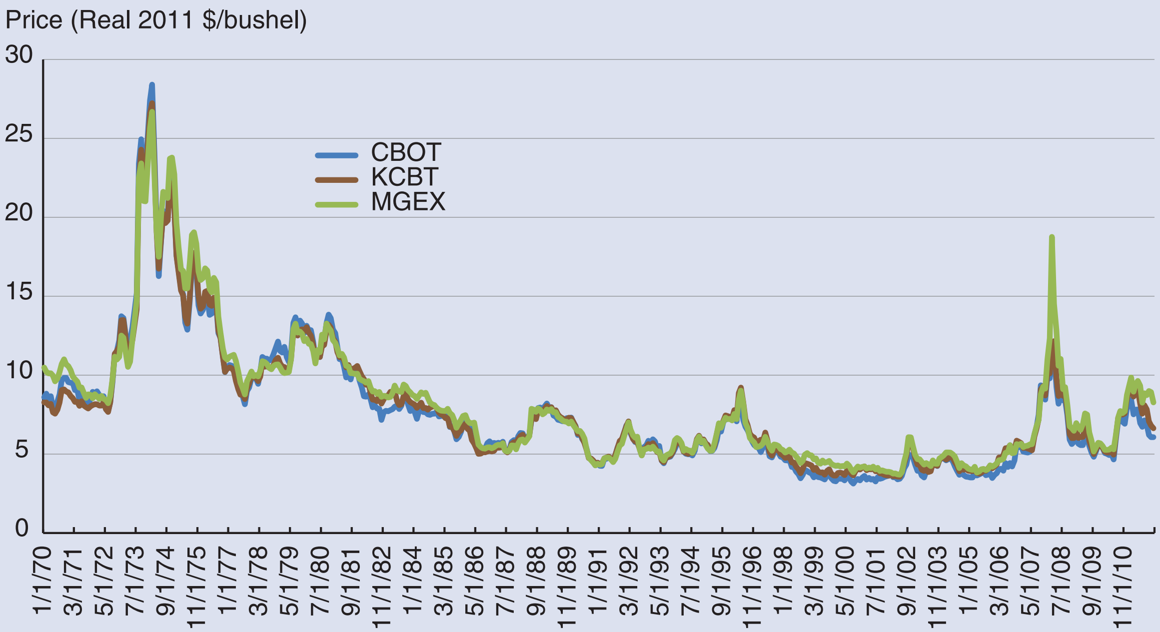
Prior to 2004, wheat prices had been in a long-term decline in real (inflation-adjusted) terms (see box fig. 2a). This decline in real prices was associated with a reduction in wheat acres in the United States and a general decline in profitability of wheat production relative to other crops (Taylor and Koo, 2011). This movement was generally true of prices for many agricultural commodities relative to corn and soybeans, as identified by Timmer (2009) in the case of rice. Since 2004, wheat prices have risen and remained at historically elevated levels. Beginning in 2004, wheat prices rose steadily, culminating in spikes in 2008 and 2011 (see box fig. 2b). During this period, Minneapolis Grain Exchange (MGEX) wheat futures reached a record level of $24 per bushel on February 28, 2008. Chicago Board of Trade (CBOT) and Kansas City Board of Trade (KCBT) prices hit more modest highs of $13.35 and $13.70, respectively, on February 27, 2008.

Over the period of observation, several events related to contemporaneous market fundamentals corroborate major price movements:

- Adverse weather shocks often accompany rising prices. Wheat prices began to rise in mid-2007 as Australia's wheat crop was planted amidst the second year of a severe drought (Flood, 2008). Wheat production was approximately two-thirds of normal in Australia that year (USDA, Foreign Agricultural Service, 2011), a shortfall that contributed to rising prices.

Box figure 2a

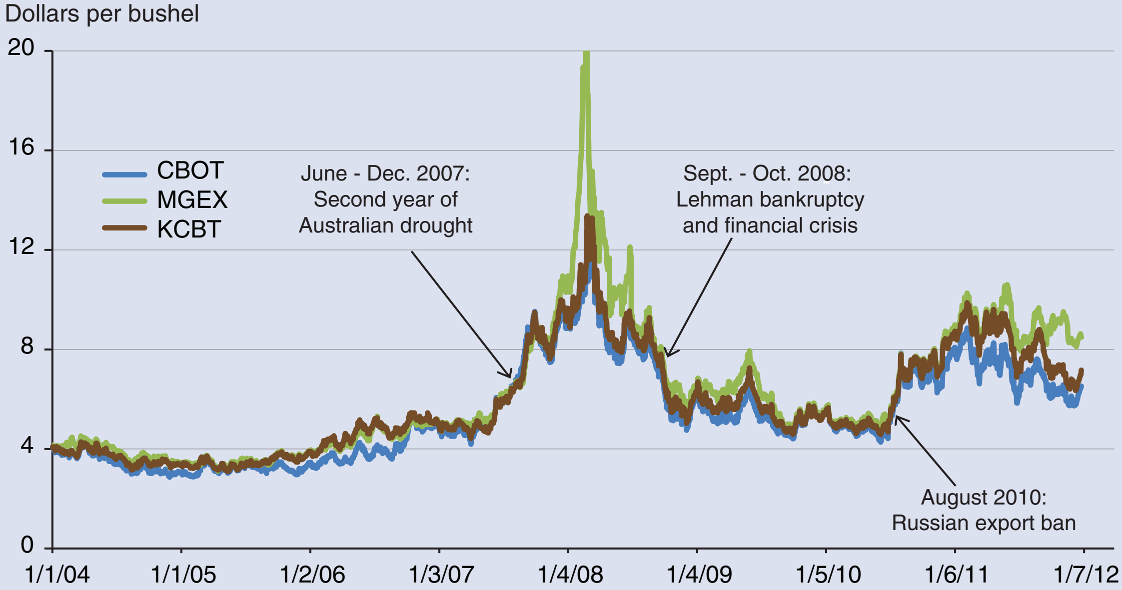
Nearby U.S. wheat futures prices in real terms



Note: CBOT = Chicago Board of Trade. KCBT = Kansas City Board of Trade. MGEX = Minneapolis Grain Exchange.
Source: USDA, Economic Research Service using data from Commodity Research Bureau (2011), "Futures Price Database."

Box figure 2b

Nearby U.S. wheat futures prices with selected events highlighted



Note: MGEX = Minneapolis Grain Exchange. KCBT = Kansas City Board of Trade. CBOT = Chicago Board of Trade.
Source: USDA, Economic Research Service using data from Commodity Research Bureau (2011), "Futures Price Database."

- As wheat prices fell from their peak in early 2008, macroeconomic shocks quickened the slide. The 2008 financial crisis, centered on the bankruptcy of the investment bank Lehman Brothers, was a signal to commodity markets that economic conditions, particularly in the developed world, were not as strong as once thought. Indeed, wheat prices fell sharply to around $5 per bushel in September and October 2008, near their level prior to the price spike, just as news of the financial crisis was being fully disseminated (Hurt and Boehlje, 2008).

- In August 2010, Russia enacted a ban on wheat exports in the midst of drought-related production shortfalls in the former Soviet Union. After prices rose in July, largely in response to the effects of the drought, prices increased further in the first week of August as the Russian Government made the ban official. That week, CBOT wheat prices rose by more than $1 per bushel (Kramer, 2010).

These are examples of both wheat-specific and general economic supply-and-demand-type forces affecting wheat prices. However, one cannot infer that these events caused changes in wheat prices simply by observing correlation between news and prices. First, such events may not cause contemporaneous shifts in prices because the market may anticipate the outcomes so that prices adjust earlier. Second, other factors may cause prices to deviate from the level justified by current supply-and-demand fundamentals.

Comparing the Three U.S. Wheat Futures Markets: Specifications and Trading Volume

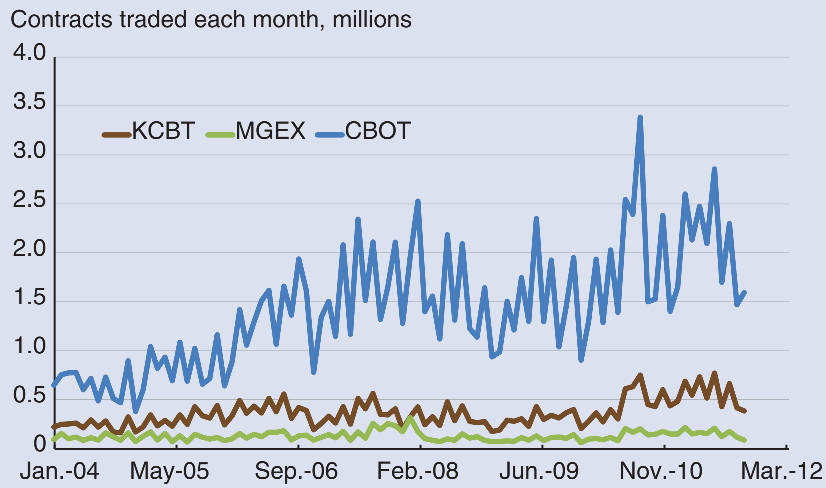
For a given commodity, trading volume will tend to consolidate on a single exchange because, all else equal, traders will be attracted to the most liquid market (Silber, 1981). The United States has not one but three wheat futures contracts because in the case of wheat, all else is not equal. Each market serves as a benchmark for a specific class of wheat: (in decreasing order of trading volume) Chicago Board of Trade (CBOT) - soft red winter contract; Kansas City Board of Trade (KCBT) - hard red winter contract; and Minneapolis Grain Exchange - hard red spring contract. Each contract calls for 5,000 bushels of wheat to be delivered in 1 of 5 months (March, May, July, September, and December) of each year. Contract prices are quoted in U.S. cents per bushel. Wheat deliverable against CBOT, KCBT, and MGEX futures contracts is distinguished by class and by protein content. The CBOT contract has no protein requirement, the KCBT contract requires 11 percent protein content, and the MGEX contract requires 13.5 percent protein content.

The presence of three wheat futures markets establishes price differentials across classes and allows these differentials to vary over time. Relative prices between contracts for nearby delivery reflect the current availability and value of wheat protein. Stiegert and Balzer (2001) frame price differentials between classes and contracts as the premium for protein above an "intrinsic level" that is generally available among all classes at a point in time. The intrinsic level fluctuates from year to year and is determined by how much wheat of each class is planted and weather-related shocks that determine the protein content of harvested grain. When the intrinsic level of protein adequately meets current demand, the premium for higher protein specifications, like the MGEX hard red spring wheat futures, will be low. Recent empirical studies (Goodwin and Smith (2009) and Wilson and Miljkovic (2013) consider the relationship between the supply of wheat quality, as measured by protein level, and prices in the three markets. These studies find strong relationships between available protein and prices for higher protein wheat classes like HRS. Prices for CBOT wheat do not reflect the availability of quality as at MGEX and KCBT, to the point where CBOT essentially reflects the value of feed wheat.

The presence of three wheat futures contracts conflicts with the demand from wheat futures traders for market liquidity, especially among speculators, as noted generally by Silber (1981) and for wheat specifically by Gray (1961). Futures trading volume in wheat grew rapidly in the 2000s, especially in the CBOT market, where trading volume is an order of magnitude greater than at KCBT or MGEX. In 2004, the volume of trade at CBOT was approximately 2.7 times larger than that at KCBT and 5.7 times larger than that at MGEX (see box figure). In 2011, these amounts increased to 3.7 and 13.4, respectively. It is unclear whether this reflects the consolidation of trading on a single exchange, as predicted by Silber (1981), as trading volume has grown for all wheat futures.

Box figure 3a

Trading volume for U.S. wheat futures contracts



Note: KCBT = Kansas City Board of Trade. MGEX = Minneapolis Grain Exchange. CBOT = Chicago Board of Trade.
Source: USDA, Economic Research Service using data from Commodity Futures Trading Commission (2012), "Disaggregated Commitment of Traders Report."

indexes to their investment portfolios (Stoll and Whaley, 2010). Most traders following index-trading strategies tend to take only long positions (i.e., positions that make money if prices rise). Because they want exposure to commodity returns, they do not take short positions (i.e., positions that make money if prices drop.) Hereafter, any firms that follow index-tracking trading strategies are referred to as commodity index traders, or CITs.

Criticism of financial speculation and CITs generally focuses on the size of the futures positions held by CITs and the invariance of CIT trading strategies to available information about expected future prices, leading some observers to refer to these traders as "massive passives." Market participants, such as hedge fund manager Michael Masters (2011) and investor George Soros (2008), and some governmental and nongovernmental organizations, such as United Nations Conference on Trade and Development (UNCTAD) (2011), publicly allege that the large presence of CITs in commodity markets, trading in large volume but uninformed about commodity supply-and-demand fundamentals, causes prices to conform to the actions of these firms. CITs are hypothesized to encourage "herding behavior" (UNCTAD, 2011), leading prices to overshoot fundamentally justified levels because traders buy or sell to follow trends. A range of policy responses have been suggested as a way to curb financial speculation and control commodity price levels and volatility, including speculative position limits (Masters, 2011), virtual grain reserves (Von Braun and Torero, 2009), transaction taxes, and proprietary trading bans (UNCTAD, 2011).

Some econometric studies (e.g., Singleton, 2011) find that empirical evidence of correlation between the futures market positions held by CITs and commodity futures prices is suggestive of a causal effect running from speculative trading activity to observed prices. Irwin and Sanders (2011) and Fattouh et al. (2012) provide extensive criticism of these studies. A considerable body of evidence (e.g., Stoll and Whaley, 2010; Buyuksahin and Harris, 2011; Irwin and Sanders, 2011) suggests that CIT futures market positions are not associated with price levels or price changes of the underlying futures. (For a review of publicly available data on CIT futures market positions in wheat, see box "The Prevalence of Index Trading in U.S. Wheat Futures.")

Tang and Xiong (2012) suggest an alternative mechanism by which financial speculation and the presence of CITs may affect agricultural commodity prices: through comovement with other commodity prices. The same study finds correlation between many commodity prices and the price of crude oil—the most widely traded commodity futures contract—which rose over the period in which CIT trading became prevalent, and this effect was stronger for commodities included in major indexes than for nonindex commodities. Tang and Xiong test the linkage between returns for many nonenergy commodities and crude oil and conclude that this comovement among prices is driven by the inclusion of commodities into major indexes such as the GSCI and the DJ-UBSCI. The "index inclusion" impact of CITs alleged by Tang and Xiong (2012) follows a similar effect found in equity markets by Barberis et al. (2005). That study shows that inclusion in a major index leads to comovement among the prices of the index components. This impact of speculation is independent of directional position taking by traditional arbitraging speculators that was identified earlier as a precautionary demand shock.

Concerns about commodity price comovement are not new and are not uniquely related to CITs. Comovement has been a source of concern at least since Pindyck and Rotemberg (1990) found "excessive" correlation among prices for commodities with unrelated fundamental supply and demand drivers, even after controlling for macroeconomic factors that cause common movement among prices. Pindyck and Rotemberg suggested that a herd mentality caused this comovement because "traders are alternatively bullish or bearish on all commodities for no plausible reason," a

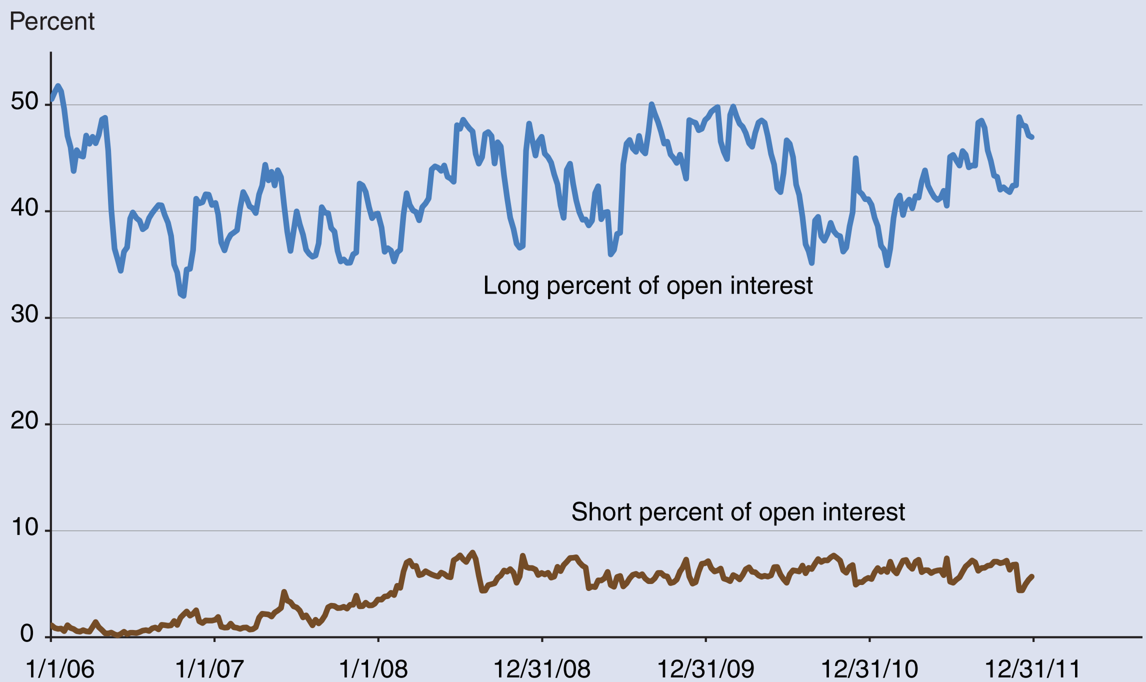
The Prevalence of Index Trading in U.S. Wheat Futures Market

Much of the recent focus on speculation in agricultural futures markets has been in terms of who is buying and selling futures contracts. The trading volume in U.S. wheat futures markets rose between 2001 and 2011. How much of this increase in trading can be attributed to financial speculators in general and commodity index traders (CITs) in particular?

The *Commitment of Traders* reports disseminated by the Commodity Futures Trading Commission (CFTC) provide a weekly snapshot of the identity of futures traders. Historically, these reports presented the number of contracts held by traders in three groups that roughly corresponded with large hedgers, large speculators, and small traders. In 2009, the CFTC began releasing position data for disaggregated groups of traders, including CITs. Historical data on the positions held by CITs are publicly available for a set of agricultural futures, including two of the three wheat futures markets from January 2006 to present. CIT positions are not available for Minnesota Grain Exchange (MGEX) wheat futures because of the lack of index trading in that market. Unlike Chicago Board of Trade (CBOT) and Kansas City Board of Trade (KCBT) wheat, MGEX wheat is not included in the major indexes tracked by CITs, such as the Goldman Sachs Commodity Index and the Dow Jones-UBS Commodity Index. Unfortunately, the CFTC does not provide publicly available records of CIT positions prior to 2006. Sanders and Irwin (2011) use nonpublic CFTC data to show that index trading came to

Box figure 4a

Commodity index trader share of total open interest in CBOT wheat futures market



Note: CBOT = Chicago Board of Trade.

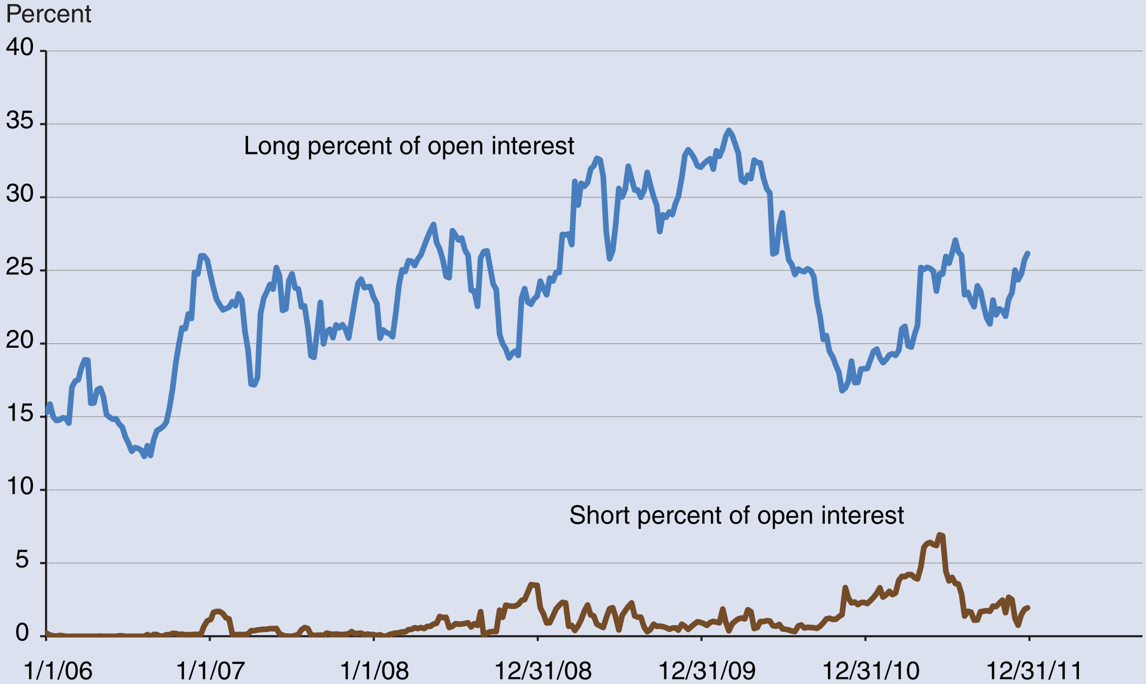
Source: USDA, Economic Research Service using data from Commodity Futures Trading Commission (2012), “Index Investment Data.”

its current prominence between 2004 and 2006. Similarly, Tang and Xiong (2012) propose that CIT-driven comovement began to take effect in 2004.

The box figures present the proportion of outstanding futures positions held by CITs in CBOT and KCBT wheat markets since 2006. Most CIT positions are long, since major commodity indexes tracked by investors represent the returns to holding long positions in the nearby contract. Since 2006, the proportion of long open interest held by CITs has been relatively constant. CITs hold 35 to 50 percent of CBOT long open interest and 15 to 35 percent of KCBT open interest. These proportions illustrate why the wheat futures markets provide suitable data to study the impact of CITs. To the extent that CITs cause comovement-driven price effects along the lines suggested by Tang and Xiong (2012), those effects are expected to be stronger in markets where CITs account for a greater share of trading. In this case, they should be negligible for MGEX wheat, greater for KCBT wheat, and greatest for CBOT wheat.

Box figure 4b

Commodity index trader share of total open interest in KCBT wheat futures market



Note: KCBT = Kansas City Board of Trade.

Source: USDA, Economic Research Service using data from Commodity Futures Trading Commission (2012), “Index Investment Data.”

rationale similar to the one employed to criticize CITs. While a number of studies (e.g., Deb et al., 1996) question the validity of the statistical methods employed by Pindyck and Rotemberg (1990), Ai et al. (2006) show that, to the extent that agricultural commodity prices move together, this comovement can be explained by common tendencies in supply-and-demand factors. Ai et al. use quarterly price and inventory data from the United States to demonstrate that prices of agricultural commodities did not exhibit excess comovement, but they did not consider the potential for comovement with other widely traded nonagricultural commodities.

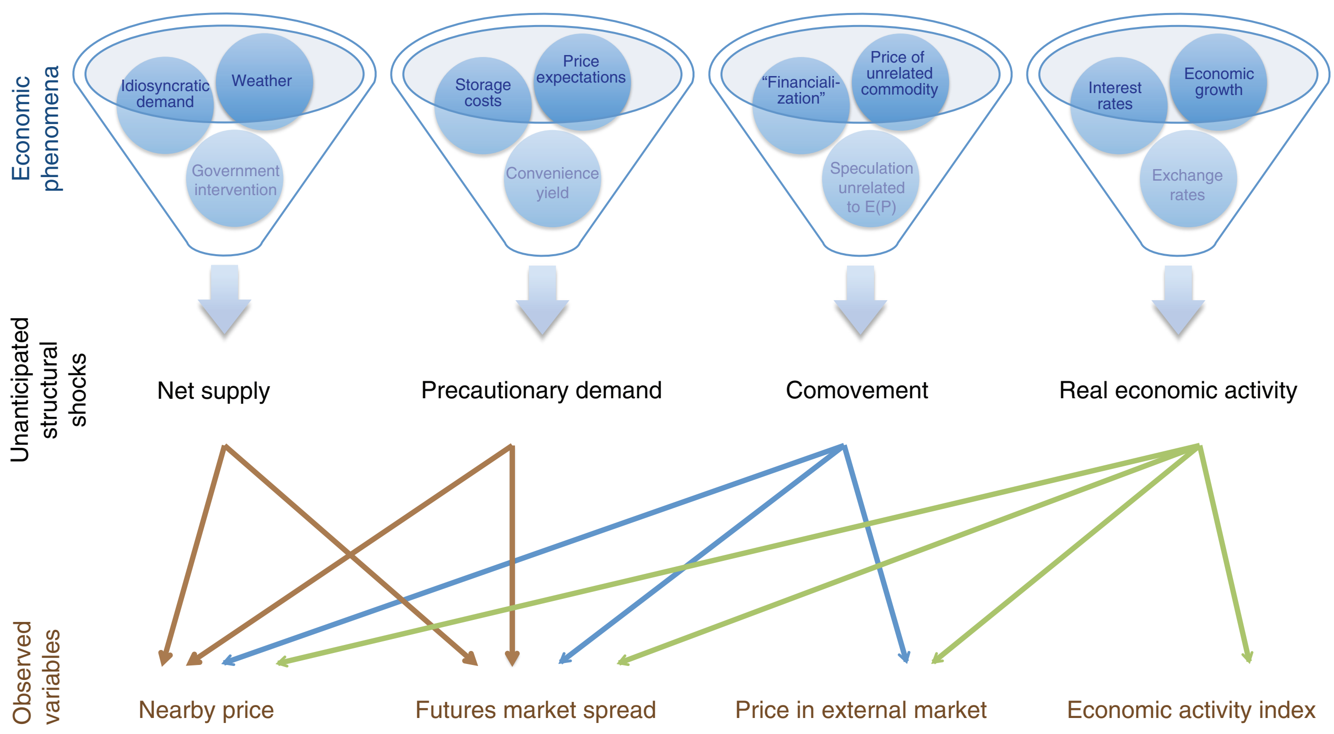
To separate precautionary demand from comovement related to CITs, one must recognize that financialization, or an increase in the influence of financial markets and institutions, affected numerous commodities at the same time. If it affected wheat prices, then it would also have affected other commodities, such as crude oil. Therefore, this study measures the extent to which wheat prices move together with these external commodities. Essentially, this is a test for "excessive comovement," or comovement that cannot be explained by fluctuations in supply drivers such as weather, demand drivers related to economic activity, or expectations about future price movement.

Modeling Wheat Price Dynamics

At least two issues make it difficult to use economic modeling to disentangle the many influences on wheat prices. First, one must decide which of the many relevant influences are important enough to be explicitly identified in the model. Second, one must avoid confounding various explanations for observed variation in wheat prices. At the center of this exercise is an implicit thought experiment in which one of the four unique factors identified earlier affects the wheat price, but the other factors are held fixed. The magnitude of the observed price change in this case can be attributed to the varying factor. In reality, each of these factors affects wheat prices simultaneously, so an econometric model must distinguish price variation attributable to each factor.

As part of the modeling effort, this study identified four key drivers of wheat futures prices in each futures market: real economic activity, comovement, precautionary demand, and net supply (see fig. 3). Each of these drivers encapsulates numerous economic phenomena, as discussed earlier. Structural vector autoregression, or SVAR, is used to identify the influence of each driver on observed wheat futures prices, with the econometric estimation procedure run separately for each futures market and results compared across markets.

Figure 3
Visual representation of an econometric model relating structural shocks to variables



Source: USDA, Economic Research Service.

SVAR begins with a simple system of linear equations to represent the observed value of each variable included in the model as a function of past of all of the variables in the system, plus some unanticipated variation. For example, the price of wheat in a given futures market in period *t* is presented as:

$$(1) \qquad p_t = b_{p1} p_{t-1} + b_{p2} p_{t-2} + \ldots + b_1 y_{t-1} + b_2 y_{t-2} + \ldots + d_1 x_t + e_t$$

where *y* represents other variables relevant to the price of wheat; *x* represents time-of-year indicators, long-term trends, and other predictable measures affecting the price of wheat; and *e* is residual variation. This residual variation, e_t, represents new information about the left-hand-side variable entering the market in each period.

The SVAR model isolates the residual variation for each variable in the model and attributes some portion of it to each of the four economic factors mentioned earlier. The unique variation in each variable attributed to a specific economic factor is called a structural shock. The shocks represent unanticipated variation in the system of variables so they have an average value of zero. Negative shocks are associated with below-average conditions for that factor, and positive shocks are associated with above-average levels. By construction, the structural shocks are uncorrelated with each other, allowing one to examine the relationship between each of the structural shocks and observed commodity prices holding all other structural shocks fixed.

The residual variation in the SVAR model, e_t, may be thought of as the difference between observed prices at a given period t and the best forecast of the period *t* price based on all past information. This difference can then be represented as a weighted sum of the structural shocks. For example, the forecast error for the price of wheat is the difference between the observed price, p_t, and a forecast price, $p^{forecast}$, based on available information up to and including period $t - 1$. The forecast error can be written as:

$$(2) \qquad e_t = p_t - p^{forecast} = d_1 u_t^{REA} + d_2 u_t^{CM} + d_3 u_t^{PD} + d_4 u_t^{NS} \quad ,$$

where the *d* coefficients are the weights to be identified for each of the structural shocks, *u*. The *REA*, *CM*, *PD*, and *NS* superscripts for *u* denote structural shocks related to real economic activity, comovement, precautionary demand, and net supply respectively. In figure 3, the arrows linking the structural shocks to the variable “nearby price” represent each right-hand-side term in equation 2, namely, the contemporaneous impact of each structural shock on the nearby wheat futures price.

Model Variables

Since there are four structural factors to identify, the model contains four variables, four equations similar to 1 to be estimated, and four structural shocks. To begin, the four variables to include in the model are selected, which determines the structural interpretation given to each of the four shocks. This study chooses to include three variables in addition to the wheat futures price in each of the three futures markets, which are the main variables of interest. The three additional variables identify the real economic activity, comovement, and precautionary demand shocks; the remaining residual variation represents the net supply shock.

Given the importance of demand growth in emerging economies to stimulate wheat consumption, the economic activity measure must be a global measure. To represent the global demand for commodities, the analysis uses an index of real economic activity developed in Kilian (2009).

This index aggregates ocean freight rates based on an empirically validated relationship between freight rates and economic activity. Because freight rates rise and fall in response to fluctuations in economic activity in any region of the world, this measure is not biased by changes in the direction or composition of trade. This measure was used successfully in Kilian (2009), Kilian and Murphy (2013), and Carter et al. (2012), among others.

One can approximate commodity price movements that may be associated with speculation-induced comovement using the prices of major commodities themselves. If the implications of the financialization hypothesis are correct, it should follow that nonagricultural commodity prices have driven wheat price changes. Following the findings of Tang and Xiong (2012), wheat prices should have become increasingly related to crude oil prices since 2004, so the model accounts for the price of nearby West Texas Intermediate crude oil futures. As a test of robustness, the analysis is repeated using the value of the GSCI, introduced earlier, as an alternate measure of external market price movement. Recall that the GSCI represents a basket of commodity prices with heavy weight placed on energy commodities tracked by many market participants following commodity index trading strategies.

The incentive to hold inventories is measured using the spread (or the difference) between the fifth deferred futures contract price and the nearby futures prices based on the Working curve relationship between the distant-to-nearby price spread and inventory levels. This spread represents the incentive to hold inventory between the current period and some distant period in which supply conditions may be resolved as newly produced grain enters the market. In periods when available supply is tight, nearby spreads may be positive to ration available supplies through the remainder of the crop year, even though inter-crop-year spreads are negative. In this way, one may capture a precautionary demand shock related to expectations about future crop year supply-and-demand conditions.

Physical wheat inventory data would be an alternative to the spread variable in the model if the data existed. However, quantity measures are either unavailable at the frequency required by the model or cover only a limited set of locations, such as the warehouses licensed to receive grain delivered against the various wheat futures contracts. Available quantity data are not the global measure of wheat scarcity that is required.

Garcia et al. (2012) show that the spread underestimated the true price of storage at various points for CBOT and KCBT wheat at various points between 2006 and 2010 due to the maximum storage rate imposed by the exchanges. This problem was particularly acute in the period when prices were low between the 2008 and 2010 peaks, especially for CBOT wheat. However, since the measurement error only occurred in periods where spreads reached the full carrying charge between periods implied by the exchange-determined storage rate, the spread is still indicative of expectations about supply-and-demand conditions in the upcoming crop year relative to the current crop year.

The nearby futures prices for each wheat futures contract are included as the final variable in the model, which decomposes the changes observed in wheat price to three structural shocks associated with the other variables. Any changes in wheat price unrelated to the first three factors represent net supply shocks. Thus, this fourth structural shock, which is interpreted as being due to current wheat-specific supply-and-demand factors, encompasses residual variation in price.

Identification

To identify the impact of the structural shocks on the price of wheat, one must be able to calculate values for the coefficients d_1-d_4 in equation 2. Because there are four coefficients for each of the four equations in the SVAR model, each parameter cannot be identified separately. As with all SVAR models, additional assumptions are requited about the economic process that determines the observed values of the variables in the model. This section briefly explains the intuition behind the identification strategy. For a more complete mathematical representation, see the appendix to this report and Janzen et al. (2013).

Identifying the source of price variation in each wheat futures market, particularly speculative shocks, requires different assumptions than other applications of SVAR to agricultural markets. Agricultural economists have mainly applied SVAR methods to questions of market integration. In the case of wheat, SVAR studies examine linkages between prices for one commodity in different locations (e.g., Goodwin and Schroeder, 1991; Mohanty et al. 1999; McKenzie, 2005), prices for different degrees of product processing (Babula et al., 2004) for wheat and wheat products, and prices across commodities (Power and Vedenov, 2009) for a set of agricultural and energy commodities during the 2008 price boom and bust. In general, these applications sought to examine relationships between prices across markets. This analysis considers the effect of various shifters on a single market in a manner grounded in an understanding of commodity price formation based on the competitive storage model.

The analysis employs two types of assumptions to identify the structural shocks in the model: ordering assumptions and volatility assumptions. Ordering assumptions have been widely used in the literature reviewed earlier but require stronger assumptions about the relationship between the structural shocks and the variables. Ordering essentially assumes that certain structural shocks have no contemporaneous impact on some of the model variables. It assumes that there is an order to the shocks such that some shocks take precedence over others in determining the observed variables.

The ordering assumption is justified when identifying the weights for some of the structural shocks but not others. Take for instance the measure of real economic activity. Supply-and-demand shocks specific to the wheat market are unlikely to affect the macroeconomy immediately, so it is safe to assume that the weights on the comovement and wheat-specific shocks in the equation that represents real economic activity are zero. This assumption does not preclude any feedback from the wheat market or other specific commodity markets to real economic activity, only that such feedback occurs with at least a 1-month delay. Kilian (2009) notes that the sluggish response of economic activity to market-specific shocks is consistent with past behavior.

In figure 3, the arrows represent the contemporaneous impact of shocks on variables. The ordering assumption is reflected in the absence of arrows from the precautionary demand and net supply shocks to the external market price and from these wheat-specific shocks and from the comovement shock to the economic activity index. In terms of equation 2, the ordering assumption sets some of the coefficients on the right-hand side equal to zero. This assumption does not imply that wheat-specific shocks do not affect general economic activity or the prices of nonagricultural commodities, only that these impacts occur with a minimum on period lag.

A similar assumption is made about the relationship between prices in nonagricultural markets, such as crude oil, and the wheat-specific shocks. It is assumed that wheat markets may respond contemporaneously to shocks generated in external markets, but external market prices do not respond immediately to wheat market shocks. This assumption is intended to provide the most robust test of the comovement hypothesis generated by Tang and Xiong (2012). If under this assumption wheat-specific shocks are found to cause more observed variation in wheat prices than do external markets, one can be confident that the converse outcome was given the best chance to reveal itself in the data.

The ordering assumption cannot be used to disentangle wheat market shocks. Contemporaneous observed changes in prices and spreads could be the result of precautionary demand shocks or net supply shocks. Precautionary demand shocks do not take precedence over net supply shocks, or vice-versa. One would expect a positive precautionary demand shock to have a positive impact on price and a positive impact on the term spread. A net supply shock should also have a positive price impact but a negative impact on spreads. Importantly, net supply and precautionary demand shocks may affect prices and spreads simultaneously, so assigning priority to one or the other is not realistic.

The analysis uses information about the volatility of the variables in the model to separately identify the wheat-market-specific structural shocks due to precautionary demand and net supply. As discussed earlier, inventories must be non-negative, and the non-negativity constraint implies that prices will be relatively more volatile when inventories are low. Prices and spreads can therefore be thought of as following two regimes: one volatile and one tranquil. The presence of volatile and tranquil price regimes allows one to use an "identification through heteroskedasticity" approach due to Rigobon (2003) to allow net supply shocks and precautionary demand shocks to affect prices and spreads simultaneously. Incorporating additional information about volatility regimes overcomes the simultaneity problem. For more information on the econometric methodology, see the appendix to this report and Janzen et al. (2013).

Data and Results

The reduced-form vector autoregression (VAR) system of regression equations as in (1) is estimated using monthly data spanning January 1991 to December 2011. Separate VAR models are estimated for each wheat futures contract. Monthly indicator and linear trend variables in each equation control for seasonality and long-term trends, such as the longrun decline in inflation-adjusted commodity prices. Practical considerations, including the availability of data, determine the frequency of observations used for estimation. The analysis uses monthly data to examine price behavior at higher frequency than in other studies of comovement for agricultural commodities that identified the impact of speculation (Ai et al., 2006). While even higher frequency data may also yield interesting conclusions, monthly frequency should adequately capture comovement driven by index trading and financial speculation.

The length of the time-series is also dictated by modeling necessity and practical constraints. The analysis uses the results to examine the 2008 and 2011 price boom and bust periods, but data in the model extend back to 1991. A longer time series enables more precise estimation of the regression parameters. Because the econometric identification requires the presence of volatile and tranquil periods for wheat prices, the inclusion of additional "price spike" periods allows for a more accurate portrayal of how each of the structural shocks drive price volatility. The results become more robust than if the model had only used the 2008 and 2011 spikes to estimate price response to structural shocks. Prior to the early 1990s, wheat futures contracts for distant-month delivery were traded erratically, if at all, on the smaller KCBT and MGEX exchanges. The spread measure in the analysis relies on an indicator for the intertemporal price relationship between wheat for nearby delivery and wheat for more distant delivery, so the sample is limited to the period when this measure is available for each market.

Impulse Response Functions

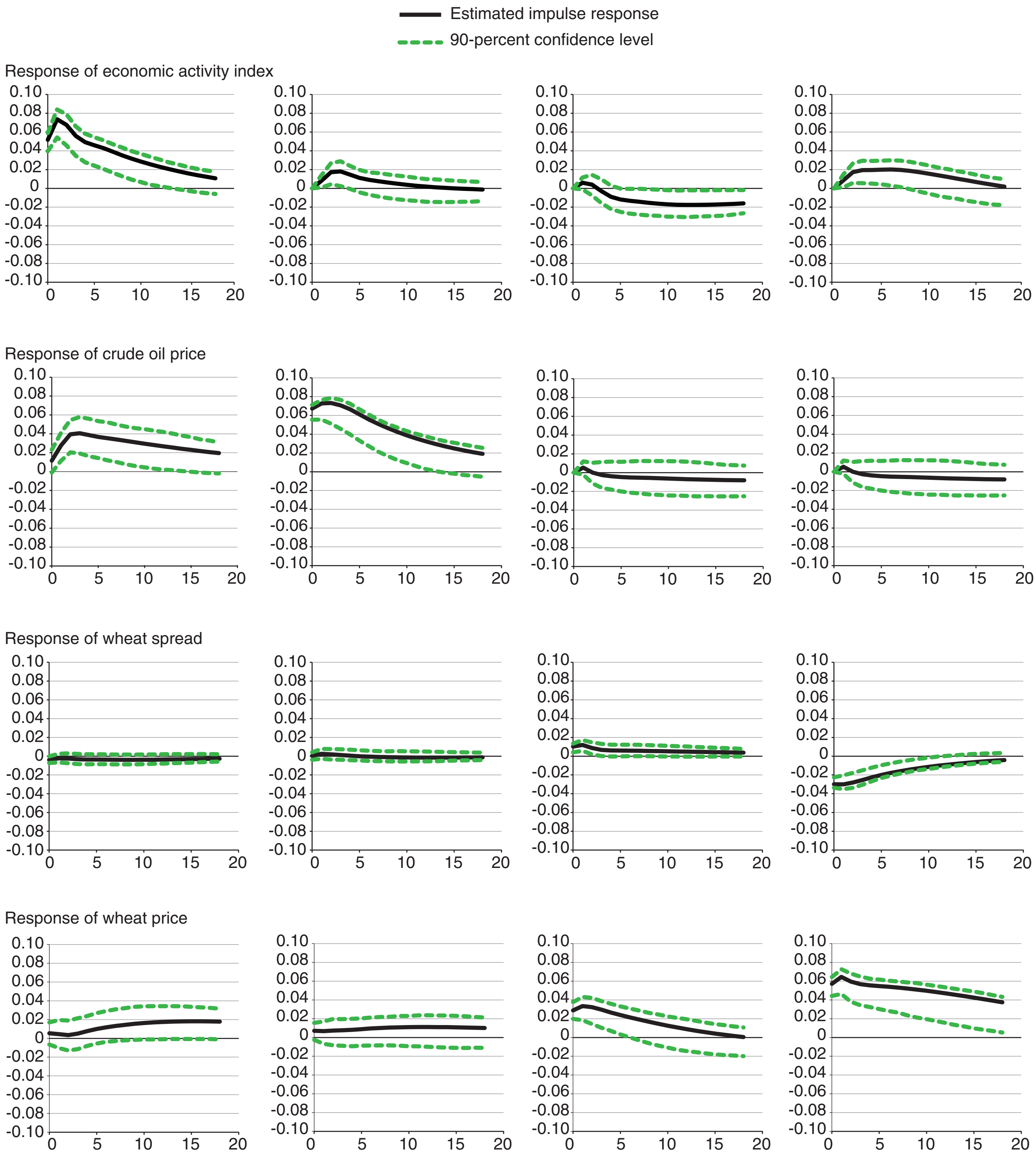
Figure 4 plots the time path for the response of each variable in the model to the economic activity, external market, speculative demand, and net supply shocks. These graphs illustrate, based on the average response observed in the data, the response of each variable in the model to a hypothetical shock equal to one standard deviation from the assumed zero mean. Note that the normalization used to identify the model implies that each of the shocks causes an increase in the price of wheat. In particular, positive net supply shocks are defined to represent a supply disruption.

The impulse response functions serve two purposes. First, they act as a check on the validity of the assumptions about the shocks. The signed impact of the observed structural shocks should be consistent with expectations; otherwise, the structural shocks captured in the model may not capture the impacts suggested earlier. Second, the impulse response functions for the price of wheat can be compared to ascertain the magnitude and duration of the influence of each structural shock.

Figure 4 shows impulse responses for the model where the CBOT wheat price is the fourth variable. (Results for KCBT and MGEX wheat prices are similar.) Each row of graphs shows the response of one variable to the four structural shocks. The dashed lines measure the precision of the estimated response and constitute 90 percent confidence bands. Focusing on the bottom-right corner of figure 4, one can check the validity of the identification scheme used to identify the endogenous net supply and precautionary demand shocks in the wheat market. Price responds positively to precautionary demand shocks and net supply shocks as expected, based on the model assumptions. As shown in

Figure 4

Impulse response functions from structural vector autoregression model of CBOT wheat prices using crude oil as external market



Note: CBOT = Chicago Board of Trade.

Source: USDA, Economic Research Service.

the third graph in the third row, if a precautionary demand shock increases price, the spread also increases. Similarly, a net supply shock (equivalent to a supply disruption) raises wheat prices and has a negative influence on the spread to draw supplies in storage to the market (see the third graph in the fourth row).

As shown in the figure, external forces have a relatively small impact on wheat prices, relative to unexpected shocks specific to the wheat market. Real economic activity and external market shocks are small but long lived. Real economic activity shocks have minimal initial impact but cause moderate effects on wheat prices after approximately 4 months. However, neither type of shock is statistically significant on average.

The insignificance of crude oil market shocks suggests that broad-based commodity market speculation has not affected wheat prices and that returns from wheat markets are not strongly associated with those from crude oil. Figure 5 presents a similar analysis, except that the GSCI is used instead of crude oil as a composite measure of commodity price movement. Recall that Tang and Xiong (2012) suggest that commodities included in indexes should be more strongly correlated. The impulse response functions suggest that the association between wheat price changes and movement in the GSCI is relatively small.

Inventory demand and net supply shocks specific to the wheat market have positive and significant initial impacts on prices. The precautionary demand shock displays some evidence of overshooting—prices increase quickly in the months following the shock and then drop sharply toward zero. After 9 or 10 months, the response is indistinguishable from zero. In contrast, net supply shocks have a significant and long-lasting impact on prices.

Historical Decomposition

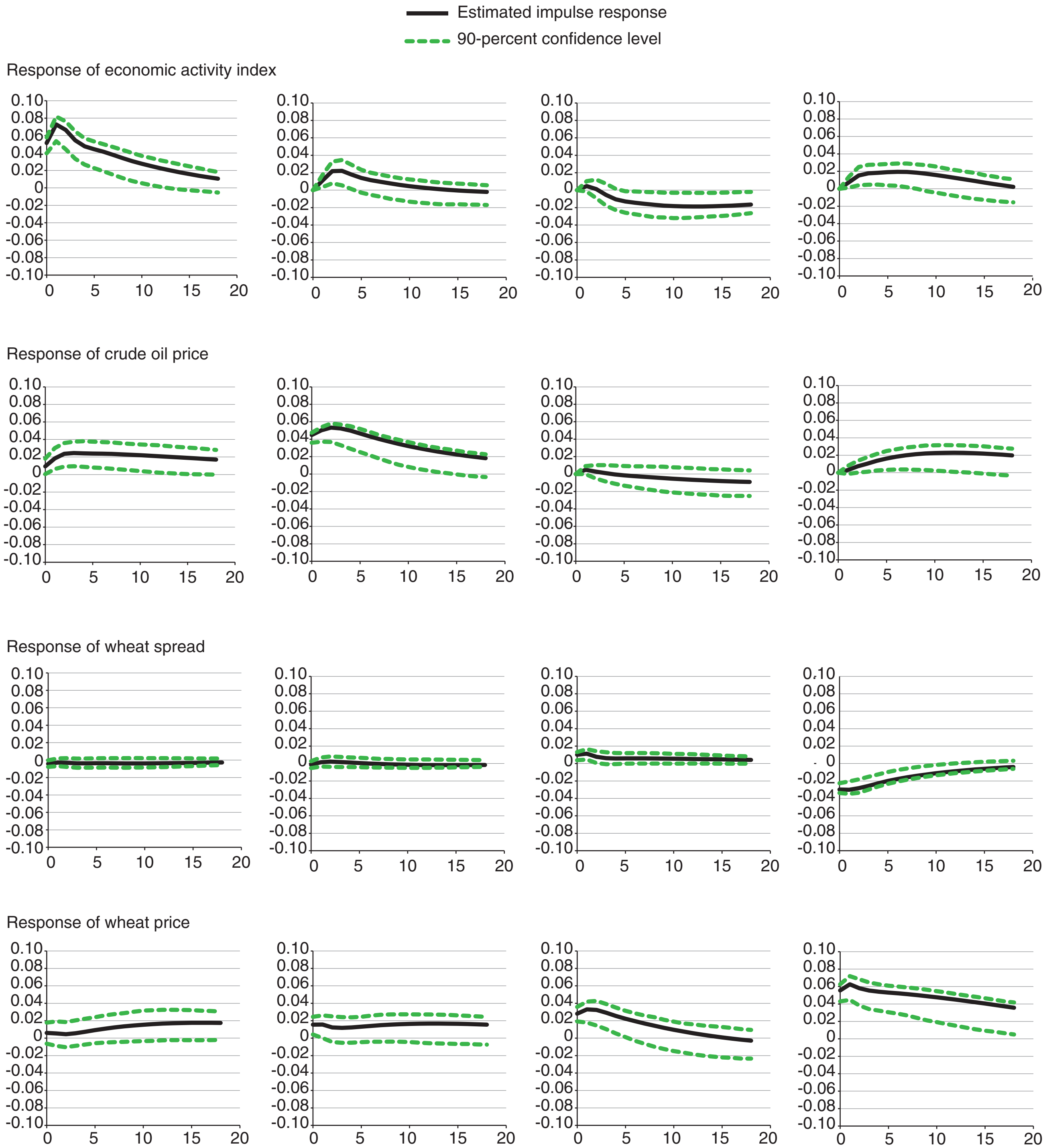
Because the forecast error in each variable each month can be expressed by the model as the weighted sum of the structural shocks realized in that month, one can plot the cumulative contribution of each structural shock to the price of wheat across time. As shown in figures 6-8, the historical decomposition is constructed such that the sum of the four series equals the realized price net of trend in any period. These figures further support the narrative presented in the impulse response analysis. Considerable variation in wheat prices is due to the two wheat-market-specific shocks. Longer, smaller swings in price are attributed to the shocks to real economic activity and external markets. This suggests that these factors can contribute to periods of high and volatile prices, but their effects are likely to be small.

Unlike the impulse responses, historical decomposition enables consideration of specific episodes in the observed time series of wheat prices. The impulse responses present an average response, which may overlook the contribution of the structural shocks to a specific price change. If the financialization hypothesis is correct, the small measured impact of external market shocks discussed earlier may be due to a lack of external market effects prior to the rise of CIT activity since 2004. These external market shocks are found to be relatively small throughout the period covered in the sample, whether crude oil or the GSCI represents the external market (see figs. 9-11). The two largest comovement shocks in the sample occur in 2005 and 2011. Though these peaks roughly correspond with increases in CIT long open interest, as discussed earlier, they do not correspond to price spikes.

The results of the decomposition analysis differ from analyses of crude oil prices by Kilian (2009) and Kilian and Murphy (2013) that use similar methods. These studies find that fluctuations in real

Figure 5

Impulse response functions from structural vector autoregression model of CBOT wheat prices using GSCI as external market

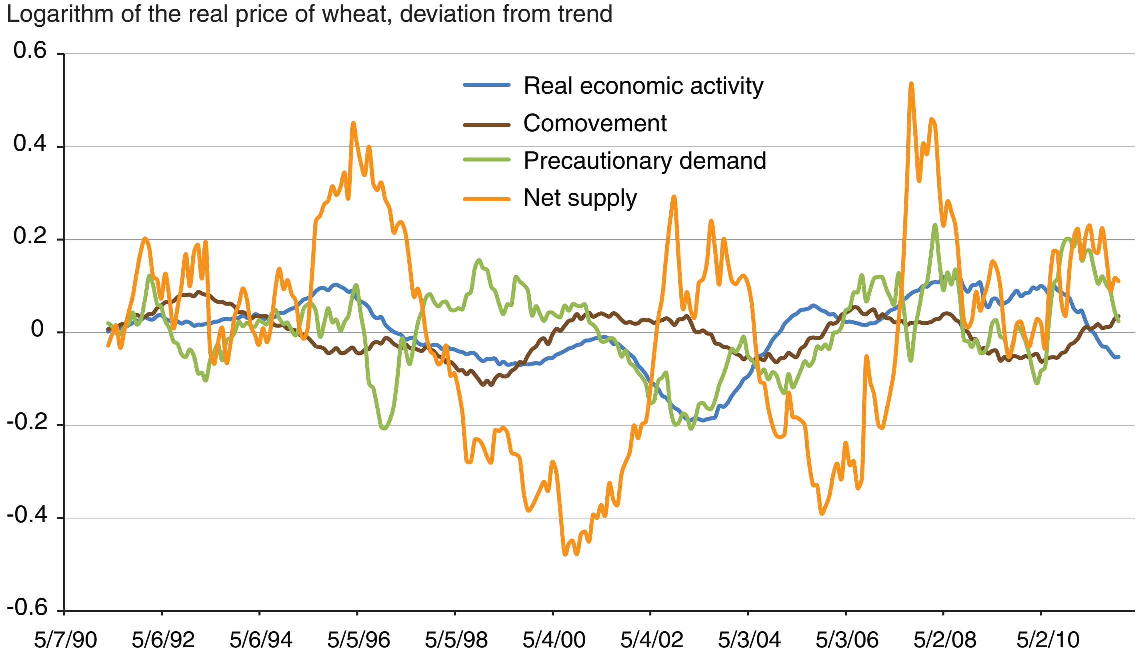


Note: CBOT = Chicago Board of Trade. GSCI = Goldman Sachs Commodity Index.

Source: USDA, Economic Research Service.

Figure 6

Historical decomposition of CBOT wheat futures prices with crude oil as external market

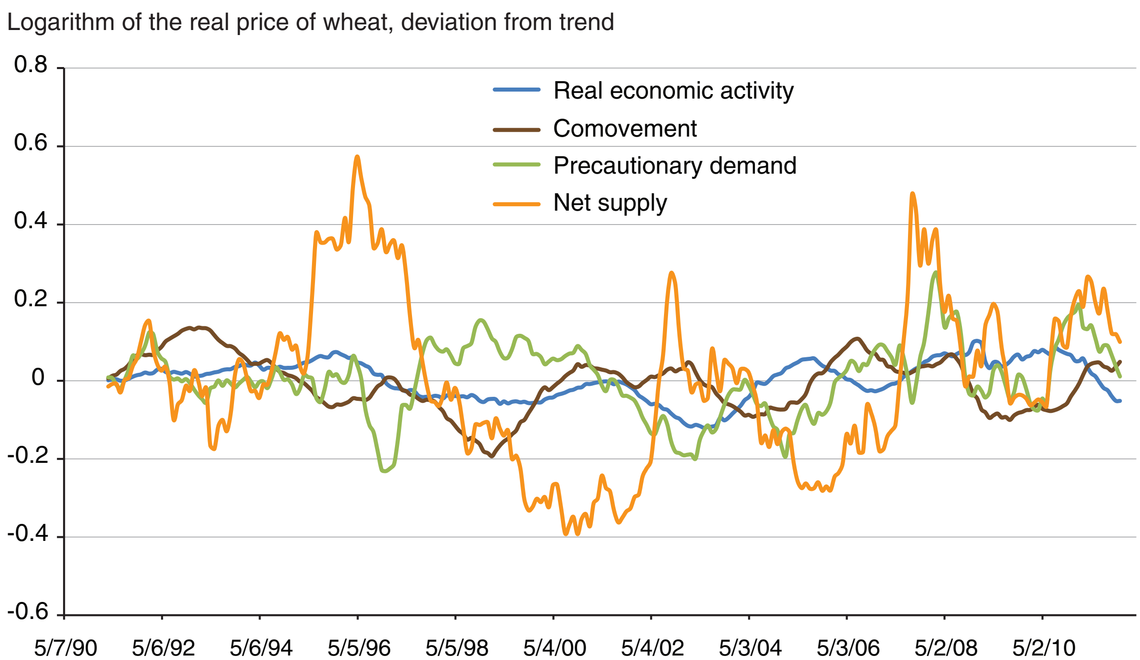


Note: CBOT = Chicago Board of Trade.

Source: USDA, Economic Research Service.

Figure 7

Historical decomposition of KCBT wheat futures prices with crude oil as external market

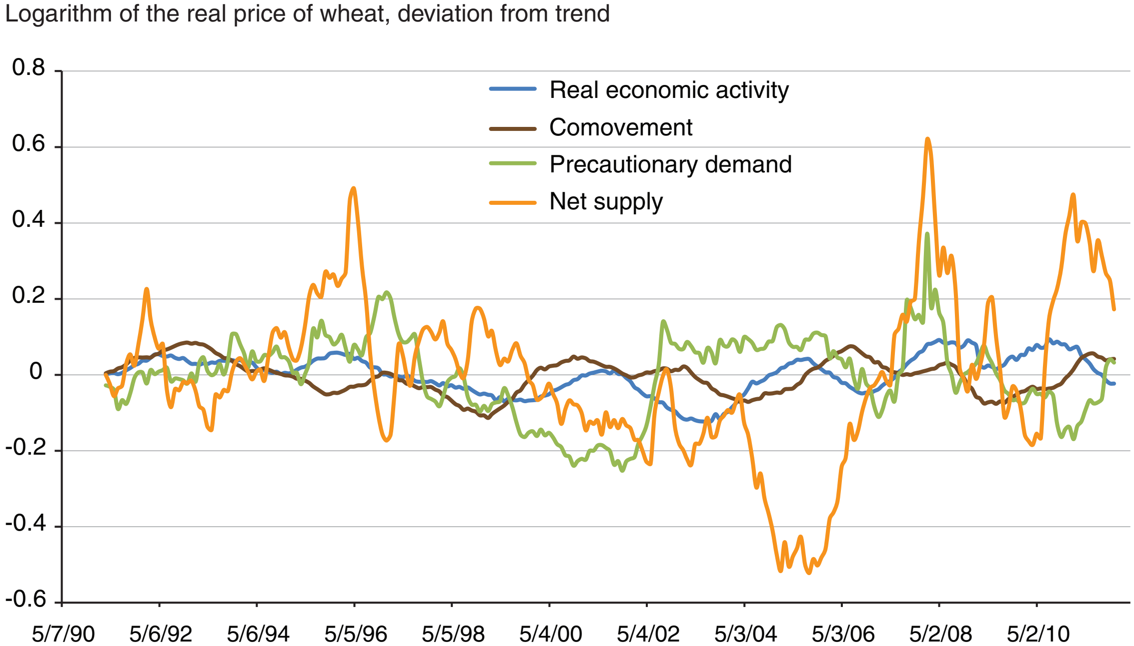


Note: KCBT = Kansas City Board of Trade.

Source: USDA, Economic Research Service.

Figure 8

Historical decomposition of MGEX wheat futures prices with crude oil as external market

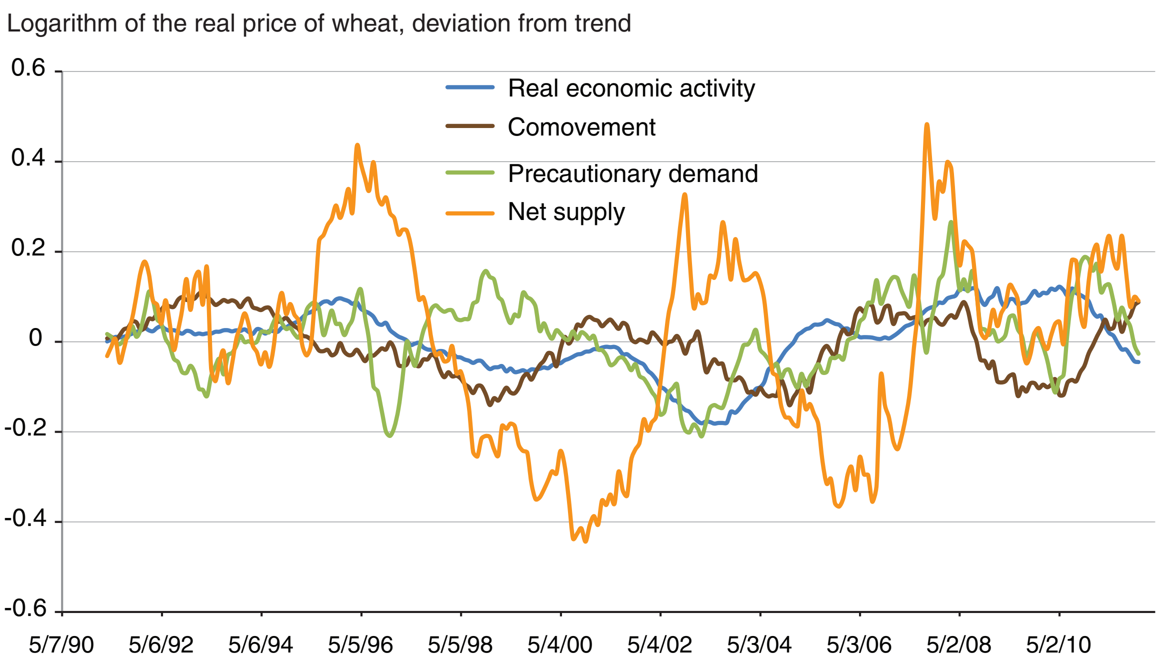


Note: MGEX = Minneapolis Grain Exchange.

Source: USDA, Economic Research Service.

Figure 9

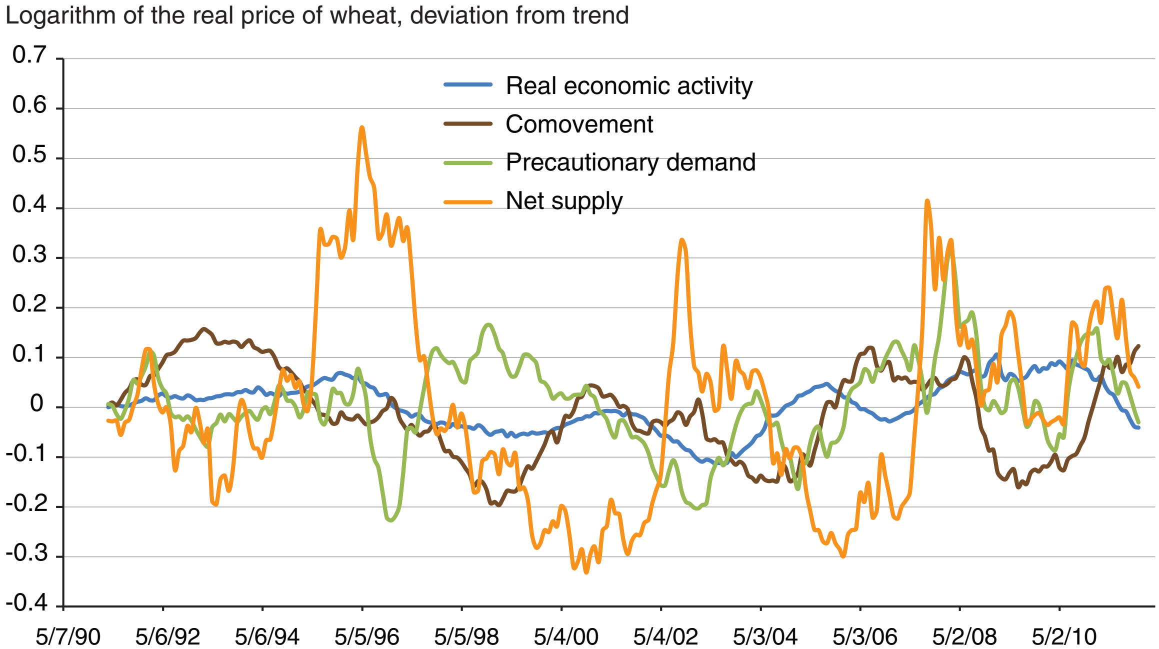
Historical decomposition of CBOT wheat futures prices with GSCI as external market



Note: CBOT = Chicago Board of Trade. GSCI = Goldman Sachs Commodity Index.

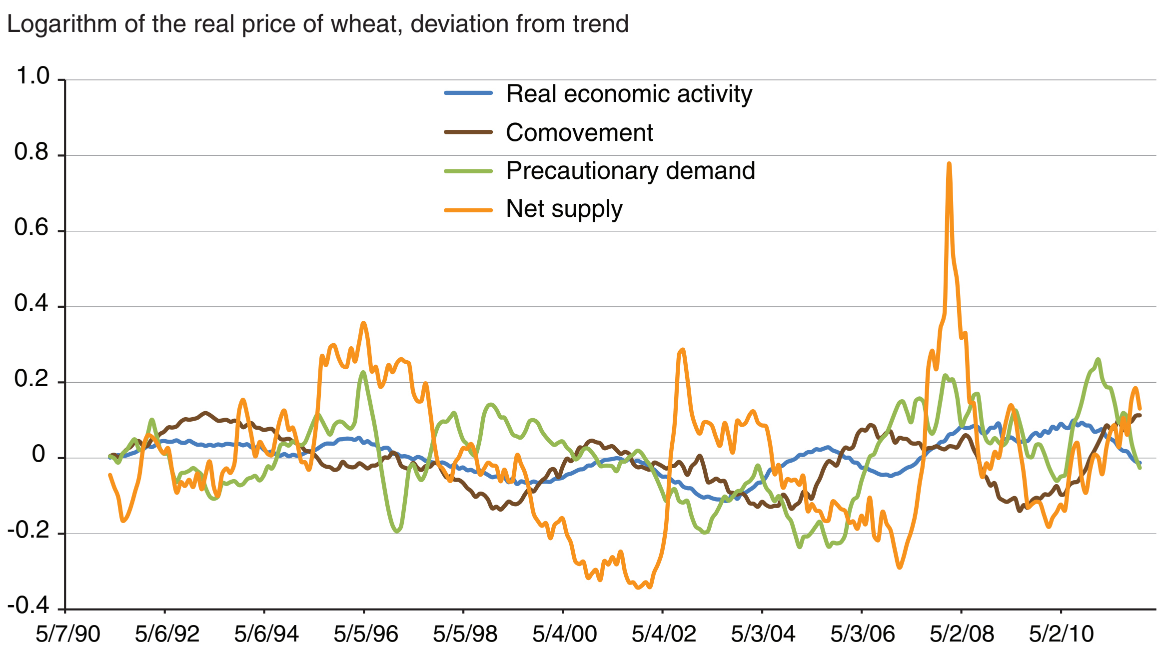
Source: USDA, Economic Research Service.

Figure 10
Historical decomposition of KCBT wheat futures prices with GSCI as external market



Note: KCBT = Kansas City Board of Trade. GSCI = Goldman Sachs Commodity Index.
Source: USDA, Economic Research Service.

Figure 11
Historical decomposition of MGEX wheat futures prices with GSCI as external market



Note: MGEX = Minneapolis Grain Exchange. GSCI = Goldman Sachs Commodity Index.
Source: USDA, Economic Research Service.

economic activity related to the macroeconomic business cycle were the largest and most persistent driver of crude oil prices, particularly during period of rising prices that ended in 2008. Similarly, Carter et al. (2012) find that between its 2003 low and 2008 high, real economic activity caused corn prices to increase by approximately 50 percent. The results of this analysis for wheat price spikes suggest that real economic activity does not similarly impact the wheat market. Between 2003 and 2008, real economic activity raised wheat prices in the three wheat futures markets by 20-30 percent. Though not a small amount overall, it is small relative to the net-supply-generated portion of the price spike.

Net supply shocks are the visibly dominant series in figures 6-8. Three major peaks in the net supply series consistent across the three wheat markets are roughly centered on the years 1996, 2003, and 2008. Each of these major positive net supply shocks is associated with U.S. and world production declines (see box figure on page 5). Net supply shocks remain the primary driver of large changes in price when the GSCI is the external market variable in the model, as shown in figures 9-11.

Net supply and precautionary demand shocks follow similar time paths across each of the three markets. The net supply shocks in MGEX wheat in 2007 and 2008 are a notable exception; MGEX net supply shocks were substantially greater than those in the CBOT and KCBT markets, consistent with observed production numbers for spring wheat relative to winter wheat. Whereas U.S. winter wheat production rebounded for the 2007-08 marketing year, U.S. spring wheat was below average for a second consecutive year. J.P. Morgan (2010) suggests that a “stock out” of high quality wheat pushed MGEX prices far above CBOT and KCBT.

As mentioned earlier in this report, three recent specific shocks to wheat market fundamentals included the Australian drought, the Russian export ban, and the global financial crisis. While other factors may have affected wheat prices over the period of analysis, these three are representative of the types of structural shocks measured in the model. Accordingly, this analysis considers the estimated structural shocks when these events occurred.

The drought and export ban should reflect wheat-specific shocks that may be captured in the model as net supply or precautionary demand shocks (see next section for a discussion of the impact of the Russian export ban). The Australian drought shock is consistent with the results observed in the historical decompositions. Figures 6-8 show that net supply shocks increased dramatically in the second half of 2007. The net supply shock “peak” in these figures occurs in September 2007. Much of the subsequent increase in wheat prices is due to precautionary demand shocks. The net supply shock coincides with information flows about supply shortfalls that would have come during the growing season for Australian winter wheat from June through December (USDA, Office of the Chief Economist, 2011). The global financial crisis should represent a contraction in real economic activity. Examining the series of real economic activity shocks shows that lower economic activity shocks did not hit wheat prices until January 2009, slightly later than the first news of the financial crisis.

Counterfactual Analysis of the Wheat Prices From 2006 to 2011

Following the general results about the origins of price levels and price changes in the three U.S. wheat markets, this analysis uses counterfactual scenarios to examine the period of relatively high wheat prices between 2006 and 2011. What would have happened to these prices in the absence of any one of the effects identified earlier? For example, how would the time series of observed wheat prices have differed if the external market shocks did not affect wheat prices? To answer such questions, this study considers the percentage difference between the observed and counterfactual scenarios.[5]

Figures 12-14 and 15-17 show the observed series of prices since 2000 and four counterfactual scenarios over the period January 2006 to December 2011 using both crude oil and GSCI to measure external market prices. In this period, one would expect the influence of comovement shocks to matter more if the financialization hypothesis is correct. Based on this simulation, prices are found to be little changed in the absence of external market shocks whether crude oil prices or the GSCI is used to measure the comovement effects.

During 2006-2008, comovement shocks are nearly imperceptible. At the peak of the price spike in February 2008, wheat prices would have been only 1 percent lower in the absence of comovement shocks attributable to financial speculators like CITs. Subsequently, comovement shocks increase in magnitude, but the overall effect is still small: comovement shocks related to crude oil prices raised wheat prices only 5-8 percent at the peak of their impact, depending on the market. In absolute terms, the maximum wheat price impact of comovement shocks at any point in the counterfactual analysis is approximately $0.67 per bushel. Relative to the price volatility observed over this period, such an effect is small: CBOT and KCBT monthly average prices rose by approximately $8 per bushel between 2005 lows and 2008 highs and by nearly $5 per bushel between 2009 lows and 2011 highs. MGEX prices rose by even more between 2005 and 2008. The comovement shock has similar impacts across markets, but the effect is strongest and hits earliest in the MGEX wheat market (see figs. 14 and 17). This runs counter to the hypothesis that comovement shocks should be greater in CBOT wheat, where the presence of CITs as a percentage of open interest is greatest.

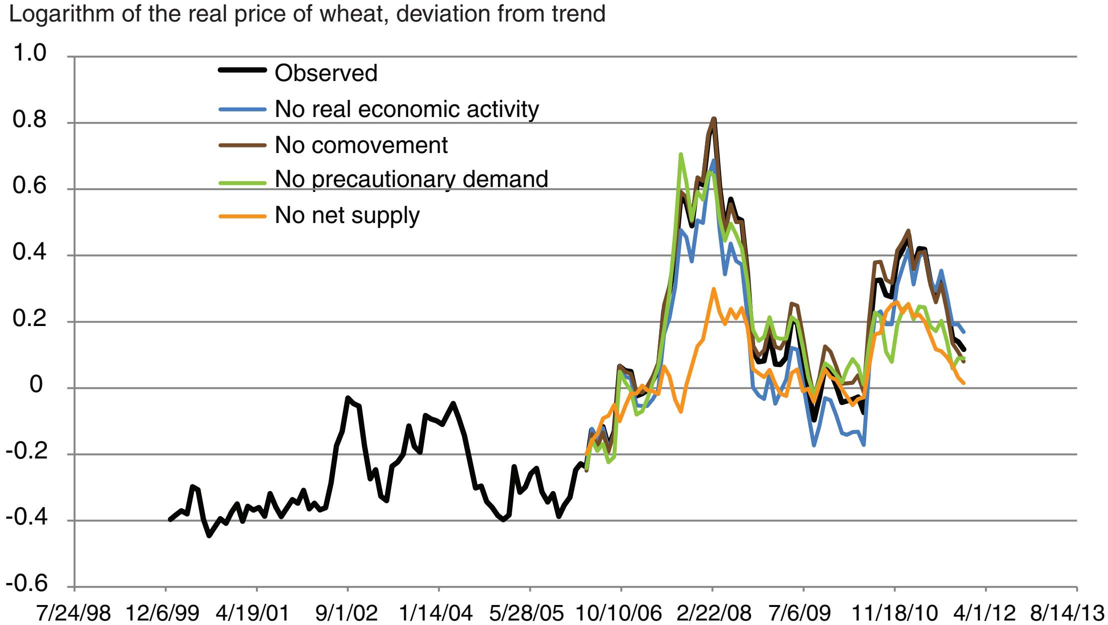
Figures 12-14 and 15-17 show that the price peak in early 2008, when the MGEX price rose far above the CBOT and KCBT prices, was driven by combined net supply and precautionary demand shocks. In February 2008, in the absence of net supply shocks, prices would have been 53 percent lower for CBOT, 40 percent lower for KCBT, and 62 percent lower for MGEX. At the same time, in the absence of precautionary demand shocks, prices would have been 11 percent lower for CBOT, 20 percent lower for KCBT, and 36 percent lower for MGEX.

Figures 12-17 reveal that the wheat-specific shocks related to precautionary demand and net supply differ in impact between the 2006-08 and 2009-11 periods. Net supply shocks caused much of the increase in prices for all wheat that occurred in 2006 and 2007. Much of the subsequent increase in price was driven by precautionary demand shocks. That the impact of precautionary demand was greatest at the price peak may be evidence of anticipatory demand by firms who held inventory. A dramatic rise in price to historically high levels may have induced fears of further price increases, causing firms to add to inventories.

Elevated wheat prices in 2010-11 did not signal a repeat of the events of 2007-08. Through 2010, concurrent shocks to net supply and precautionary demand drove prices higher in the CBOT and KCBT wheat markets. Figures 12 and 13 show that precautionary demand and net supply made similar contributions to higher prices in 2010-11. That precautionary demand played a more significant role in the initial increase in prices in 2010 than in 2007 is consistent with anticipation of the Russian export ban that went into effect in August 2010. The complete elimination of Russian exports would lead to higher future wheat exports from the United States and other countries; an

[5]We measure this difference as the log difference between prices with and without each of the shocks. These log differences approximate a percentage change, so we use percent to refer to these log differences.

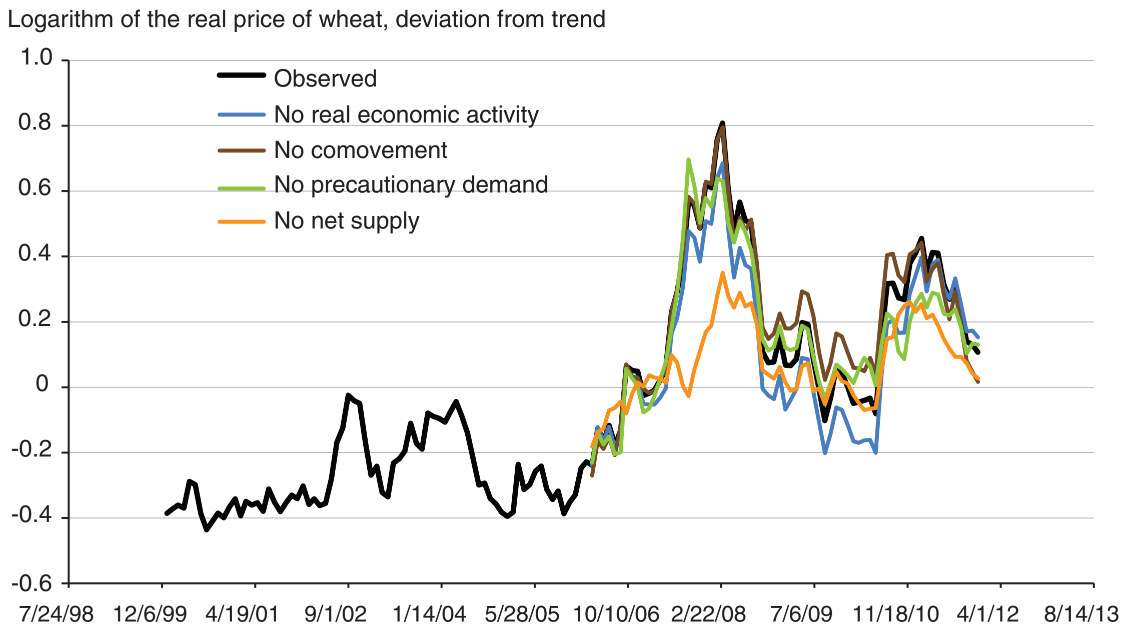
Figure 12
Counterfactual simulation of CBOT wheat futures prices using crude oil as external market



Note: CBOT = Chicago Board of Trade.

Source: USDA, Economic Research Service.

Figure 13
Counterfactual simulation of KCBT wheat futures prices using crude oil as external market

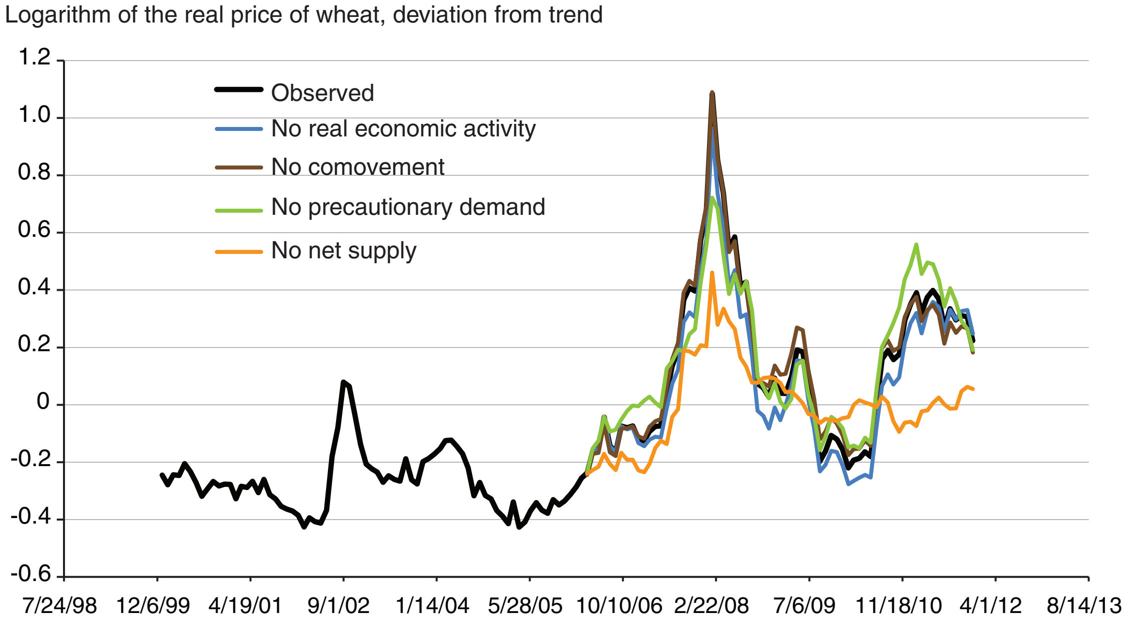


Note: KCBT = Kansas City Board of Trade.

Source: USDA, Economic Research Service.

Figure 14

Counterfactual simulation of MGEX wheat futures prices using crude oil as external market

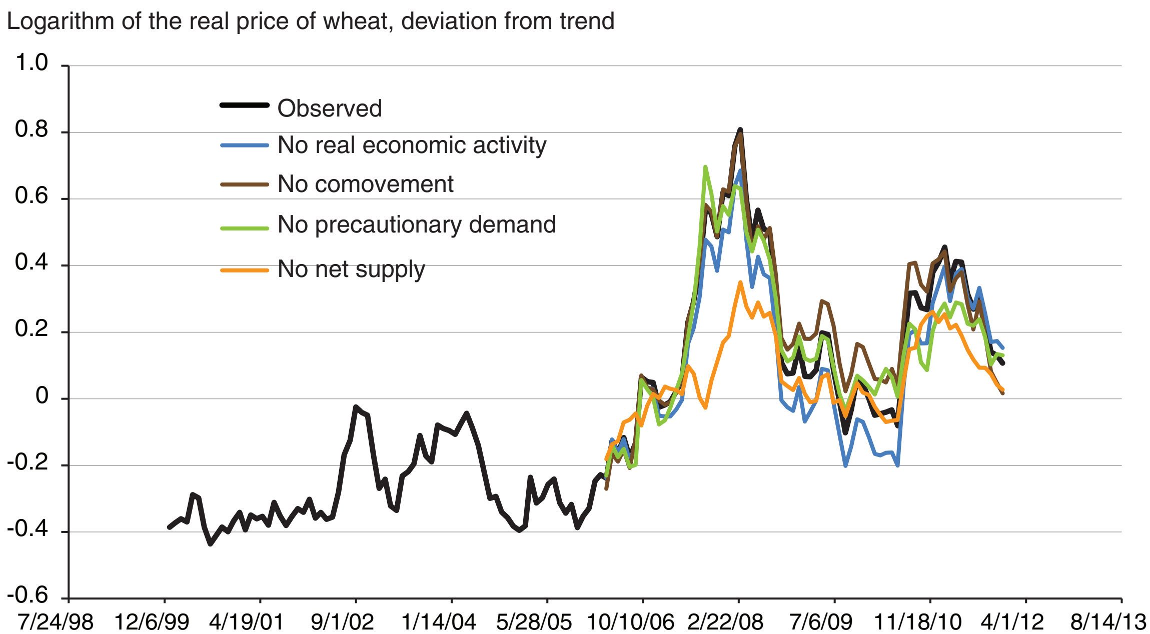


Note: MGEX = Minneapolis Grain Exchange.

Source: USDA, Economic Research Service.

Figure 15

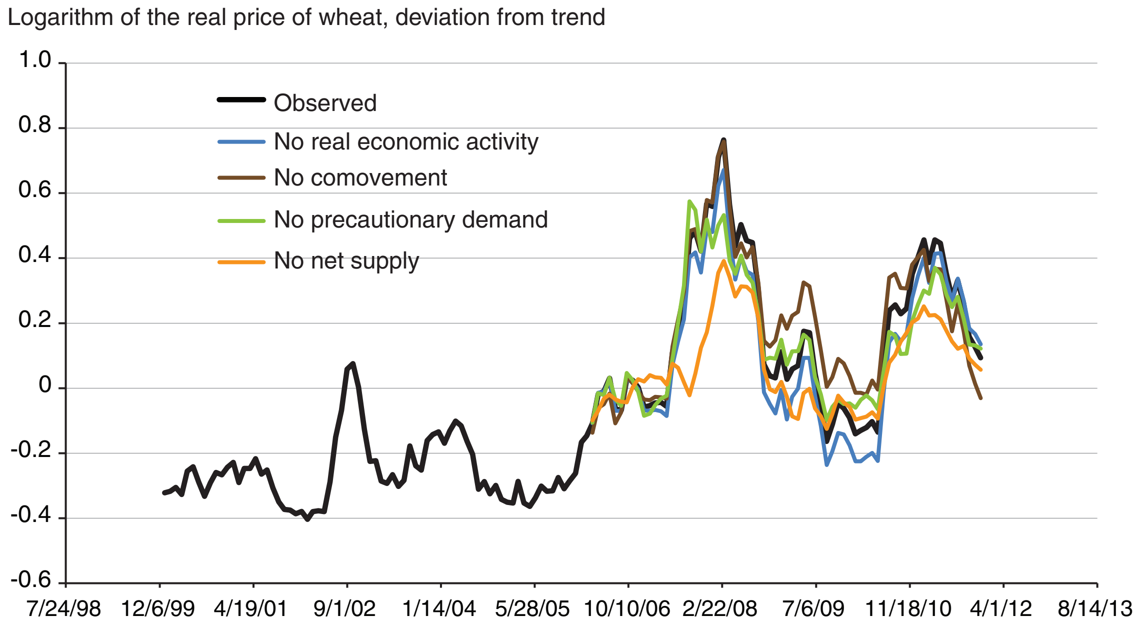
Counterfactual simulation of CBOT wheat futures prices using GSCI as external market



Note: CBOT = Chicago Board of Trade. GSCI = Goldman Sachs Commodity Index.

Source: USDA, Economic Research Service.

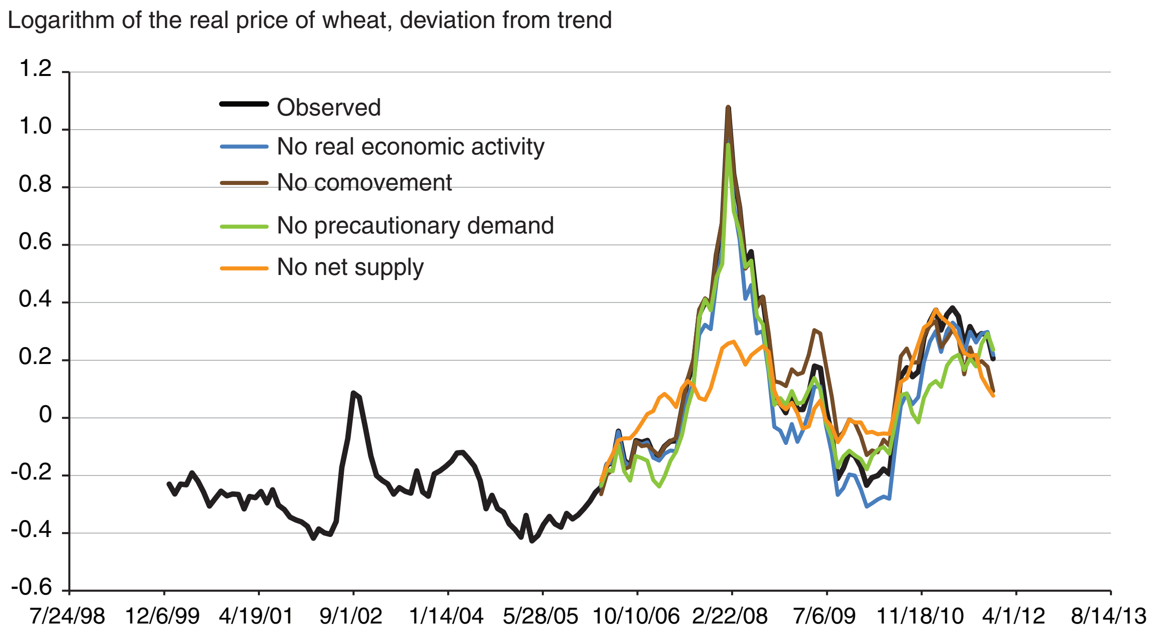
Figure 16
Counterfactual simulation of KCBT wheat futures prices using crude oil as external market



Note: KCBT = Kansas City Board of Trade. GSC I= Goldman Sachs Commodity Index.

Source: USDA, Economic Research Service.

Figure 17
Counterfactual simulation of MGEX wheat futures prices using GSCI as external market



Note: MGEX = Minneapolis Grain Exchange. GSCI = Goldman Sachs Commodity Index.

Source: USDA, Economic Research Service.

increasing impact from precautionary demand beginning in spring 2010 captures these anticipated future export sales.

Wheat futures basis convergence may account for the greater impact of precautionary demand shocks in 2010 and 2011. Garcia et al. (2012) find that the futures spread underestimated the true price of storage in 2009 and early 2010, especially for CBOT. This means that, as inventories accumulated and prices declined during this period, the futures term spread (the measured price of storage) did not increase as much as the true price of physical storage. Because it looked like the price of storage was not increasing as much as it ordinarily would from a pure increase in net supply, the model may have attributed part of the decline in prices to a decline in precautionary demand and, therefore, it would inaccurately attribute part of the increase in prices in 2010 to a subsequent increase in precautionary demand. Thus, the partial attribution of the 2010 price increase to increasing precautionary demand may be overstated. More of the observed effect may be due to net supply shocks.

Conclusions

U.S. wheat futures markets have been criticized for a perceived inability to reflect underlying supply-and-demand conditions for wheat. Speculation, particularly by commodity index traders and other financial speculators, is often cast as the culprit for poor price discovery in wheat futures markets. This analysis uses a structural vector autoregression model to measure the relationship between U.S. wheat futures prices and four unique structural explanations: real economic activity, comovement induced by speculative trading, precautionary demand, and shocks to current net supply. The comovement-driven portion of wheat prices represents the impact of speculation that is unrelated to expected future prices. Such speculation is attributed to commodity index traders who are accused of causing recent periods of elevated prices in agricultural markets.

Wheat price spikes are fundamentally driven and strongly associated with shocks to current supply. Agricultural production remains susceptible to weather-related risk and other factors that cause unexpected variation in available supply. Additionally, supply shocks are compounded by expectations about future shocks; wheat price spikes are a combination of shocks to current supply-and-demand fundamentals and expectations about future prices as represented by the demand for inventories.

The analysis finds little evidence of a comovement-driven price effect associated with commodity index traders. The model is designed to capture comovement with nonagricultural markets as suggested by Tang and Xiong (2012). The analysis even allows comovement shocks to take precedence over wheat-specific shocks and finds negligible comovement effects at the frequency of the data. The absence of a comovement effect suggests that wheat futures markets have performed efficiently in the sense that wheat futures prices have reflected fundamental factors. Consequently, restrictions on commodity index trading are not likely to prevent future price spikes.

Unlike studies of other commodity markets using a similar approach, this study finds that broad trends in global commodity demand related to real economic activity matter less to wheat price determination than do its own supply-and-demand factors. This may be due to the nature of wheat as a staple cereal grain. While global wheat production and consumption is growing, per capita demand growth is decelerating even in the developing world (Alexandratos and Bruinsma, 2012). Emerging economies may not be as hungry for wheat as they are for industrial commodities.

References

Adjemian, M.K., and A.D. Smith. 2012. "Using USDA Forecasts To Estimate the Price Flexibility of Demand for Agricultural Commodities," *American Journal of Agricultural Economics* 94: 978-995.

Adjemian, M.K., P. Garcia, S.H. Irwin, and A.D. Smith. 2013. *Non-convergence in Domestic Commodity Futures Markets: Causes, Consequences, and Remedies*, Economic Information Bulletin No. 115, U.S. Department of Agriculture, Economic Research Service, August, www.ers.usda.gov/publications/eib-economic-information-bulletin/eib115.aspx#.UxjX14XDt28

Ai, C., A. Chatrath, and F. Song. 2006. "On the Comovement of Commodity Prices," *American Journal of Agricultural Economics* 88:574-588.

Alexandratos, N., and J. Bruinsma. 2012. *World Agriculture Towards 2015/2030: The 2012 Revision*, ESA Working Paper 12-03, Food and Agriculture Organization of the United Nations, June.

Antle, J.M., and V.H. Smith. 1999. "An Overview of World Wheat Markets," in J.M. Antle and V.H. Smith (eds.), *The Economics of World Wheat Markets*, CABI Publishing, pp. 1-20.

Antle, J.M., D. Hayes, S. Mohanty, P. Vavra, and V.H. Smith. 1999. "Long-Term Supply and Demand Trends: Whither the Real Price of Wheat," in J.M. Antle and V.H. Smith (eds.), *The Economics of World Wheat Markets*, CABI Publishing, pp. 39-76.

Babcock, B.A. 2007. "Money for Nothing: Acreage and Price Impacts of U.S. Commodity Policy for Corn, Soybeans, Wheat, Cotton, and Rice," in B.L. Gardner and D.A. Sumner (eds.), *The 2007 Farm Bill and Beyond*, Washington, DC: AEI Press, pp. 5-20.

Babula, R.A., D.A. Bessler, and W.S. Payne. 2004. "Dynamic Relationships Among U.S. Wheat-Related Markets: Applying Directed Acyclic Graphs to a Time Series Model," *Journal of Agricultural and Applied Economics* 36:1-22.

Barberis, N., A. Shleifer, and J. Wurgler. 2005. "Comovement," *Journal of Financial Economics* 75:283-317.

Buyuksahin, B., and J.H. Harris. 2011. "Do Speculators Drive Crude Oil Futures Prices?" *The Energy Journal* 32:167-202.

Carter, C.A. 2001. "Current and Future Trends in the Global Wheat Market," in J. Ekboir (ed.), *World Wheat Overview and Outlook 2000-2001: Developing No-Till Packages for Small-Scale Farmers*, CIMMYT, pp. 45-51.

Carter, C.A., and C.L. Revoredo-Giha. 2007. "The Working Curve and Commodity Storage Under Backwardation," *American Journal of Agricultural Economics* 89:864-872.

Carter, C.A., G.C. Rausser, and A. Smith. 2011. "Commodity Booms and Busts," *Annual Review of Resource Economics* 3:87-118.

Carter, C.A., G.C. Rausser, and A.D. Smith. 2012. "The Effect of Ethanol Production on Corn Prices," Working Paper, University of California, Davis.

Chambers, W. 2004. *Forecasting Feed Grain Prices in a Changing Environment*, Outlook Report No. FDS-04F-01, USDA, Economic Research Service.

Chicago Mercantile Exchange. 2012. "Global Wheat Futures Market Share," Working Paper.

Curtis, B.C. 2002. "Wheat in the World," in B.C. Curtis, S. Rajaram, and H. Gomez-Macpherson (eds.), *Bread Wheat: Improvement and Production*, Rome: Food and Agriculture Organization of the United Nations.

Deb, P., P.K. Trivedi, and P. Varangis. 1996. "The Excess Co-movement of Commodity Prices Reconsidered," *Journal of Applied Econometrics* 11:275-291.

Fattouh, B., L. Kilian, and L. Mahadeva. 2012. "The Role of Speculation in Oil Markets: What Have We Learned So Far?" CEPR Discussion Paper No. DP8916, Center for Economic Policy Research.

Flood, C. 2008. "Australia Wheat Hit by Drought," *Financial Times*, June 17.

Frankel, J.A. 1986. "Expectations and Commodity Price Dynamics: The Overshooting Model," *American Journal of Agricultural Economics* 68:344-348.

Garcia, P., S.H. Irwin, and A.D. Smith. 2012. "Futures Market Failure?" Working Paper, University of California, Davis.

Goncalves, S., and L. Kilian. 2004. "Bootstrapping Autoregressions With Conditional Heteroskedasticity of Unknown Form," *Journal of Econometrics* 123: 89-120.

Goodwin, B.K., and T.C. Schroeder. 1991. "Price Dynamics in International Wheat Markets," *Canadian Journal of Agricultural Economics* 39:237-254.

Goodwin, B.K., and V.H. Smith. 2009. "Harvest-Time Protein Shocks and Price Adjustment in U.S. Wheat Markets," *Journal of Agricultural and Resource Economics* 34:237-255.

Gorton, G., and K.G. Rouwenhorst. 2004. "Facts and Fantasies About Commodity Futures," Working Paper No. 10595, National Bureau of Economic Research, June.

Gray, R.W. 1961. *The Relationship Among Three Futures Markets: An Example of the Importance of Speculation*, Food Research Institute Studies 2:21-32.

Hurt, C., and M. Boehlje. 2008. "Financial Crisis Engulfs Agriculture," Working Paper, Purdue University, October 16.

Irwin, S.H., and D.R. Sanders. 2011. "Index Funds, Financialization, and Commodity Futures Markets," *Applied Economic Perspectives and Policy* 34:1–31.

Janzen, J.P., A.D. Smith, and C.A. Carter. 2013. "Commodity Price Comovement and Financial Speculation: The Case of Cotton," Working Paper, University of California, Davis.

J.P. Morgan. 2010. "The Wheat Price Spike of 2007/08: A Case Study of How Markets Resolved a Stock-Out in Physical Inventory," in *Global Commodities Research: Commodity Markets Outlook and Strategy*, New York: J.P. Morgan, 5-9.

Kilian, L. 2009. "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market," *American Economic Review* 99:1053-69.

Kilian, L., and D. Murphy. 2013. "The Role of Inventories and Speculative Trading in the Global Market for Crude Oil," *Journal of Applied Econometrics*, article first published online: 10 APR 2013DOI: 10.1002/jae.2322

Kramer, A.E. 2010. "Russia, Crippled by Drought, Bans Grain Exports," *New York Times*, August 6, pp. A1.

Liefert, W., O. Liefert, G. Vocke, and E. Allen. 2010. "Former Soviet Union Region To Play Larger Role in Meeting World Wheat Needs," *Amber Waves*, June, pp. 12-20, www.ers.usda.gov/amber-waves/2010-june/former-soviet-union-region-to-play-larger-role-in-meeting-world-wheat-needs.aspx#.UxjbsIXDt28

Masters, M.W. 2011. "Testimony of Michael W. Masters Before the U.S. Senate," in B. Lilliston and A. Ranallo (eds.), *Excessive Speculation in Agriculture Commodities: Selected Writings from 2008-2011*, Minneapolis, MN: Institute for Agriculture and Trade Policy, 89-94.

McKenzie, A.M. 2005. "The Effects of Barge Shocks on Soybean Basis Levels in Arkansas: A Study of Market Integration," *Agribusiness: An International Journal* 21(1): 37-52.

Mohanty, S., W.H. Meyers, and D.B. Smith. 1999. "A Reexamination of Price Dynamics in the International Wheat Market," *Canadian Journal of Agricultural Economics* 47:21-29.

Pindyck, R.S., and J.J. Rotemberg. 1990. "The Excess Co-Movement of Commodity Prices," *Economic Journal* 100:1173-1189.

Power, G., and D.V. Vedenov. 2009. "The Price Shock Transmission During the 2007-2008 Commodity Bull Cycle: A Structural Vector Auto-Regression Approach to the "Chicken-or-Egg" Problem," Selected paper, Agricultural and Applied Economics Association Annual Meeting.

Rigobon, R. 2003. "Identification Through Heteroskedasticity," *The Review of Economics and Statistics* 85:777-792.

Sanders, D.R., and S.H. Irwin. 2011. "New Evidence on the Impact of Index Funds in U.S. Grain Futures Markets," *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 59:519-532.

Senate Permanent Subcommittee on Investigations. 2009. "Excessive Speculation in the Wheat Market," Staff report, U.S. Senate.

Silber, W.L. 1981. "Innovation, Competition, and New Contract Design in Futures Markets," *Journal of Futures Markets* 1:123-155.

Singleton, K.J. 2011. "Investor Flows and the 2008 Boom/Bust in Oil Prices," Working Paper, Stanford University.

Soros, G. 2008. "The Perilous Price of Oil," *New York Review of Books* 55: 36.

Stiegert, K., and B. Balzer. 2001. "Evaluating the U.S. Wheat Protein Complex," Working Paper No. FSWP2001-5, Food System Research Group, University of Wisconsin.

Stoll, H.R., and R.E. Whaley. 2010. "Commodity Index Investing and Commodity Futures Prices," *Journal of Applied Finance*, pp. 1-68.

Tang, K., and W. Xiong. 2012. "Index Investment and the Financialization of Commodities," *Financial Analysts Journal* 68:54-74.

Taylor, R.D., and W.W. Koo. 2011. *2011 Outlook of the U.S. and World Wheat Industries, 2011-2020*, Agribusiness and Applied Economics Report No. 680, Center for Agricultural Policy and Trade Studies, North Dakota State University.

Timmer, C.P. 2009. "Did Speculation Affect World Rice Prices?" Working Paper No. 09-07, Agricultural and Development Economics Division of the Food and Agriculture Organization of the United Nations (FAO - ESA).

Trostle, R. 2008. *Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices*, Outlook Report No. WRS-0801, U.S. Department of Agriculture, Economic Research Service, July, www.ers.usda.gov/publications/wrs-international-agriculture-and-trade-outlook/wrs-0801.aspx#.UxjdE4XDt28

UNCTAD. 2011. "Price Formation in Financialized Commodity Markets: The Role of Information," Working Paper, United Nations Conference on Trade and Development.

U.S. Department of Agriculture, Economic Research Service. 2011. *Wheat Outlook*. Outlook Report No. WHS-11.

U.S. Department of Agriculture, Foreign Agricultural Service. 2011. "Production, Supply, and Distribution Online." Online database, U.S. Department of Agriculture, www.fas.usda.gov/psdonline/.

U.S. Department of Agriculture, Office of the Chief Economist. 2011. "Major World Crop Areas and Climatic Profiles," Online database.

Von Braun, J., and M. Torero. 2009. *Implementing Physical and Virtual Food Reserves to Protect the Poor and Prevent Market Failure*, IFPRI Policy Brief No. 10, International Food Policy Research Institute.

Wegren, S.K. 2011. "Food Security and Russia's 2010 Drought," *Eurasian Geography and Economics* 52:140-156.

Williams J.C., and B.D. Wright. 1991. *Storage and Commodity Markets*. New York: Cambridge University Press.

Wilson, W.W., and D. Miljkovic. 2013. "Dynamic Inter-Relationships in Hard Wheat Basis Markets," *Canadian Journal of Agricultural Economics* 61:395-416.

Working H. 1933. *Price Relations Between July and September Wheat Futures at Chicago Since 1885*, Wheat Studies of the Food Research Institute 9: 187-238.

Working, H. 1970 "Economic Functions of Futures Markets," in H.H. Bakken, *Futures Trading in Livestock: Origins and Concepts*, Chicago: Chicago Mercantile Exchange.

Wright, B.D. 2011. "The Economics of Grain Price Volatility," *Applied Economic Perspectives and Policy* 33:32-8.

Appendix: Model Specification, Identification, and Estimation

We use a structural vector autoregression (SVAR) model of the wheat market that captures commodity price formation as understood in the competitive storage model (Williams and Wright, 1991) and the impact of financial speculation as put forward in the work of Tang and Xiong (2012). SVAR models the contemporaneous interrelationships between all variables included in the model. Our data vector y_t includes four variables: (i) real economic activity, *rea*; (ii) the real price of the external market commodity, *ext*; (iii) the spread between distant and nearby futures prices for wheat, *spr*; and (iv) the real price of nearby wheat futures, *pwt*. Price variables are expressed as logarithms. We plot each of these variables net of seasonality and trend, including price and spread measures, for each wheat market in figure A1.

Specification and Identification

The SVAR model is a system of equations relating current levels of each variable to past observations of all variables up to some finite lag *p*, a vector of exogenous variables x_t, and the structural shocks, u_t, from all equations in the model. The model is:

(A1) $$A(L)y_t \equiv \left(A_0 - A_1 L - A_2 L^2 - \ldots - A_p L^p\right) y_t = Cx_t + u_t$$

where *A* and *C* represent the coefficients to be estimated and *L* represents the lag operator. The parameters and the structural shocks from this model cannot be directly estimated, so the SVAR model is related to a reduced-form vector autoregression model that can be estimated by ordinary least squares. The reduced-form model is:

(A2) $$B(L)y_t \equiv \left(I - B_1 L - B_2 L^2 - \ldots - B_p L^p\right) y_t = Dx_t + e_t$$

where *B* and *D* represent the coefficients in the reduced-form model, *I* is the identity matrix, and e_t are the reduced-form residuals. From this representation, the estimable reduced-form residuals are related to the structural residuals, $e_t = A_0^{-1} u_t$. Therefore, identifying the structural residuals requires the identification of the matrix A_0.

We can expand the equation relating reduced-form and structural residuals to describe our identification strategy. This condition, applying our identification assumptions for the matrix A_0, is:

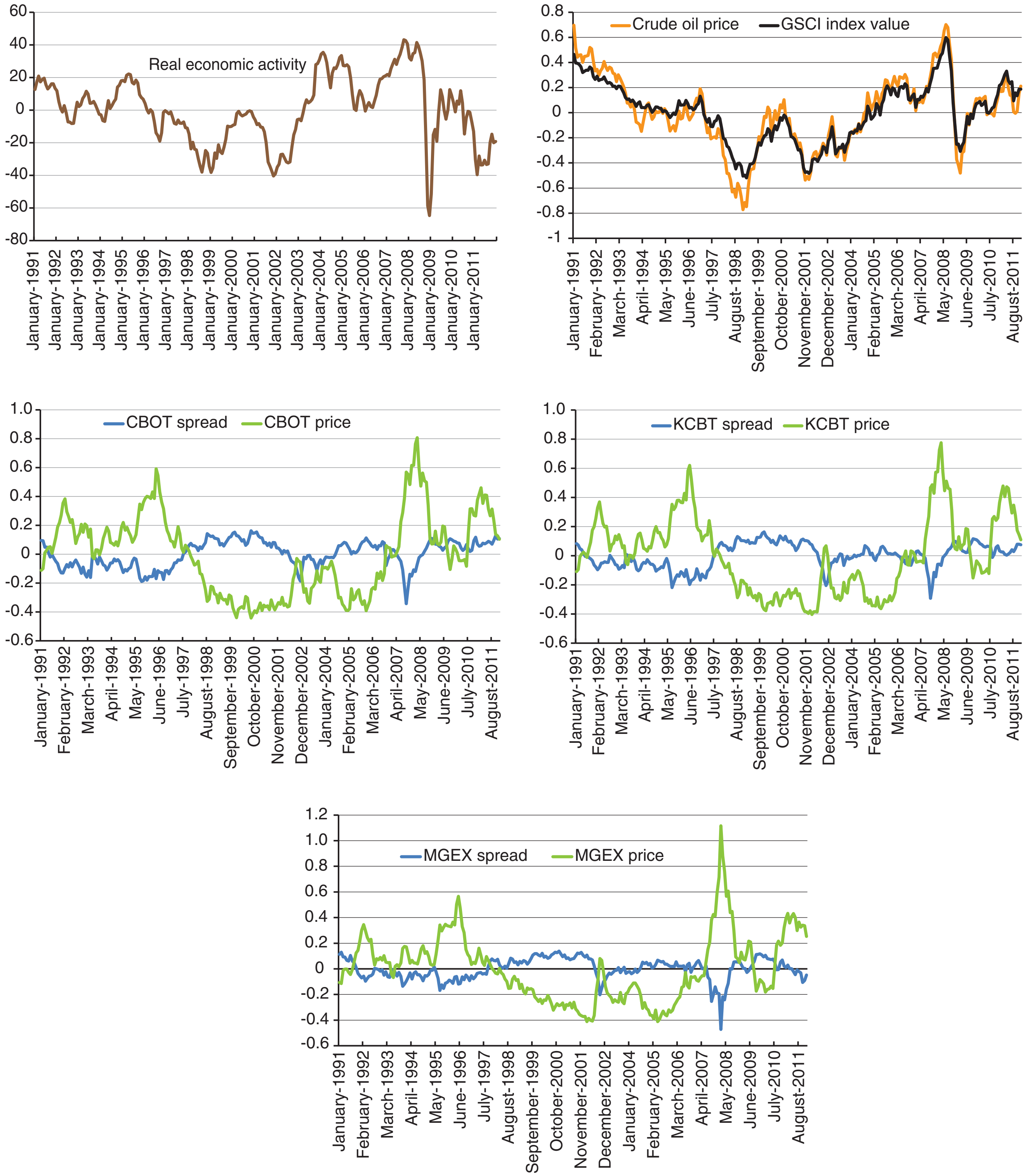
(A3) $$\begin{bmatrix} e_t^{rea} \\ e_t^{ext} \\ e_t^{spr} \\ e_t^{pw} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ A_{21} & 1 & 0 & 0 \\ A_{31} & A_{32} & 1 & A_{34} \\ A_{41} & A_{42} & A_{43} & 1 \end{bmatrix}^{-1} \begin{bmatrix} u_t^{REA} \\ u_t^{CM} \\ u_t^{PD} \\ u_t^{NS} \end{bmatrix}$$

This condition shows clearly that the reduced-form residuals are a weighted sum of the structural shocks. We note our interpretation of the structural shocks as being driven by real economic activity, comovement with external markets, precautionary demand, and net supply with the superscripts *REA*, *CM*, *PD*, and *NS*.

Figure A1

Wheat market variables

Response of economic activity index



Note: GSCI = Goldman Sachs Commodity Index. CBOT = Chicago Board of Trade. KCBT = Kansas City Board of Trade. MGEX = Minneapolis Grain Exchange.

Source: USDA, Economic Research Service using data from Kilian (2009) and Commodity Research Bureau (2011).

We use a combination of three methods to identify A_0. First, we normalize A_0 so that we consider only the relative magnitude of the structural shocks (not the absolute level) by setting the diagonal terms in A_0 to one. Second, we restrict the contemporaneous impact of the structural shocks in the first two equations in the SVAR by setting the above-diagonal terms in the first two equations equal to zero. The section titled "Identification" justifies the recursive ordering assumption.

We cannot assume that either the A_{43} or A_{34} parameters in A_0 equal zero. To identify both of these parameters, we employ the Identification through Heteroskedasticity technique described in Rigobon (2003). Underlying this technique is an assumption that the structural shocks exhibit heteroskedasticity. The competitive storage model of Williams and Wright (1991) supports this assumption since structural shocks in their model have a larger price impact when inventories are scarce relative to when they are plentiful. We consider heteroskedasticity through the second moments of the condition relating the reduced-form and structural shocks. Moving the A_0 term to the left-hand side of equation A1, this condition is:

(A4) $$var\left(A_0 e_t\right) = var\left(u_t\right) \equiv A_0 \boldsymbol{\Omega} A_0^{'} = \boldsymbol{\Sigma}$$

Assuming the existence of volatile periods when inventories are scarce and a tranquil regime when inventories are plentiful generates additional equations that can be used to identify the parameters of A_0. Equation A4 can be written as $A_0 \boldsymbol{\Omega}^r A_0^{'} = \boldsymbol{\Sigma}^r$, where the superscript r denotes the variance-covariance matrix calculated only using observations from one regime. So long as these variance-covariance matrices differ between the two regimes, there are twice as many equations to identify the model parameters. For more information about the procedure, see Rigobon (2003) and Janzen et al. (2013).

Estimation Procedure

To estimate the structural shocks associated with real economic activity, comovement, precautionary demand, and net supply, we first estimate the reduced-form VAR model using ordinary least squares. We choose the number of lags in this model based on Akaike and Schwarz-Bayesian Information Criteria. These measures find that three lags are optimal. We include seasonal (monthly) indicators and a linear trend as exogenous variables, x_t, in these regressions.

To employ the Identification through Heteroskedasticity technique, we divide our time series into volatile and tranquil periods. Based on the competitive storage model, we select as volatile periods crop years where projected inventories for that crop year were low relative to consumption. Volatile periods in our model are those where USDA World Agricultural Supply and Demand (WASDE) projected stocks-to-use are below 20 percent for at least 3 months. We extract the estimated reduced-form residuals, partition them by regime, and calculate residual variance-covariance matrices for each regime, $\boldsymbol{\Omega}^r$. Using constrained optimization methods, we minimize the distance function $A_0 \boldsymbol{\Omega}^r A_0^{'} - \boldsymbol{\Sigma}^r$ defined by the conditions that relate reduced-form and structural variances to determine the parameters in A_0 where $\boldsymbol{\Sigma}^r$ represents the structural shock variance from each regime r. In identifying the simultaneous impacts of precautionary demand and net supply shocks on prices and spreads, we restrict the magnitude of the weighting parameters so that the spread must be at least as responsive to precautionary demand shocks as it is to net supply shocks. The solution allows us to calculate values for the structural shocks in each period covered by our sample.

We present the relationship between observed wheat prices and the structural shocks using impulse response functions, historical decompositions, and counterfactual scenarios. The impulse responses represent the time path of the response of each variable in the model to a one-time, one-standard deviation structural shock, where the standard deviation of the structural shocks is calculated across all time periods in the sample. We generate confidence intervals about these impulse responses using 1,000 iterations of the wild bootstrap technique developed by Goncalves and Kilian (2004). For the historical decompositions and counterfactual scenarios, we rely upon the interpretation of the reduced-form residual as a forecast error equal to a weighted sum of the structural shocks. We plot the weighted structural shocks representative of the contribution of each shock to the unexpected variation in each observed wheat price series. The sum of the four series in the historical decomposition is the observed wheat price in our dataset. For the counterfactual analysis, we take the historical decomposition and set one of the structural shocks equal to zero. Since the wheat price in our model is the logarithm of the real wheat price, the difference between the series shown in the counterfactual analysis is a log-difference approximating a percentage difference between wheat prices including the influence of a given structural shock and without that shock.