A roller coaster ride: an empirical investigation of the main drivers of the international wheat price

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Abstract

Over the last decade, commodity prices have registered substantial booms and busts marked by extreme volatility. Wheat in particular, one of the main nonoil commodities, has registered a roller coaster in price levels which seems to be inconsistent with supply and demand fundamentals. To acutely investigate the drivers of wheat prices and quantify their impact, a vector error correction model (VECM) has been used. The exogenous variables have been distinguished into four groups: market-specific factors, broad macroeconomic determinants, speculative components, and weather variables. The quadriangulation of the determinants will enable us to better understand the movements in wheat price and identify the specific role of each component. The results show that a mix of factors are contributing to wheat price movements, including speculation, global demand, and real effective exchange rate.

\textit{JEL classifications: C22, E31, Q11}

\textit{Keywords:} Wheat price; Fundamentals; Speculation

1. Introduction

In recent years, food commodity prices have increased unusually rapidly, and wheat prices in particular have registered marked upsurges interrupted only briefly by the global financial crisis. These trends can be particularly detrimental because they could amplify the incidence of poverty (Benson et al., 2013; Dethier and Effenberger, 2012; IMF, 2011; von Braun and Tadesse, 2012), hamper economic growth in poor countries (Jacks et al., 2011), and generate worldwide protests and demonstrations, such as those registered in several sub-Saharan African regions. This occurs because people living in these areas spend a larger share of their income on food (about 50\%) than urban residents do in other parts of the world (about 30\% and 15\% in middle- and high-income countries, respectively) (Simon et al., 2011). Given that Africans depend on a small number of staple crops, increases in cereal prices can be particularly destructive. More consumer money on food, in fact, means fewer purchases of services such as sanitation, health, and education (\textit{The Economist}, May 26, 2011). In addition, the Middle East and North Africa regions are the world’s largest importers of cereals, particularly wheat, exposing them to higher international prices. This can lead to substantial terms-of-trade shocks, which affect countries’ internal and external balances, with higher nonaccelerating inflation rates of unemployment and balance of payments deficits.

In this context, this study tries to shed light on the main drivers of wheat prices by identifying the influence of the fundamental factors of supply and demand on the one side, and the behavior of investors in the financial markets on the other side. In light of the steep hikes in the price of several commodities, it becomes especially important to investigate the underlying factors that exert an influence on the wheat market.

Specifically, the study distinguishes wheat price drivers into market-specific variables, broad macroeconomic variables, financial factors, and weather conditions. The empirical analysis is based on monthly data for the period 1980:1–2012:1 and the subperiod 1995:1–2012:1. The quadriangulation of the drivers will allow us to better understand commodity price patterns.

The article provides several contributions to the existing literature. It explicitly examines the case of the wheat market, merging different strands of the literature. To my knowledge, the empirical analyses on the factors behind wheat spot price

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are quite scanty (Borenstein and Reinhart, 1994; Westcott and Hoffman, 1999). Some studies on wheat have more of a descriptive nature. For instance, Trostle (2008) and Mitchell (2008), carrying out a graphical inspection, suggest that wheat price bounced up due to a large demand for biofuels, high transportation costs, and severe drops in world supply. Other analyses consider demand and supply factors leaving out the role of financialization or other broad macroeconomic factors (Goodwin and Schroeder, 1991; Westcott and Hoffman, 1999). This study tries to extend the discussion on the wheat market by singling out specific factors behind price swings within a cointegration framework. A further novelty consists in comparing two long-run relationships, before and after the “financialization” of the commodity markets, to catch similarities and differences. A final important element of this study relates to the use of monthly data, allowing for a finer analysis of price dynamics. Most papers are based on annual or quarterly data (Westcott and Hoffman, 1999).

2. Literature review

The significant roller coaster in commodity prices over the recent years has triggered a vivacious discussion regarding the causes of these ups and downs.

Some observers argue that the run-ups in commodity prices reflect strong changes in economic fundamentals, with price fluctuations moderated by the participation of nonuser speculators and passive investors in commodity futures markets. Others point to the role of broader macroeconomic factors as main drivers pushing up prices. Finally, some other observers argue that commodity prices have been exuberant and divorced from market fundamentals. The first view can be dubbed the “fundamentalist” view, the second the “broad” macro view, and the third the “financialization” view.

According to the market “fundamentalist” view (Dwyer et al., 2011, 2012; Irwin et al., 2009; Irwin and Sanders, 2010; Krugman, 2010a, 2011; Yellen, 2011), the price of any good or asset should be driven by demand and supply in the absence of “irrational exuberance.” In this context, any shock to demand and supply which leads to rising global demand and disruption to global supply causes relevant price swings. Negative shocks to agricultural commodities supply, which imply price surges, are mainly determined by adverse weather conditions and collapses in the stock-to-use ratios. Put differently, extreme weather conditions result in greater yield variability, with likely damage to existing cropping areas and consequent price changes. In addition, when stocks are low relative to use, the market is less prone to cope with significant supply drops or demand excesses, and thus prices skyrocket (Gilbert and Morgan, 2011; Williams and Wright, 1991). Pre-existing stocks are thus a fundamental source of stability in commodity markets. According to a report on the pre-recession spike in food commodity prices by FAO (2009), stock levels have been decreasing, on average, by 3.4% per year since the mid 1990s, and the highest prices were registered during a period in which the stock-to-use ratios were at historical lows. Low stocks in food and other crops finish exacerbating weather disruptions. For instance, the 47% increase in wheat prices in 2010 was largely attributable to droughts in Russia and China and to floods in Canada and Australia.

With respect to demand, the process of income catch-up (convergence) between developing and advanced countries has triggered demand growth for commodities, and hence the price of commodities. More than 90% of the augmented demand for agricultural commodities over recent years has, in fact, originated from developing countries, mainly from India and China (Cevik and Sedik, 2011; Coxhead and Jayasuriya, 2010; Fawley and Juvenal, 2011; Heap, 2005). In Krugman’s words (2010b), rising commodity prices are a sign that “we are living in a finite world, in which the rapid growth of emerging economies is placing pressure on limited supplies of raw materials, pushing up their prices.” However, it should be noted that, in real terms, the price of food commodities has increased by 75% from 2003 to 2008 (Erten and Ocampo, 2013). This pattern was a reversal of the strong downward trends experienced since the 1980s, but it is still too early to assess if the reversal implies a long-term change (shift) in the trend (in its direction), a pronounced short-run spike of food commodity prices around the long-run trend, or a commodity price supercycle (Heap, 2005; Jacks, 2013; Rogers, 2004).

According to the “broad” macro view, other macroeconomic determinants, such as exchange rates, monetary policies, inflation, energy price, global economic activity, and the “thinness” of markets, could have affected price levels and their fluctuations via demand or supply channels. For instance, exchange rates can influence commodity prices through several conduits, such as international purchasing power and the effects on margins for producers with non-U.S. dollar costs (Borenstein and Reinhart, 1994; Gilbert, 1989; Manera et al., 2013; Mussa, 1986; Roache, 2010). This means that dollar depreciation increases prices to U.S. producers and consumers inside the dollar area. A change in the dollar exchange rate thus conditions prices measured in dollar terms, but its effect would fizzle out if prices were measured in terms of a weighted basket of currencies. Monetary policies, including interest rate maneuvers, can as well impact on a number of demand and supply channels (Bakucs et al., 2009; Calvo, 2008; Frankel, 2008; Orden and Fackler, 1989), leading to greater movements in real commodity prices when changes in real interest rates become frequent. This occurs particularly when interest rates are low, and there is an incentive to hoard physical commodities as an investment vehicle, causing price to go up. Inflation is a common factor driving prices of different commodities. Furthermore, oil prices have been mentioned as an additional shock to food price via demand channels (Mercer-Blackman et al., 2007; Thompson et al., 2009). This is because a surge in oil price leads to an

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1 A rational expectations model predicts that the existence of a futures market would reduce the fluctuation of spot prices for reasonable value of input parameters.
increase in demand for grains as biofuels, and this causes a consequent raise in food commodity prices.\(^2\)

Also, the “thinness” of markets, which is the combined share of imports and exports relative to the size of global consumption or production, significantly affects commodity price movements. It does this because in thinner markets, where domestic prices do not follow the international market, world market prices have to vary more to accommodate an external shock to traded quantities (OECD, 2008).

Some other observers doubt that fundamental shocks could justify the whole price run-ups. Instead, they point to the “financialization” of commodity markets and speculation as the main culprits of the drifts and fluctuations of commodity prices (Gilbert and Morgan, 2011; Hamilton, 2009; Masters, 2008; Stewart, 2008; Tang and Xiong, 2012). “Financialization” refers to the large flows of capital into the commodity market, explicitly in the long-only commodity index fund (Acworth, 2005; Domanski and Heath, 2007; Miffre, 2011; Miffre and Brooks, 2013). Speculation involves buying, holding, and selling of stocks, bonds, commodities, or any valuable financial instrument to profit from fluctuations in its price, as opposed to buying for use, dividend or interest income, or hedging purposes by market participants (Robles et al., 2009). Speculation may take the form of speculative stockholding, speculative purchase and sale of commodity futures, or other derivative contracts.

Along this line was the report by the U.S. Senate’s Permanent Subcommittee on Investigations (USS/PSI, 2009, p. 2) which argued that commodity traders and futures contract were disruptive forces, pushing prices away from fundamentals and inducing excessive price movements.

In this context, some believe that a speculative bubble is forming in commodities as a consequence of the highly accommodating stance of the U.S. monetary policy, including the maintenance of the target federal funds rate at exceptionally low levels (Hamilton, 2009), and extremely high flows of investment funds into commodity futures. Loose monetary policy influences commodity prices by reducing the cost of holding inventories or by fomenting “carry trades” and other forms of speculative behavior (Frankel, 2013). However, the “fundamentalist” view points to the fact that stocks of agricultural products have generally been falling over 2006–2008, thus undermining the hypothesis that speculators contributed to the spike in prices.

The financialization hypothesis suggests that prior to the recession, the large gains in commodity prices were accompanied by a large flow of funds. According to Barclay’s, index fund investment in commodities augmented from $90 billion in 2006 to about $200 billion by the end of 2007, to record a historical peak in July 2011 with $431 billion. In this context, the speculative buying of index funds on a large base created a “bubble,” with the result that commodity future prices far exceeded fundamental values during the boom. However, the fundamentalists again argue against the “speculation theory,” suggesting that commodities without any futures markets have experienced approximately as much fluctuations as commodities with a derivative market.

3. Variables and data

3.1. Data description

In order to empirically examine the causes of price fluctuation, I consider wheat spot prices at monthly frequency for the whole sample 1980–2012 and the subperiod 1995–2012. The subsample starts in 1995 due to the unavailability of some financial data before that period. To identify the key drivers, I have merged the different strands of the extant literature and distinguished the determinants of wheat price into four dimensions: market-specific variables, broad macroeconomic variables, financial components, and weather conditions. A detailed data description is reported in the Appendix.

The focus is on the spot market, rather than the futures market for two main reasons. First, it is important to understand the interconnections between the two markets and assess how futures market trading activities affect the patterns of spot prices for their economic and welfare consequences. Second, the existing analyses are mainly focused on commodity futures markets and less on the cash markets.

Wheat spot prices are taken from the IMF International Financial Statistics, via Datasream. They are expressed in US$, averaged from daily quotations, and then prices have been deflated using the U.S. consumer price index (CPI) to have real values and finally indexed (year 2000 = 100).

3.2. Market-specific variables

Market-specific variables include inventory-to-consumption and the “thinness” of markets.

Inventory-to-consumption (−). Inventory stock levels have a crucial role in commodity pricing (Krugman, 2011; Pindyck, 2001; Williams and Wright, 1991). As in manufacturing industries, inventories are used to reduce costs of adjusting production over time in response to fluctuations in demand, and to shrink marketing costs by facilitating timely deliveries and preventing stock-outs. Producers can reduce their costs over time by selling out of inventories during high-demand periods, and replenishing inventories during low-demand periods. Since inventories can be used to ease production and marketing costs despite fluctuating demand conditions, they will have the effect of lowering the degree of short-run market price fluctuations.

\(^2\) To reduce oil dependence as the main source of energy, several countries, including the United States, have adopted new energy policies to promote the use of biofuel. The 2005 US energy bill mandated that 7.5 billion gallons of ethanol be used by 2012. The 2007 energy bill further raised the mandate to 36 billion by 2022. The mix of increasing ethanol subsidies and high oil prices determined a rapid growth of the ethanol industry, which consumes about one-third of the US maize production. The rise of the ethanol industry might have led prices of maize, and other close substitutes such as soybeans and wheat, to comove with oil prices (EPA, 2012; Roberts and Schlenker, 2010).
Formally, it

The construction of this measure includes exports and imports to be con-
ceptually parallel to the degree of openness of an economy. As imports equal
exports at a global level, the thinness index could also be represented by either
exports or imports.

Therefore, one would expect that price levels and their fluctuations increase when inventories lessen.

While inventory holdings can change, production in any pe-
riod does not need to be equal to consumption. As a result,
the market-clearing price is determined not only by current
production and consumption, but also by changes in inventory
holdings.

I have considered stocks at the end of year as a propor-
tion of the consumption for the previous year at an aggregate
world level. This ratio is also referred to as the stock-to-use
ratio (Eq. 1). The inventory data are the predicted end-of-
season global wheat inventories as they are published in the
monthly United States Department of Agriculture (USDA)
reports. Therefore, the inventories appraise the projected quanti-
ties of grain reserves carried from the ongoing marketing year
to the new marketing year. The definition of the marketing year
is based on the aggregate of local marketing years. The largest
trader of wheat in the international market is the United States,
where the marketing season starts at the beginning of June and
ends at the end of May. The consumption data are the projected
season’s consumption levels. The source of data is USDA.

International thinness of markets ($+$/−). The “thinness” of
markets refers to the share of the imports and exports of a
specific commodity relative to the size of global consumption
or production (OECD, 2008). This ratio describes to which extent
agricultural products are internationally traded.\(^3\) Formally, it
has considered the thinness of the wheat market as follows:

\[
\text{thinness} = \frac{\text{exports}}{\text{consumption}}
\]

A low ratio means that market is “thin,” whereas a high
ratio implies “fatness” of the market. A thin market is a market
characterized, hence, by low trading volume.

The thinness of a market could exert two opposite effects on
price. Higher trading volume may lead to a higher demand for
commodities; this could result in a price run-up. Conversely,
trade could help smooth production and consumption across
space by moving goods from surplus to deficit regions, thus
mitigating price movements. In this context, more trade im-
plies more stability and price drops, whereas lack of trade
implies high movements and price increases (Jacks et al., 2011).
Increased trade integration would thus facilitate the stabiliza-
tion of food prices and the reduction of prices for consumers
(The World Bank, 2012).

In regards to volatility, a thin market, characterized by low
trading volumes, tends to show high fluctuations (illiquid),
whereas fat markets display high trading volumes and high liq-
uidity. It is often argued that agricultural markets are “thin” be-
cause the ratio of trade flows to global production/consumption
is considered low as a consequence of protectionist measures or
because most of commodity’s production is consumed where it
is produced, like in the case of rice (Timmer, 2009). This causes
price swings that are larger than would be expected in more liq-
uid or deeper markets. With reference to wheat, a change in the
thinness variable can be considered more directly as a proxy of
changes in trade policy since wheat is consumed independently
from where it is produced, and the market dimension is more
linked to the existence of restrictive or expansive trade policies.

When markets are thinner and prices in domestic markets do
not follow those in international trade because of insulating poli-
cies or market imperfections, world market prices must change
to better accommodate an external shock to traded quantities,
if all else is equal. Trade thus would be an important buffer for
localized fluctuations originating in the domestic market and
could also be useful to level out local supply shocks around the
globe.

3.3. Broad macroeconomic variables

Broad macroeconomic variables include global economic ac-
tivity, interest rates, real exchange rates, oil price, and inflation.

Global economic activity (+). To measure the global economic
activity, the monthly global industrial production index has been
considered. The latter has been used because real-world GDP is
not available on a monthly basis but only at quarterly frequen-
cies. Initially, it was thought to separately consider industrial
production for advanced and emerging economies to analyze
the impact of aggregate demand growth; however, these data
are available only with annual frequency, and in any case world
figures have the advantage of including emerging countries such
as China and India. This is in line with the study by Frankel and
Rose (2009).

Interest rate and yield curve (−) and (+)/(−). Real interest
rates can influence commodity prices in several ways, as
explained by Frankel (2006, 2012, 2013). For instance, the
prices of storable commodities would rise as interest rates fall.
Commodity markets...turns commodity prices.

Another mechanism by which real interest rates impact commodity prices relates to financial speculation in commodity markets. Commodities can also be thought of as financial assets, thus when real interest rates are very low, investors are more prone to take open positions in the financial market for commodities, and this pushes their prices up. Conversely, an increase in interest rates encourages speculators to shift from spot commodity contracts to Treasury bills, and this curbs commodity prices. Following this line of thought, Calvo (2008) put forward that the increase in commodity prices mostly stems from the combination of low central bank interest rates, the growth of sovereign wealth funds, and the consequent lower demand for liquid assets.

In order to account for monetary policy, the U.S. money market rate (federal funds) deflated by the consumer price has been considered. The interest rate is thus expressed in real values.

In addition, to have an idea of the expected future path of the short-term interest rates, the U.S. interest rate spread has been included, constructed as the difference between the 10-year Treasury bonds and the federal funds. This spread or difference between long and short rates is often called the yield curve. It is felt to be an indicator of the stance of monetary policy and general financial conditions because it rises (falls) when short rates are relatively low (high). When it becomes negative (i.e., short rates are higher than long rates and the yield curve inverts), its record as an indicator of recession is particularly strong. Shortly, it is a leading indicator which signals changes in the direction of aggregate economic activity.

The expected relationship between yield spread and commodity prices is uncertain. If the presence of risk premiums in Treasury bond markets represents rewards to investors for exposure to economy-wide macroeconomic risks, then we should expect a strong positive linkage between variation in commodity spot prices and measures of risk in Treasury bond markets. This indicates that higher yield spreads, which signal a declining risk tolerance in the Treasury bond market, mean higher commodity prices, which indicate an increasing risk tolerance in the commodity markets. This pattern is consistent with the thesis that the asset classes are being treated as substitutes in diversified portfolios.

If risk aversion is instead expressed in similar ways across the Treasury and commodity markets during the period, then rising Treasury yields are correlated with lower commodity prices. This pattern is consistent with the thesis that the asset classes are being treated as complements in diversified portfolios.

Oil spot price (+). The oil price is a critically important contributing factor in the increase in production costs for agricultural commodities and food (cost of processing, transportation, and distribution) and ultimately in the market prices for these goods. In addition, an increase in oil price provides an incentive to produce biofuels and thus exerts a further pressure on food commodity prices. Therefore, wheat prices and oil prices are expected to be positively related.

Cushing, Oklahoma West Texas Intermediate (WTI) Spot Price FOB (Dollars per Barrel) has been collected from Datasream. To have real values, the average petroleum spot price has been deflated using the U.S. CPI.

Real effective exchange rate (+)/(-). Trade in many agricultural commodities (as also for oil) is denominated in US$; this implies that movements in the dollar effective exchange rate affect the price of commodities as perceived by all countries outside the United States. Therefore, a change in the dollar exchange rate can modify the demand and supply for agricultural commodities and thus change their prices. A real exchange rate appreciation (depreciation) can be positively or negatively related to prices.

On the one hand, dollar depreciation tends to reduce the commodity price in domestic currencies for countries with floating exchange rates, such as the euro area, Japan, the Philippines, and South Korea. This leads to an increase in their commodity demand. Therefore, dollar depreciation has a positive impact on commodity demand and should contribute to raise prices. Conversely, a dollar appreciation makes exports less competitive and decreases the demand for commodities, causing dollar denominated international commodity prices to diminish. The effect is neutral for countries that have a currency pegged to the US$, such as Oman, Saudi Arabia, Eritrea, and Hong Kong.

On the other hand, if uncertainty increases, both the demand for dollars and the demand for commodities increase, thus causing commodity prices to rise.

Inflation (+). Since commodities are considered to store value, their demand as financial assets or stocks increases with inflation. Inflation tends to affect commodity prices through the portfolio choices of financial investors; this occurs because holding commodities can hedge investment portfolios against inflation risks (Roache, 2010). The inflation rate is computed using changes in the U.S. CPI.

3.4. Financial variables

To account for Financial Variables, I have included a measure of financialization and speculation in the wheat market.

Financialization and Speculation (+)/(-). Commodity markets have registered a progressive financialization over time. This is clear if one looks at the evolution of the level in Open interests which describes the total number of futures contracts long (purchased contracts outstanding) or short (sold contracts outstanding) for a given commodity in a delivery month or market that has been entered into and not yet liquidated by an offsetting transaction or fulfilled by delivery of the
commodity. Open interests are hence a widely used measure of the size of a commodity futures market. Specifically, Fig. 2 sketches the disaggregated open interest for type of traders and nature of contract in wheat market; i.e., it considers the long and short open interests for commercial traders, noncommercial traders, and nonreportables.

Specifically, “commercial traders” are also known as hedgers. This type of futures trader holds position in the underlying commodity and attempts to offset risk exposure through future transactions. “Noncommercial traders” are called also speculators. They only hold positions in futures contracts and do not have any involvement in the physical commodity trade. Commercial and noncommercial traders are defined as reportable traders because they hold positions in futures and options at or above specific reporting levels set by the U.S. Commodity Futures Trading Commission (CFTC). “Nonreportables” are small traders who do not meet the reporting thresholds set by the CFTC. Traders could take either long (buy) or short (sell) positions in commodity futures markets, depending on whether commodity prices are expected to appreciate or depreciate.

It is worth noticing that although wheat futures can be traded on the Kansas City Board of Trade (KCBT), and the Minneapolis Grain Exchange, I have used figures from the Chicago Board of Trade (CBT) because it is the world’s oldest futures and options exchange and the largest commodity exchange in the world. Founded in 1848, it accounts for about half of the turnover in futures contracts in the United States and the bulk of the world’s grain futures trading.

As displayed in Fig. 2, open interest recorded significant raises from 2003 onward, to register a drop during the financial crisis and a surge soon afterward. The fact that the long and short positions of all types of investors in the wheat market have increased over time suggests a rise in the financialization of commodity futures markets.

In a well-functioning futures market, hedgers, who are willing to lessen their exposure to price risks, find counterparts. In the absence of any speculative activity, long hedgers have to find short hedgers with an equal and opposite position. Since long and short hedgers do not always trade simultaneously or in the same amount, there is space for speculators to satisfy the unmet hedging demand. Speculators thus reduce searching costs by taking the opposite positions when long and short hedgers do not perfectly match each other (Buyukshahin and Harris, 2011). This follows Friedman’s (1953) argumentation, according to which speculators stabilize prices by buying low and selling high so as to bring prices closer to fundamentals. Conversely, it often turns out that the speculative activity exceeds the level required to offset any unbalanced hedging, thus destabilizing markets. According to De Long et al. (1990), in fact, rational speculators finish setting price trends and leading short-term prices away from fundamentals by anticipating the buy/sell orders of trend followers.

In short, the financialization of commodity markets has brought about an increase in speculation, which could have positive or negative effects on commodity markets, and consequently on prices.

Since the share of net long positions of noncommercial traders is frequently used as a variable to capture financial investor activity in commodity markets (Domanski and Heath, 2007; IMF, 2006; Micu, 2005), an excessive speculation index has been constructed following Working (1953). This metrics is a good measure of speculative activities in futures markets,
since it assesses the relative importance of speculative positions with respect to hedging positions and indeed as Working suggested, the level of speculation is meaningful only in comparison with the level of hedging in the market. The Working index has been used also by Sanders et al. (2010), Büyükşahin and Harris (2011) to examine the adequacy or excessiveness of speculative participation in the commodity futures markets. Formally, the excessive speculative index is given by

\[
ESPI = \left[ 1 + \frac{NC\ OI\ Short}{C\ OI\ Short + C\ OI\ Long} \right] \cdot 100
\]

if \( C\ OI\ Short \geq C\ OI\ Long \),

\[
ESPI = \left[ 1 + \frac{NC\ OI\ Short}{C\ OI\ Short + C\ OI\ Long} \right] \cdot 100
\]

if \( C\ OI\ Short < C\ OI\ Long \),

where \( NC\ OI\ Short \) indicates open futures position of short speculators, \( NC\ OI\ Long \) indicates open futures position of long speculators, \( C\ OI\ Short \), open futures position of short hedgers, and \( C\ OI\ Long \), open futures position of long hedgers. In other terms, the nominator denotes the speculation positions short and long. The denominator is the total amount of futures open interest resulting from hedging activity.

Fig. 3 reports the excessive speculation index in the wheat market and its descriptive statistics.

Finally, the model controls for Global weather conditions.

### 3.5. Weather conditions

To account for weather conditions, the following two indicators have been considered:

(i) The sea surface temperature (SST) anomalies for the El Niño region 3.4 (a central region of the Pacific). This index measures the deviations between the SSTs in the El Niño region 3.4 and its historical average, and it is calculated by the National Climatic Data Center U.S. Department of Commerce and National Oceanic and Atmospheric Administration (NOAA) Satellite and Information Service using the extended reconstructed SST.

(ii) The Southern Oscillation Index (SOI) anomalies, which measures the fluctuations in air pressure occurring between the western and eastern tropical Pacific during El Niño and La Niña episodes (i.e., the state of the Southern Oscillation). It is a standardized index based on the observed sea level pressure differences between Tahiti, French Polynesia and Darwin, Australia. In general, a negative phase of the SOI represents below-normal air pressure at Tahiti and above-normal air pressure at Darwin. SOI data are taken from the National Oceanic and Atmospheric Administration National Climatic Data Center.

Although the events described by these indices arise in the Pacific Ocean, they have strong effects on the world’s weather and an important influence on the world’s production and price of primary nonoil commodities (Brunner, 2002). The monitoring of both SOI and SST variables allow for a better understanding of global climatic fluctuations enabling us to nicely distinguish between atmosphere and ocean influences on yield and thus prices. In addition, their combination significantly
improves the weather forecast, compared to the use of one of the two variables separately (Russell et al., 2010).

The dynamics of SST and SOI are reported in Fig. 4. As regards the SST index, positive anomalies (index values above zero) are related to abnormally warm ocean waters across the eastern tropical Pacific typical of an El Niño event, and negative anomalies are related to a cool phase typical of a La Niña episode. Conversely, prolonged periods of positive SOI values (values above zero) coincide with La Niña events during which water becomes cooler than normal; vice versa, SOI values below zero mirror El Niño episodes during which water becomes warmer than normal. La Niña events are associated with increasing droughts throughout the midlatitudes, where much of wheat and other relevant grains such as corn and soybeans are produced, thus suppressing their yield (Hurtado and Berri, 1998) and driving up prices. For this reason, La Niña episodes have historically been associated with global food crises. El Niño is associated with an increased likelihood of droughts in tropical land areas, which mainly affects crops such as sugar and palm oil.

It is worthwhile noticing that, the SST and the SOI anomalies tend to vary with opposite signs, and that SOI has a higher variability than the SST index as computed by the coefficient of variation reported below.

4. Empirical evidence

4.1. Preliminary unit root test

Prior to testing for cointegration, the time series examined in Section 3 have been trasformed in log form, and their properties have been carefully investigated. The transformation in log form has the advantage of interpreting the coefficients as elasticities. The grafical inspection of the data (see Appendix Fig. A1) reveals that most of the series resemble random walk processes, some “trending” upward, and some “trending” downward with fluctuations, therefore the Augmented Dickey–Fuller (ADF) (1981) and the Phillips–Perron (P–P) (1988) tests have been conducted for each variable to formally test for the presence of unit roots. The critical values for the rejection of the null hypothesis of a unit root are those computed according to the MacKinnon criterion (1991). The lag length for the ADF test is based on the Schwarz Information criterion. The lag structure for the P–P is selected using the Bartlett Kernel with automatic Newey–West bandwidth. The two tests have been carried out with a constant plus a linear trend.

The ADF and P–P tests show that all the independent and dependent variables are integrated of order one \( I(1) \), i.e., the series become stationary after their first differenciation. This occurs because the computed values do not exceed the MacKinnon critical values. The only exceptions are for the U.S. fed spread and the SST index which show different results according to the two tests.\(^5\) However, it is acceptable to consider the series integrated of order one, because it is confirmed by a supplementary

\[^{5}\text{Although Engle and Granger’s (1987) original definition of cointegration refers to variables that are integrated of the same order, Enders (2009) argues that “It is possible to find equilibrium relationships among groups of variables}}\]
The outcomes of the tests are reported in Table 1. The presence of nonstationarity implies that standard time-series methods are no longer suitable, and that, consequently, a cointegration analysis is required (Enders, 2009). To have a broader indication on the variables of interest, the correlation matrix has been computed⁹ (Table 2).

### 4.2. Johansen and Juselius analysis

The Johansen and Juselius methodology (1990), based on maximum likelihood estimation, permits us to simultaneously evaluate equations involving two or more variables and to determine whether the series are cointegrated; that is to say, that there is a long-term relationship among variables. Furthermore, this technique controls for endogeneity, and enables us to assess and test for the presence of more than one cointegrating vector.

Finally, this methodology performs better than other estimation methods by including additional lags, even when the errors are nonnormal distributed or when the dynamics are unknown, and the model is overparameterized (Gonzalo, 1994). Consider a $p$-dimensional vector autoregressive model, which in error correction form is given by

$$\Delta x_t = \Pi x_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \Phi S_t + \xi_t,$$  \hspace{1cm} (1)

where $\Delta$ is the difference operator and $x_t = (k \times 1)$ is the vector of nonstationary $I(1)$ variables, explicitly $x_t = [\text{wheat price;} \text{market specific variables;} ; \text{broad macro variables;} ; \text{weather;} ; \text{speculation;} ]$ (2) and

$$\Pi = \sum_{i=1}^{p} A_i - I, \hspace{1cm} I = a(k \times k) \text{ identity matrix,}$$  \hspace{1cm} (3)

$$\Gamma_i = \sum_{j=1}^{i} A_j - I, \hspace{1cm} A = a(k \times k) \text{ matrix of parameters.}$$  \hspace{1cm} (4)

The variable $S_t$ contains a constant term and a time trend, and $\xi$ is a vector of Gaussian, zero mean disturbances. $\Gamma_i$ are $(k \times k)$-dimensional matrices of autoregressive coefficients. The long-run matrix $\Pi$ can be decomposed as the product of $\alpha$ and $\beta$, two $(k \times r)$ matrices each of rank $r$, such that $\Pi = \alpha \beta'$, where $\beta'$ contains the $r$ cointegrating vectors and $\alpha$ represents the adjustment parameters, which reflect the speed of adjustment of particular variables with respect to a disturbance in the

---

### Table 1

<table>
<thead>
<tr>
<th></th>
<th>ADF level</th>
<th>ADF first difference</th>
<th>PP level</th>
<th>PP first difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$t$-stat</td>
<td>prob</td>
<td>$t$-stat</td>
<td>prob</td>
</tr>
<tr>
<td>Ln p</td>
<td>−2.992336</td>
<td>0.1357</td>
<td>−14.91106</td>
<td>0.0000</td>
</tr>
<tr>
<td>Ln real p</td>
<td>−2.431287</td>
<td>0.3627</td>
<td>−14.53731</td>
<td>0.0000</td>
</tr>
<tr>
<td>Ln real fed fund</td>
<td>−1.068320</td>
<td>0.9316</td>
<td>−11.71861</td>
<td>0.0000</td>
</tr>
<tr>
<td>Ln rex</td>
<td>−2.354874</td>
<td>0.4028</td>
<td>−13.60509</td>
<td>0.0000</td>
</tr>
<tr>
<td>Ln end stock-to-use</td>
<td>−3.065811</td>
<td>0.1162</td>
<td>−18.98650</td>
<td>0.0000</td>
</tr>
<tr>
<td>SST</td>
<td>−4.110884</td>
<td>0.0066</td>
<td>−3.852657</td>
<td>0.0150</td>
</tr>
<tr>
<td>SOI</td>
<td>−5.795922</td>
<td>0.0000</td>
<td>−9.231864</td>
<td>0.0000</td>
</tr>
<tr>
<td>Ln US CPI</td>
<td>−2.674356</td>
<td>0.2480</td>
<td>−11.59517</td>
<td>0.0000</td>
</tr>
<tr>
<td>Ln world ind prod</td>
<td>−1.775113</td>
<td>0.7150</td>
<td>−6.057624</td>
<td>0.0000</td>
</tr>
<tr>
<td>US fed spread</td>
<td>−4.483997</td>
<td>0.0018</td>
<td>−3.363331</td>
<td>0.0580</td>
</tr>
<tr>
<td>Ln thiness</td>
<td>−2.636053</td>
<td>0.2645</td>
<td>−18.78330</td>
<td>0.0000</td>
</tr>
<tr>
<td>Ln speculation</td>
<td>−6.667659</td>
<td>0.0000</td>
<td>−6.765594</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Note: Test equation includes trend and intercept. MacKinnon crit-values. The sample goes from 1980 to 2012 with monthly observations. Only for speculation does the sample refer to the period 1995–2012.

Null hypothesis: there is a unit root.

Ln = logarithm; real $p$ = real wheat price; real $p$ = real oil price; real fed fund = real federal fund; rex = real effective exchange rate; SST = sea surface temperature anomalies; SOI = Southern Oscillation Index anomalies; US CPI = U.S. inflation rate; world ind prod = world industrial production; US fed spread = U.S. bond yield; thiness = thinness of the market; speculation = excessive speculation.
equilibrium relationship. Therefore, Eq. (1) becomes

$$
\Delta x_t = (\alpha \beta^\top) x_{t-p} + \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \Phi S_t + \xi_t.
$$

The maximum likelihood approach makes it possible to test the hypothesis of \( r \) cointegrating relations among the elements of \( x_t \),

$$
H_0 : \Pi = \alpha \beta^\top,
$$

where the null of no cointegration relation (\( r = 0 \)) implies \( \Pi = 0 \). If \( \Pi \) is of rank \( k \), the vector process is stationary. If rank \( \Pi \) = 1 there is a cointegrating vector; for other cases in which 1 < rank \( \Pi \) < \( k \) there are multiple cointegrating vectors.

### 4.3. Empirical results

A vector autoregressive system of variables has been constructed to test whether real wheat prices are cointegrated with specific market variables, broad macroeconomic factors, speculation, and weather events. To identify the proper model, five possibilities considered by Johansen (1995) were tested, specifically: (1) the series have no deterministic trends and the cointegrating equations do not have intercepts, (2) the series have no deterministic trends and the cointegrating equations have intercepts, (3) the series have linear trends but the cointegrating equations only have intercepts, (4) both series and the cointegrating equations have linear trends, and (5) the series have quadratic trends and the cointegrating equations have linear trends. Following the Pantula test (Pantula, 1989), the third and the fifth models are the most appropriate for two samples. To identify the lag length, the Akaike Information (AIK) criterion has been implemented. The chosen lag structure is three (the smallest value) for the complete sample and five for the subsample, following the AIK criterion. A number of dummies have been included in the cointegration test to take into account periods of social and economic instability and structural breaks.\(^7\)

The results of Johansen’s test for cointegration are displayed in Table 3, which reports the hypothesized number of cointegration equations in the first left column, the eigenvalue, the trace\(^8\) statistics, the max eigenvalue statistics,\(^9\) and 5% critical values. The asterisks indicate the rejection of the hypothesis.

In detail, the first row of the trace statistic tests the hypothesis of no cointegration, the second row tests the hypothesis of one cointegrating relation, the third row tests the hypothesis of two cointegrating relations, and so on, all against the alternative hypothesis of full rank; i.e., all series in the model are stationary. For the longer sample, the \( \lambda_{\text{trace}} \) test and the \( \lambda_{\text{max}} \) statistic indicate the presence of one cointegrating equation at the 5% level. For the shorter sample, the \( \lambda_{\text{trace}} \) test indicates the presence of three cointegrating equations at the 5% level. The \( \lambda_{\text{max}} \) statistic does not confirm this result: the null hypotheses of no cointegrating vector (\( r = 0 \)) can be rejected at the 5% level, but the null of \( r = 1 \) cannot be rejected. So, it can be concluded that there is one cointegrating vectors at the 0.05 level in the system.

Although the results of trace tests and maximum eigenvalue tests point to different outcomes, we can conclude for one cointegrating vector since as Johansen and Juselius note, “one would, however, expect the power of this procedure [the trace

---

\(^7\) Specifically, outliers were detected by looking at the graphs of the residuals. Five dummies relative to 1998, 2007, 2008, 2010, and 2011 were inserted in the short sample wheat price equation. The effects of including dummy variables to capture structural breaks in cointegration models have been analyzed in Kremers et al. (1992) and Campos et al. (1996).

\(^8\) The trace statistic of \( r \) cointegration relations is a sequence of likelihood ratio tests, computed as \( \lambda_{\text{trace}}(r) = -T \sum_{i=1}^{r} \ln(1 - \hat{\lambda}_i) \), where \( \hat{\lambda}_i \) is the estimated value of the characteristic roots (also called eigenvalue) obtained from the estimated long-run \( \Pi \) matrix, and \( T \) is the number of usable observations.

\(^9\) The max eigenvalue statistic is calculated as \( \lambda_{\text{max}}(r) = -T \ln(1 - \hat{\lambda}_{r+1}) \).
Table 3
Johansen cointegration tests

Sample (adjusted). Included observations: 365 after adjustments. Trend assumption: Quadratic deterministic trend

<table>
<thead>
<tr>
<th>Hypothesized no. of CE(s)</th>
<th>Eigenvalue</th>
<th>Trace statistic</th>
<th>5% critical value</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.172202</td>
<td>233.6297</td>
<td>219.4016</td>
<td>0.0090</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.110743</td>
<td>164.6500</td>
<td>179.5098</td>
<td>0.2206</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.096942</td>
<td>121.8105</td>
<td>143.6691</td>
<td>0.4306</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.076587</td>
<td>84.5919</td>
<td>111.7805</td>
<td>0.6913</td>
</tr>
<tr>
<td>At most 4</td>
<td>0.049592</td>
<td>55.5090</td>
<td>83.93712</td>
<td>0.8503</td>
</tr>
</tbody>
</table>

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

Unrestricted cointegration rank test (maximum eigenvalue)

<table>
<thead>
<tr>
<th>Hypothesized no. of CE(s)</th>
<th>Eigenvalue</th>
<th>Max-eigen statistic</th>
<th>5% critical value</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.362402</td>
<td>68.97972</td>
<td>61.03407</td>
<td>0.0071</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.304058</td>
<td>42.83950</td>
<td>54.96577</td>
<td>0.4688</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.295918</td>
<td>37.21862</td>
<td>48.8720</td>
<td>0.4742</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.247968</td>
<td>29.08291</td>
<td>42.77219</td>
<td>0.6531</td>
</tr>
<tr>
<td>At most 4</td>
<td>0.167292</td>
<td>18.5644</td>
<td>36.3019</td>
<td>0.9422</td>
</tr>
</tbody>
</table>

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

Sample (adjusted). Included observations: 173 after adjustments. Trend assumption: Linear deterministic trend

<table>
<thead>
<tr>
<th>Hypothesized no. of CE(s)</th>
<th>Eigenvalue</th>
<th>Trace statistic</th>
<th>5% critical value</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.362402</td>
<td>350.6322</td>
<td>285.1425</td>
<td>0.0000</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.304058</td>
<td>272.7739</td>
<td>239.2354</td>
<td>0.0006</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.295918</td>
<td>210.0632</td>
<td>197.3709</td>
<td>0.0100</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.247968</td>
<td>149.3645</td>
<td>159.5297</td>
<td>0.1561</td>
</tr>
<tr>
<td>At most 4</td>
<td>0.167292</td>
<td>100.1256</td>
<td>125.6154</td>
<td>0.5978</td>
</tr>
</tbody>
</table>

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level

Unrestricted cointegration rank test (maximum eigenvalue)

<table>
<thead>
<tr>
<th>Hypothesized no. of CE(s)</th>
<th>Eigenvalue</th>
<th>Max-eigen statistic</th>
<th>5% critical value</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.362402</td>
<td>77.85829</td>
<td>70.53513</td>
<td>0.0091</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.304058</td>
<td>62.71069</td>
<td>64.50472</td>
<td>0.0736</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.295918</td>
<td>60.69876</td>
<td>58.43354</td>
<td>0.0294</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.247968</td>
<td>49.23886</td>
<td>52.36261</td>
<td>0.1010</td>
</tr>
<tr>
<td>At most 4</td>
<td>0.167292</td>
<td>31.6714</td>
<td>46.23142</td>
<td>0.6786</td>
</tr>
</tbody>
</table>

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

Note: * denotes rejection of the hypothesis at the 0.05 level.
** MacKinnon et al. (1999) P-values. Estimations include significant dummies.

To extract the cointegrating vectors, a vector error correction representation has been adopted. Convergence was reached after few iterations for the entire and small sample. The restricted cointegrating vectors and the speed of adjustment coefficients are reported in Table 4.

4.4. Discussion of results and implications

The cointegration analysis suggests that real wheat prices are cointegrated with market-specific, broad economic variables, weather events, and speculation. In particular, the columns of $\beta$ in Table 4 are interpreted as long-run equilibrium test] to be low, since it does not use the information that the last three eigenvalues have been found not to differ significantly from zero. Thus one would expect the maximum eigenvalue test to produce more clear cut results” (1990:19).

To extract the cointegrating vectors, a vector error correction representation has been adopted. Convergence was reached after few iterations for the entire and small sample. The restricted cointegrating vectors and the speed of adjustment coefficients are reported in Table 4.

Table 4
Vector error correction estimations

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln real poil</td>
<td>0.231 (4.44)</td>
<td>0.294 (2.84)</td>
</tr>
<tr>
<td>Ln real fed fund</td>
<td>−0.132 (−2.55)</td>
<td>−0.207 (−6.03)</td>
</tr>
<tr>
<td>Ln rex</td>
<td>−0.771 (−3.12)</td>
<td>−0.726 (−9.77)</td>
</tr>
<tr>
<td>Ln end-stock-to-use</td>
<td>−0.999 (−3.94)</td>
<td>−0.436 (−1.99)</td>
</tr>
<tr>
<td>SST</td>
<td>−0.244 (−3.50)</td>
<td>−0.248 (−4.54)</td>
</tr>
<tr>
<td>SOI</td>
<td>0.166 (5.71)</td>
<td>0.104 (4.26)</td>
</tr>
<tr>
<td>Ln world ind prod</td>
<td>3.29 (2.80)</td>
<td>1.807 (2.63)</td>
</tr>
<tr>
<td>US fed spread</td>
<td>0.045 (1.99)</td>
<td>0.021 (1.09)</td>
</tr>
<tr>
<td>Ln thinness</td>
<td>−1.008 (−2.56)</td>
<td>0.340 (1.42)</td>
</tr>
<tr>
<td>Ln speculation</td>
<td>0.715 (7.14)</td>
<td>0.715 (7.14)</td>
</tr>
<tr>
<td>Constant</td>
<td>27.99</td>
<td>25.80</td>
</tr>
<tr>
<td>Trend</td>
<td>0.006 (3.51)</td>
<td>0.001 (2.01)</td>
</tr>
<tr>
<td>Speed of adjustment $\alpha$</td>
<td>−0.069 (−4.87)</td>
<td>−0.085 (−2.07)</td>
</tr>
</tbody>
</table>

Regressand: Ln real wheat price index. t-stat in brackets. Ln stands for logarithm.
relationships between variables, and the matrix $\alpha$ determines the speed of adjustment toward this equilibrium. The estimated speed of adjustment coefficients carry the expected signs and are statistically significant different from zero. This means that cointegrating vectors converge toward their long-run equilibrium in the presence of a shock to the system. Expressly, 6.9% of the disequilibrium is eliminated in one month for the complete sample and 8.5% for the subsample; i.e., it takes 14.5 months ($1/0.069$) and 11.7 months ($1/0.085$), respectively, to restore the equilibrium after a shock.

More specifically, Table 4 provides suggestive evidence that higher oil prices lead to an increase in wheat prices due to greater use of petroleum-based inputs in the wheat market. Put differently, on the supply side a rise in oil price exerts an upward pressure on input costs such as fertilizers, irrigation, and transportation costs, which lead to a decline in profitability and production, with a consequent shift of the supply curve to the left and a rise in wheat prices. This result is evidence that energy and agricultural prices are interwoven. In detail, a 10% increase in international oil prices is statistically associated with an approximately 2.3% rise in wheat price for the longer sample and a 2.9% increase for the shorter sample, other things being equal. This result is in line with the studies by Tang and Xiong (2012) and Chen et al. (2010), which find an increasing correlation between agricultural commodities and oil price.

In addition, wheat prices appear to be sensitive to fluctuations in the real exchange rate. This intensity is almost the same for the two samples before and after the financialization of the wheat market. Specifically, the elasticity of about $-0.7$ suggests that a real dollar depreciation translates to a rise in wheat prices as they are denominated in US$. The coefficients of the real exchange rate fall in the range of 0 and $-1$ as predicted by the economic theory (Borensztein and Reinhart, 1994; Gilbert, 1989).

The real federal fed fund variable is negatively linked to the real wheat price, thus confirming the presence of the monetary policy effect. A loose monetary stance of 1% in fact implies that the price level increases by about 0.1% and 0.2%. When the real interest rate is high, as it was in the 1980s, money flows out of commodities and prices shrink. This confirms the studies by Dornbusch (1976), Frankel (2008), Svensson (2008), Anzuini et al. (2012) that emphasize the high responsiveness of agricultural prices to monetary policy changes. The spread variable has a positive sign, signaling that the future expectations on tightened monetary policies do not have a depressing effect on wheat prices and that the Treasury bond market and the commodity market for wheat are treated as substitutes asset classes in diversified portfolios. Put differently, when the long-term rate is larger than the short-term interest rate this signals an increase in the financial and macroeconomic risk linked to Treasury bonds. This causes investors to shift from the bond market to the commodity market, which in turn raises commodity prices. An increase in the spread by 10% increases prices by about 0.5%; this value decreases to 0.2% in the short sample, although it becomes insignificant.

The stock-to-use ratio is used to capture the effects of market supply and demand factors on price determination (Westcott and Hoffman, 1999). The variable shows a negative relationship with the wheat price. A faster growth in use than in ending stocks would in fact imply that demand growth outpaces supply growth. This would put an upward pressure on prices. Specifically, a reduction in the stock-to-use ratio by 1% triggers a real price surge by 0.9% and 0.4% for the longer and shorter samples. This means that the combined effects of market supply and demand factors matter in determining prices, and a rise in the stock-to-use ratio translates to an almost proportional drop in its price in the longer sample and to a more contained effect in the shorter sample.

As expected, bad weather conditions negatively affect wheat prices. Specifically, La Niña weather patterns tend to lower wheat yields and lift prices. It should be noted that the SST anomalies have a larger impact than the fluctuations in air pressure occurring between the western and eastern tropical Pacific during El Niño and La Niña episodes. However, since the variability of SOI is larger than SST, the effect of SOI could be more detrimental for wheat production and prices.

An increase of industrial production by 1% produces a significant rise in price by about 3% and 2%. This implies, in accordance with the studies by Svensson (2008) and Wolf (2008), that global demand is an important determinant of commodity prices.

The thinness of the market, while negative and significant for the sample 1980:1–2012:1, turns out to not be significant for the sample 1995:1–2012:1. This implies that trade restricting policies could exert a detrimental effect as they tend to push wheat prices further up.

Finally, the speculation variable that is included only in the shorter sample indicates that the financialization of markets has contributed to push prices up. In fact, in traded markets, when futures traders seek exposure to commodities without holding the underlying commodity and speculate on future price movements of the commodity, they finish amplifying the price fluctuations on cash markets. This implies that speculative behavior in the wheat futures market affects the associated spot market. In particular, a 1% increase in financial speculation boosts cash prices by about 0.7%.

In a nutshell, the estimated coefficients testify that market-specific variables, broad macroeconomic variables, speculative components, and weather conditions have a significant effect on real wheat price, and thus the existing theories complement rather than contradict one another. The key to understand this finding is that commodities have different aspects: they are both consumption goods and financial assets for investments. Specifically, the positive effect of world demand on wheat commodity prices reflects the aspect of wheat as a consumption good. The positive impact of open interest and yield curve on wheat price mirrors the second aspect.

Besides, an increasing demand is a dominant factor in driving up wheat prices, together with inventories for the longer sample; excessive speculation turned out to be significant and a relevant
factor behind price swings for the shorter sample. Real price pressures are trimmed down by restrictive monetary policies, a real dollar appreciation, and to some extent, by expansive trade policies.

The properties of the residuals of the estimated model have been carefully analysed. A battery of tests reveals that residuals are stationary, homoskedastic, and uncorrelated. The estimated model is also “dynamically stable.”

5. Conclusions

The roller coaster ride in commodity prices over the last decade has generated considerable interest among academicians, policy makers, and investors for its effects on the real economy, and thus on economic growth, food security, and investment decisions. In this context, this study has tried to shed light on the key factors of price movements of one of the major food grains throughout the world, wheat. The analysis has been carried out for the period 1980–2012 and the subperiod 1995–2012, using monthly data.

The results of the study indicate that all the theories on the drivers of commodity price do not necessarily contradict, but rather complement each other. In fact, the results show that there has been a complex of factors that together have caused quick price increases in the wheat markets, including speculation in futures markets, macroeconomic fundamentals, market-specific variables, and weather conditions.

It emerges that loose monetary policy reflected in low real interest rates, strong economic activity proxied by industrial production, and speculative pressure push wheat prices up. An increase in the stock-to-use ratio and a real appreciation has a curbing or dampening effect on wheat prices. The thinness of market turns out not to be significant in the short sample, but plays a role in the long sample with an upward pressure on prices when trade diminishes.

Furthermore, the study has shown that an additional factor behind the rise in wheat price is the increase in oil price. This makes wheat production more expensive by raising the cost of inputs like fertilizers, irrigation, and transportation, with a consequent decrease in profitability and production of wheat and a rise in its price.

The variables with the largest effects on price movements over the period 1995–2012 are the global demand, speculation, and the real effective exchange rate. This testifies that the financial and wheat markets have become more and more interwoven, and “speculation” based on investing in futures contracts on commodity markets, to profit from price fluctuations, is an important determinant of price dynamics. The wider and more unpredictable price changes are caused by greater possibilities of realizing large gains by speculating on future price movements of the commodity in question. Although the presence of “speculators” on the derivatives markets is a necessary condition for functioning markets and efficient hedging, price fluctuations can also attract significant speculative activity and destabilize markets, which are both the cause and effect of increased prices.

The adopted model satisfies the stability conditions as well as other residuals properties and indicates that cointegrating vectors converge toward their long-run equilibrium in the presence of a shock to the system after 14.7 and 11.7 months, respectively, for the two sample periods.

Acknowledgments

I am grateful to the comments and suggestions offered by the Editor-in-Chief of this Journal Gerald Shively and two anonymous referees. I would like to thank Prof. Joachim von Braun, Dr. Matthias Kalkuhl, Prof. Antonio Aquino, and the participants at the international Workshop on “Food price volatility and food security,” held in Bonn, Germany, Center for Development Research (ZEF, Bonn University), 31 January—1 February, 2013 for their helpful comments and suggestions. Financial support from the Federal Ministry for Economic Cooperation and Development, BMZ (Scientific Research Program on “Volatility in food commodity markets and the poor”) is gratefully acknowledged.

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10 The residual analysis, including details on stability, and the short-run dynamics are not reported for reasons of space, but are available upon request. The impulse response function representation based on the Cholesky decomposition method indicates that short-run wheat price patterns in response to a shock are rich and the impact of the shock is long-lived. The variance decomposition based on Monte Carlo repetitions confirms that there is a long-run relationship between the variables, and that all the determinants together have a certain power to predict real wheat prices.
## Appendix

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market price for wheat</strong></td>
<td>This is a market price series for wheat, with values expressed in USS and averaged from daily quotations. The commodity and market specifications are: U.S. No. 1 hard red winter, ordinary protein, prompt shipment, FOB Gulf of Mexico ports. The series has been collected from Datastream.</td>
</tr>
<tr>
<td><strong>Real effective exchange rate</strong></td>
<td>The U.S. real effective exchange rate series take into account not only changes in market exchange rates, but also variations in relative price levels (using, consumer prices). Data have been taken from Datastream USOCC011</td>
</tr>
<tr>
<td><strong>Oil spot prices</strong></td>
<td>This variable has been collected from EIA database and refers to Cushing, Oklahoma WTI (West Texas Intermediate) Spot Price FOB (Dollars per Barrel), Datastream USWTIOIL</td>
</tr>
<tr>
<td><strong>Stock-to-use</strong></td>
<td>Data have been taken from USDA <a href="http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1194">http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1194</a></td>
</tr>
<tr>
<td><strong>Real federal funds</strong></td>
<td>The U.S. money market rate (federal funds) deflated by the consumer price. The Series refers to the weighted average rate at which banks borrow funds through New York brokers. Monthly rate is the average of rates of all calendar days. Data are collected from Datastream.</td>
</tr>
<tr>
<td><strong>U.S. interest rate spread</strong></td>
<td>It has been constructed as difference between the 10-year Treasury bonds and the federal fund.</td>
</tr>
<tr>
<td><strong>Global activity</strong></td>
<td>It is measured as industrial production index taken from IMF, IFS, via Datastream</td>
</tr>
<tr>
<td><strong>Thinness</strong></td>
<td>It has been computed using data provided by the USDA <a href="http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1194">http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1194</a></td>
</tr>
</tbody>
</table>

![Fig. A1. Variables developments.](image_url)
References


Miffre, J., Brooks C., 2013. Did long-short investors destabilize commodity markets? University of Reading, ICMA Centre, Discussion paper 03.
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