Permanent and transitory price shocks in commodity futures markets and their relation to storage and speculation[1]

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Abstract

This paper takes an innovative look at the relationship between commodity futures prices, speculation, and storage. Contrary to other studies, we analyze temporary and permanent futures price innovations in a cointegrated system of pairwise short- and long-dated contracts. The innovations are used to perform Granger causality tests with respect to the level of net speculation and changes in inventories. With one exception, we do no find that speculation has significant effects on permanent or transitory price shocks. Moreover, temporary futures price distortions are largely absorbed by inventory adjustments, while permanent price shocks affect inventories only in a few cases.

JEL Classification: C22; G13; Q02 *Keywords:* Commodity futures prices; cointegration; temporary and permanent price shocks; speculation and storage

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1 Introduction

In recent years, commodities futures trading has repeatedly be blamed for destabilizing spot markets of commodities, in particular for the increase of many spot prices or their volatilities. While the academic and public debate covers an extremely wide range of topics such as the role of speculation in general, the emergence of long only investment products (e.g. index investing), or structural demand-side effects (e.g. biofuels), this paper addresses a rather specific issue related to the price discovery on futures markets and its relation to speculation and storage.

The distinguishing feature of this paper is that price effects are analyzed from the perspective of permanent and transitory (P-T) shocks. This is an important distinction regarding tests of popular hypotheses about the economic role of commodity futures. Most prominently, speculation is blamed to distort the price discovery process or to permanently shift the price level of commodities. A traditional way to test this claim is studying the price behavior or price impact of those futures contracts where speculation is most active, which are mostly short-dated contracts. Unfortunately, the statistics about commodity speculation (as well as hedging) are not publicly available across the maturity spectrum of futures contracts,[2] which makes it impossible to provide direct evidence about the maintained claim. Using P-T decomposed price shocks, however, and analyzing their link to speculation makes it possible to find out whether speculative

[2]As discussed below, with the recent availability of data from the disaggregated data available from CFCT's large-trader reporting system (LTRS), future studies should be able to analyze the maturity breakdown of speculative positions and to address this point directly.

activities are related to permanent or transitory price shocks, or none.

A second example are inventories. There is a vast literature about the role of inventory holdings with and without the presence futures markets.[3] The common view is that the economic function of inventories is to smooth unanticipated demand or supply shocks, or to reduce stock-out probabilities for producers and merchants. A particularly interesting model is Ribeiro and Hodges (2004) where a simple optimizing framework is used to determine the effects of inventory levels and supply shocks on the equilibrium term structure of futures prices. In this and similar models, the distinction between short run (temporary) and steady state (permanent) price effects plays a crucial role in explaining the stochastic behavior of the term structure. For example, the Ribeiro-Hodges model predicts that short run commodity price expectations are determined by temporary shocks related to actual storage levels relative to capacities, and convenience yields, while long run commodity price expectations are determined by steady state related magnitudes such as long run capacities or supply levels, which create permanent shocks by definition. Our decomposition sheds light on the role of inventories, or adjustments in inventory levels to be precise, in absorbing temporary and permanent price shocks.

We test three (related, but separately estimated) sets of hypotheses for fifteen commodities:

In a *first* test we analyze the price discovery process of short- and long-dated futures

[3]The literature dates back to Brennan (1958), Telser (1958), Cootner (1960), and was later formalized by Abel (1985), Pindyck (1994), Routledge, Seppi, and Spatt (2000), and Ribeiro and Hodges (2004).

contracts by testing for cointegration and estimating a vector error-correction model (VECM).[4] The residuals of the VECM can then be transformed to analyze the persistence of the shocks driving the futures prices; a variance decomposition reveals to what extent permanent and transitory shocks (PS, TS) determine the behavior of the futures price series. We use a variance decomposition technique proposed by Gonzalo and Ng (2001) for investigating these questions.

A *second* test addresses the causality between the permanent and transitory shocks of the cointegrated system and the net amount of speculation as measured by Working's T index. This sheds light on the stabilizing function of speculation as measured by conventional CFTC based statistics.

In a *third* step we finally address the relationship between the permanent and transitory shocks of the cointegrated system and storage, as measured by inventory changes. In order to minimize costly risk capital, speculators do not commit capital for the long run, i.e. do not invest in physical assets and do not hold inventories.[5] The economic function of inventories is not speculation, but smoothing production or hedging price risk of commercial agents. We hypothesize that transitory price shocks are absorbed by inventory changes (or eventually the reverse), whereas permanent price shocks should not be related to inventory adjustments.

The rest of the paper is organized as follows: Section 2 reviews some of the research

[4]Throughout the analysis we assume that futures prices are nonstationary, which is empirically validated for the price series used in our tests.

[5]The potential physical inventory holding of speculators is addressed by Kilian and Murphy (2011) who however classify anyone buying crude oil not for current consumption, but for future use, as speculator.

topics related to speculation and index trading in commodity markets which are relevant for our study. Section 3 outlines our empirical methodology and test procedure, and Section 4 contains a detailed description of the data sources and the construction of our time series. The results of our tests are presented in Section 5, which are summarized in Section 6.

2 Speculation and Index Trading: A Review of Selected Research Topics

The extent and role of speculation in commodity (and foreign exchange) markets has always been debated in the commodity futures literature, even back in the 19th century when the first organized markets for forward and futures contracts were launched. The vast literature is reviewed in various surveys.[6] The current debate is triggered, first, by the drastic increase of several commodity prices (for example, major food prices more than doubled within a short time period, from 2005 to mid-2008), second, by the growth of index-related commodity products, and finally by the pressure on institutional investors to respect or to define standards about responsible investing such as the UN supported "Principles of Responsible Investments" initiative. These developments have accelerated new empirical research on commodities, with new methodologies, new data, or a new focus.

A major focus of recent empirical studies is the impact of commodity index invest-

[6] Among recent reviews, see Till (2011), Gilbert (2010), Hailu and Weersink (2010), Irwin and Sanders (2011), Hamilton (2009), and others. A particularly interesting study is Jacks (2007) who reviews the antagonism and volatility-increasing presumption of speculation in futures speculation in historical perspective, in particular related "ban" of the forward trade in the aftermath to the Stock Exchange crash of the German exchanges in the 19th century.

ing on spot and futures prices. Index trading, i.e. investing in a synthetic basket of commodities which tracks a specific commodity index[7] via OTC swaps or structured products, became popular and was rapidly growing in the 2000s. The indices represent a roll-over strategy in long positions of short-dated futures contracts on the underlying commodities; most indices are heavily weighted in energy related commodities (typically between 60% and 70%), mainly crude oil. Since index investors hold net long positions in the underlying futures,[8] it is argued that the net long positions of commodity index investors push prices of certain commodities to levels beyond those justified by fundamentals. The argument is reinforced by the observation that unlike traditional speculators, index investors - by rolling the positions forward - take effectively long-term positions in the underlying risks. Index investing is also seen as one of the major causes of the increased volatility of non-energy commodity prices as well as their increasing correlation with the price of oil, which is often called "financialization" of commodity markets. The criticism is not only advanced by prominent investors (for example George Soros (2008) or Michael W. Masters (2008)), but can also be found in official reports of the US Government[9], international organizations (e.g. UNCTAD (2011)) as well as in pamphlets of special interest groups such as the World Develop-

[7]Some 95% of the index funds replicate the SP-GSCI or the DJ-UBS indices.

[8]Weekly statistics on disaggregated long/short positions on 12 agricultural futures positions by index traders, commercial traders and non-commercial traders are published in the "Commodity Index Traders" (CIT) report by the CFTC. Tang and Xiong (2010) report an average relative share of 28.4% in the long and 1.6% in the short positions relative to the total open interest across all commodities. However, as discussed below, the amount of index trading itself is not a relevant indicator of net speculation.

[9]See the U.S. Senate Permanent Subcommittee on Investigations in its examination of Chicago Board of Trade's (CBOT) wheat futures trading, released on June 23, 2009. The Report concludes that the activities of commodity index traders, in the aggregate, constituted ï£¡excessive speculationï£¡ in the wheat market under the Commodity Exchange Act.

ment Movement or research institutions, e.g. the International Food Policy Research Institute (see Cooke and Robles (2009)). Notable contradictions are advanced in reports commissioned by the IOSCO (2009), the OECD (see Irwin and Sanders (2010)) or the World Bank (see Baffes and Haniotis (2010)).

The financialization argument is well documented and discussed by Baffes and Haniotis (2010); the authors observe a strong impact of energy prices on the prices of non-energy commodities with an increase during the recent boom. Even though they conclude that "index fund activity (one type of 'speculative' activity among the many that the literature refers to) played a key role during the 2008 price spike", they do not provide any direct test addressing the role of index trading, open positions of speculators, or the like to underpin their argument. More direct to that point is a study by Tang and Xiong (2010). They analyze daily returns of nearby non-energy commodity futures from 1998 to 2009 and find that the increase of correlations with oil price changes is "significantly more pronounced for commodities in the two popular SP-GSCI and DJ-UBS commodity indices", what the authors interpret as explanation of the increased volatility of non-energy commodity prices. An econometrically more rigorous analysis of index trading can be found in Gilbert (2010). The author finds strong evidence that the correlation between the changes of oil and food prices are the result of "common causation and not of a direct causal link". Granger causality tests reveal that index investing qualifies as a channel through which macroeconomic and monetary factors affect the increase in food prices. A limiting factor of this analysis is that it is based on food and non-food price indices, rather than on individual commodities prices.

Notable counterarguments of the index based explanations of commodity price increase and volatility are the following:[10] The first and most immediate argument is that price increases over the past decade can also be observed for commodities on which no futures contracts are traded and which are not constituents of commodity indices.[11] Examples include cadmium, rhodium, cobalt, or coal. Second, speculation can only affect commodity prices in so far as it affects inventories. If speculation drives commodity prices, then it pays for speculators to increase inventories - but this is the contrary to what is observed in the recent boom: inventories are low. Gilbert (2010) argues that it takes time for this effect to materialize because the incentive to hold inventory is driven by long-dated futures prices, and there is a time lag in production and consumption decisions (and hence, inventories) to respond to higher prices. Of course, whether this is true or not is an empirical question. Third, valid speculation proxies for commodity futures markets should be measured relative to the amount of hedging. Specifically, Working (1960) proposed an index (called T index) which highlights the relative amount of net excess (long or short) speculation with respect to the hedging positions of commercial traders. Sanders, Irwin, and Merrin (2010) use data from the CFTC Commitments of Traders (COT) report and the Commodity Index Traders (CIT) report[12] from 1995 to 2005 and 2006-2008 to construct this index and

[10]A detailed discussion and critical assessment of many popular arguments about the destabilizing effect speculation is provided by Irwin, Sanders, and Merrin (2009).

[11]See Stoll and Whaley (2010), Irwin, Sanders, and Merrin (2009), and Figure 1 in Fattouh, Kilian, and Mahadeva (2012).

[12]The reports include information about open futures positions of five trader categories: large non-commercials (speculators), large commercials (hedgers), large non-commercial spread investors, commodity index traders, and non-reportable traders (small speculative and hedging positions).

to re-examine the amount of speculation, in particular related to index investing, for 9 non-energy commodities. For most commodities the authors find that "the increase in long speculative positions was equaled or surpassed by an increase in short hedging". Therefore they find no evidence that index investing may not be beneficial in markets where short hedging typically dominates. This is in line with earlier studies which apply the Working index and conclude that speculation is insufficient on most agricultural futures markets relative to the hedging demand.[13]

Unfortunately, the standard COT-data are highly aggregated across different categories of commercial and non-commercial users. In order to analyze the relationship between speculative positions and the pricing of commodities in more detail, the CFTC recently made disaggregated data available from its large-trader reporting system (LTRS) to a few researchers. These data allow to analyze futures positions for many trader sub-categories (swap dealers, insurance companies, hedge funds, producers, trading advisors etc.) for a broad range of futures contracts, on a daily basis, and for individual maturities. A description of the data can be found in e.g. Brunetti and Buyuksahin (2009). The following results are reported in the papers available to date: Buyuksahin and Harris (2009) analyze the crude oil futures market and find that Working's T index increased in parallel with crude oil prices from 2004-2009. Till (2009) reports similar results for crude oil, heating oil, and gasoline futures for the period 2006-2009. Brunetti and Buyuksahin (2009) perform Granger causality tests

[13]A list of earlier studies with this finding can be found in Sanders, Irwin, and Merrin (2010), p. 85. The CIT database is also used by Stoll and Whaley (2010) to investigate the causality between index fund trading and commodity futures prices. The authors examine weekly data of 12 agricultural markets from 2006 to 2009 and find only little impact of commodity index investing on futures prices.

between disaggregated futures positions of three groups of speculators (swap dealers, hedge funds, and floor brokers) and futures prices in the 2005-2009 period. In contrast to other studies, their VAR test allows for interactions between the traders' positions on returns and volatilities. They find that speculation does not cause price movements, reduces risk and thus hedging costs. Aulerich, Irwin, and Garcia (2010) use the LTRS database to analyze the price impact of long only index funds in twelve commodity futures markets from 2004 to mid 2008. As other studies they assume that index trading is reflected in the positions reported by the sub-category "swap dealers". They use Granger causality tests to examine the relationship between index trader position changes and commodity futures returns, and volatility respectively, as reflected in the nearby and next-to-nearby maturities. Only 16% of the coefficients are statistically significant, and signs are mixed. In particular, they do not find that index positions had a greater impact on returns during their first subperiod 2004-2005 when positions were growing most rapidly. If anything, then volatility seems to have been affected by the presence of index traders in several markets.

At this stage it is worth emphasizing that it is far from being a consensus that index trading (which comprises the activities of long-only funds with direct investment in futures markets as well as the hedging activities of OTC swap dealers) should be regarded as speculation from an economic point of view. In this paper we agree with the contrary view advocated by Stoll and Whaley (2010) that index investing is not classical speculation: the investments are not motivated by directional bets, but by the diversification benefits they provide; moreover, index investors are typically not leveraged but fully collateralized. On the other hand, OTC swap dealers hedge their commodity index exposure originating from customized products, which is a standard hedging activity like in the commercial business (see Szado (2011), p. 81). Consistent with that view, the position data collected by the CFTC and used in this study[14] classify swap dealers' positions as "commercial"; the long-only commodity funds are however classified as non-commercials, i.e. speculators[15]. Therefore, and rightly, the swap dealers' positions do not show up in our speculation index used below. However, the investment positions of funds are part of our index. If speculation (or tactical asset allocation) is indeed a substantial part of the trading activities of these funds, then this should be reflected in short-dated futures contracts and be visible in our tests.

In this paper, we use cointegration analysis for a decomposition of commodity price shocks into transitory and permanent components, which are analyzed in their relation to fundamental variables such as storage and speculation in the underlying commodities. This is the aim of this study. Methodologically, the closest to our paper is Figuerola-Ferretti and Gonzalo (2010). The emphasis of their paper is also a separation of permanent and transitory components in commodity spot and futures prices; however their focus is on the equilibrium relationship between spot and futures price levels and its violation due to imperfect arbitrage in the presence of convenience yields. They investigate the dynamic futures-spot price relationship for five non-ferrous metals in the Gonzalo-Granger P-T-framework. In contrast to this study, the focus of our paper

[14] Historical data files for the COT Futures-Only reports are available from 1986, and the the Futures-and-Options-Combined Report since 1995.

[15] As discussed by Stoll and Whaley (2010), the CFTC Supplemental report contains separate index positions since 2006.

is on price *shocks* derived from the VECM of long- and short-dated futures prices.

3 Methodology and Hypotheses

Our analysis is based on an orthogonal decomposition of the residuals of a vector error correction model of commodity prices into permanent and temporary (P-T) shocks, as suggested by Gonzalo and Ng (2001). We first test whether the prices of short- and long-dated futures contracts, represented by the vector $\underline{x}_t \in \Re^{n\times 1}$, are cointegrated by applying standard Engle-Granger and Johansen tests. We include one short and one long maturity in our price vector ($n = 2$), as described in Section 4.3. The Granger Representation theorem implies that this test is equivalent to a vector error-correction representation (VECM)

$$\Delta \underline{x}_t = \underline{\underline{\alpha}}\underline{\underline{\beta}}' \underline{x}_{t-1} + \underline{\underline{\Gamma}}(L)\, \Delta \underline{x}_{t-1} + \underline{\epsilon}_t \tag{1}$$

where $\underline{\underline{\beta}} \in \Re^{n\times r}$ represents the r cointegrating vectors, $\underline{\underline{\alpha}} \in \Re^{n\times r}$ the adjustment parameters, and $\underline{\underline{\Gamma}}(L) \in \Re^{n\times n}$ the coefficients of lagged price changes. The residuals of the VECM are used to assess the relevance of each variable in affecting the long-term equilibrium, respectively in restoring the equilibrium. The appropriate number of lags can be determined by standard model diagnostics (Akaike information or Schwarz criterion). Gonzalo and Ng (2001) apply the $P - T$ decomposition of Gonzalo and Granger (1995) to the residuals or innovations of the VECM, which are decomposed into $n - r$ permanent and r transitory shocks, $\underline{u}_t^P$ and $\underline{u}_t^T$ (abbreviated by PS and

TS).[16] The rotation of the VECM-residuals into transitory and permanent components is achieved by applying the Wold Representation Theorem to the VECM (1)

$$\begin{aligned} \Delta \underline{x}_t = \underline{\underline{C}}(L)\,\underline{\epsilon}_t &= \left[\underline{\underline{C}}_0 + \underline{\underline{C}}_1 L + \underline{\underline{C}}_2 L^2 + \ldots\right]\underline{\epsilon}_t \\ &= \underline{\underline{C}}_0\,\underline{\epsilon}_t + \underline{\underline{C}}_1\,\underline{\epsilon}_{t-1} + \underline{\underline{C}}_2\,\underline{\epsilon}_{t-2} + \ldots \end{aligned} \tag{2}$$

where $\underline{\underline{C}}(L)$ are moving average coefficients. Define the Gonzalo-Granger transformation matrix

$$\underline{\underline{G}} = \begin{bmatrix} \underline{\underline{\alpha}}_{\perp}{}' \\ \underline{\underline{\beta}}' \end{bmatrix} \begin{matrix} \in \Re^{(n-r)\times n} \\ \in \Re^{r\times n} \end{matrix}$$

where $\underline{\underline{\alpha}}_{\perp} \in \Re^{(n-r)\times n}$ is the orthonormal complement to $\underline{\underline{\alpha}} \in \Re^{r\times n}$ satisfying $\underline{\underline{\alpha}}'_{\perp}\underline{\underline{\alpha}} = \underline{\underline{0}} \in \Re^{(n-r)\times r}$ and $\underline{\underline{\alpha}}'_{\perp}\underline{\underline{\alpha}}_{\perp} = \underline{\underline{1}} \in \Re^{(n-r)\times(n-r)}$.[17] The matrix can be used to write the VECM as

$$\Delta \underline{x}_t = \underline{\underline{C}}(L)\,\underline{\epsilon}_t = \underline{\underline{C}}(L)\,\underline{\underline{G}}^{-1}\underline{\underline{G}}\underline{\epsilon}_t \equiv \underline{\underline{D}}(L)\,\underline{u}_t \tag{3}$$

such that the decomposition of the innovations is

$$\underline{u}_t = \underline{\underline{G}}\underline{\epsilon}_t = \begin{bmatrix} \underline{\underline{\alpha}}_{\perp}{}'\underline{\epsilon}_t \\ \underline{\underline{\beta}}'\underline{\epsilon}_t \end{bmatrix} = \begin{bmatrix} \underline{u}_t^P \\ \underline{u}_t^T \end{bmatrix} \begin{matrix} \in \Re^{(n-r)\times 1} \\ \in \Re^{r\times 1} \end{matrix} \tag{4}$$

[16] Because we analyse the pairwise cointegration of two futures maturities only, i.e. $n = 2$, the variance decomposition results in one permanent and one transitory component, provided that the two series are conintegrated.

[17] Gonzalo and Ng (2001) suggest that $\underline{\underline{\alpha}}_{\perp}$ is computed from the eigenvectors corresponding to the $n - r$ smallest eigenvalues of either $\underline{\underline{\alpha}}\underline{\underline{\alpha}}' \in \Re^{n\times n}$ or $\underline{\underline{\alpha}}\left(\underline{\underline{\alpha}}'\underline{\underline{\alpha}}\right)^{-1}\underline{\underline{\alpha}}' \in \Re^{n\times n}$.

Finally, the innovations in the vector $\underline{u}_t$ are orthogonalized by a block triangular matrix $\underline{\underline{H}} \in \Re^{(n \times n)}$ obtained from a Cholesky decomposition applied to the variance-covariance matrix of $\underline{u}_t$, satisfying

$$\underline{\underline{H}}'\underline{\underline{H}} = Var\left[\underline{u}_t\right] \tag{5}$$

which implies the orthogonalized decomposition

$$\underline{\eta}_t = \underline{\underline{H}}^{-1}\underline{u}_t = \begin{bmatrix} \underline{\eta}_t^P \\ \\ \underline{\eta}_t^T \end{bmatrix} \begin{matrix} \in \Re^{(n-r)\times 1} \\ \\ \in \Re^{r\times 1} \end{matrix} \tag{6}$$

Summing up, the transformation of the VECM innovations to orthogonalized transitory and permanent shocks can be characterized by

$$\begin{aligned} \Delta\underline{x}_t = \underline{\underline{C}}(L)\,\underline{\epsilon}_t &= \underline{\underline{C}}(L)\,\underline{\underline{G}}^{-1}\underline{\underline{G}}\underline{\epsilon}_t \equiv \underline{\underline{D}}(L)\,\underline{u}_t \\ &= \underline{\underline{D}}(L)\,\underline{\underline{H}\underline{H}}^{-1}\underline{u}_t \equiv \underline{\underline{\tilde{D}}}(L)\,\underline{\eta}_t \end{aligned} \tag{7}$$

where $\underline{\underline{\tilde{D}}}(L)$ is the "orthogonal" impulse response function of the cointegrated system

$$\begin{aligned} \Delta\underline{x}_t = \underline{\underline{\tilde{D}}}(L)\,\underline{\eta}_t &= \left[\underline{\underline{\tilde{D}}}_0 + \underline{\underline{\tilde{D}}}_1 L + \underline{\underline{\tilde{D}}}_2 L^2 + \ldots\right]\underline{\eta}_t \\ &= \underline{\underline{\tilde{D}}}_0\underline{\eta}_t + \underline{\underline{\tilde{D}}}_1\underline{\eta}_{t-1} + \underline{\underline{\tilde{D}}}_2\underline{\eta}_{t-2} + \ldots \end{aligned}$$

and, based on (3) and (7), the coefficients can be derived from the $\underline{\underline{C}}(L)$ of the VECM by

$$\underline{\underline{\tilde{D}}}(L) = \underline{\underline{C}}(L)\,\underline{\underline{G}}^{-1}\underline{\underline{H}} \tag{8}$$

for each lag. The variance decomposition of the innovations of $\Delta\underline{x}_t$ into permanent and transitory components then follows immediately.

We proceed as follows in testing our hypotheses: First, we test for unit roots in the level of futures prices; standard ADF and PP tests are performed. If the null hypothesis of a unit root is rejected, we would not further analyze that commodity. But in our sample, the hypothesis of a unit root cannot be rejected for any futures price series.

Second, a cointegration test for each pair of futures prices (a short- and long-dated maturity contract) is performed for each commodity, based on Johansen's trace test. If the null hypothesis of no cointegration can be rejected, the adjustment coefficients of the VECM representation of the cointegrated system indicate which of the two futures contracts, the short- or long-dated, determines the long term equilibrium of the system and, respectively, which contract establishes the adjustment towards equilibrium.

Third, the Gonzalo-Ng variance decomposition reveals the relative contribution of the permanent and transitory shocks in the adjustment process towards equilibrium.

Fourth, the Gonzalo-Ng P-T-innovations are used to perform Granger causality tests with respect to changes of inventories and net speculation, as measured by Working's T index.

Finally, a variance decomposition based on a VAR-model is performed to determine the proportion of permanent and transitory price innovations caused by speculation and storage.

4 Data

4.1 Speculation: Working's T Index

We use Working's T index to measure speculative activity. Working (1960) argued that an adequate measurement of speculation in futures markets should be net of hedging demand. He therefore suggested an index which indicates speculation in excess of those positions necessary to absorb the hedging needs. This index has been used in many empirical studies and became a widely accepted measure of speculative activity. One of the merits of the index is that it can be easily calculated from the data published in the Commitments of Traders (COT) report by the U.S. Commodity Futures Trading Commission (CFTC). Details about the underlying data are reported in Appendix (A.1). Notice that no COT data are available for Cocoa.

Table [2] Panel A provides for each commodity the number of observations, the average as well as the minimum and maximum value of the index. The largest value is reported for Wheat (1.33), the lowest for WTI Crude Oil (1.07). The standard deviation of the index ranges from 0.01 for WTI Crude Oil to 0.07 for Live Cattle. Figure [2] displays three illustrative index time series: for Corn (black line), Wheat (gray line), and Live Cattle (dotted line). None of the series experiences an apparent structural shift within the observation period.

The T index is used in this paper to test causality between speculative activity and temporary and permanent price shocks, which requires a stationary time series. The ADF test statistics for logarithmic index levels displayed in the last three columns of Table [2] reveal that the null hypothesis of a unit root can be rejected for all commodities in our sample.

4.2 Storage

Based on US statistics, we collect inventory data from four sources: the United Department of Agriculture (USDA) for Corn, Soybean, Wheat and Cotton; the National Agriculture Statistics Service (NASS) for Live Cattle; the Department of Energy (DOE) for Crude Oil (WTI) and Heating Oil (also known as No. 2 Fuel Oil); and the Energy Information Administration (EIA) for Natural Gas. Details are described in Appendix (A.2). We have no storage data available for Sugar and Copper.

Throughout our econometric analysis, we use first differences of the natural logarithm of seasonally adjusted[18], end-of-month inventory levels. This is motivated by our economic hypothesis which addresses the *adjustment* of inventories in relation to permanent and transitory shocks. The ADF test statistics displayed in the last three columns of Table [2] show that the null hypothesis of a unit root can be rejected for the first log differences across all commodities.

For an easier economic interpretation, Table [2] Panel B summarizes the descriptive statistics of inventory *levels*. Column two shows the number of observations. To fa-

[18]We use a seasonal decomposition procedure based on Loess (STL); see Cleveland, Cleveland, McRae, and Terpenning (1990).

cilitate comparison, the minimum, maximum and standard deviation are expressed as percentages of the respective mean. The lowest minimum inventory level with respect to the mean is found for Corn (22%), while the minimum inventory level of WTI Crude Oil is as large as 84%. The largest standard deviation is reported for Soybean (44%), and WTI Crude Oil exhibits the lowest value (7%). The last column displays the data source. Figure [3] displays illustrative time series for Corn and Wheat inventories from 1990 to 2010.

4.3 Futures Prices

Our empirical work is based on futures prices of 15 commodities. For each commodity, we select two contemporaneous futures prices with a short and a long delivery date. We have selected the next-to-nearby contract as short maturity, and the one-year ahead of the nearby contract as long-dated contract. Of course, the long-dated contract is not really long, but it is the longest common maturity across our commodities which is available over a sufficiently long historical period (since 1990). An annual maturity (or a multiple of it) is also advantageous with respect to adjusting for seasonal effects.

The selected commodities are displayed in column two of Table [1] and structured by sectors: grains, softs, meat, energies, and industrial metals (see column one). The future contracts are traded on different exchanges, which can be found in third column. The sample period is from January 1990 to December 2010 in most cases, with a few exceptions (see column four). Shorter time periods for some commodities are due to a lack of a sufficient number of adequate maturities. The number of months covered by the respective sample periods is displayed in column five. A breakdown of the expiry months can be found in the last column.

Futures price series are constructed applying a rollover procedure familiar in the empirical literature; details are described in Appendix (A.3).

Notice that with regard to the Granger causality tests, the futures price data must be exactly matched with the relevant reporting dates of the storage and COT data (as discussed before). We therefore use two separate futures price data sets: one adapted to the storage data, the other adapted to the speculation index. As a consequence, cointegration tests and variance decomposition are carried out for both sets of futures prices. Notice that due to the missing COT and storage data for some commodities, cointegration tests can be performed with only 14 (for the COT-adapted) and respectively 13 (for the storage-adapted) pairwise price series only.

5 Empirical Results

5.1 Cointegration between short- and long-dated contracts, and P-T variance decomposition

In this section, the results of the cointegration tests and variance decomposition in permanent and transitory price shocks are presented.

Stationarity: For all futures price series, the null hypothesis of a unit root cannot be rejected; depending on the commodity, a constant and/or a drift parameter is estimated.[19] Integrated series of the same order is a prerequisite for cointegration tests.

[19]The results are available upon request.

Cointegration: The cointegration results are displayed in Table [3], first for the price series adapted to the COT-speculation data (Panel A), and second for those adapted to the storage data (Panel B). The first set of tests is available for a total of 14 commodities, and a single cointegration vector emerges in 9 cases. For Coffee, Sojabean Oil and Copper, there is no cointegration[20], while Lean Hogs and Orange Juice exhibit two cointegration vectors implying stationarity. The Table shoes the results of the restricted model[21] estimates to which we subsequently refer are shown in the second panel. The p-values of Johansen's trace test and the coefficients of the cointegration vector are displayed in the first rows of each panel. The adjustment coefficients of the VECM indicate that the long run equilibrium for 8 commodities is driven by the long-dated contracts, while the short-dated contracts are responsible for the adjustment towards the trend. For one commodity, Cotton, the adjustment runs in the reverse direction.

The equivalent results for the futures price series adapted to the storage data in Table [3] Panel B confirm the previous findings. Due to the availability of storage data, the tests can be performed with only 13 commodities, 12 from the previous sample, plus Cocoa. Cointegration can be observed for the same commodities as in the previous test, without Sugar for which no storage data are available. Again, the price equilibrium is driven by the long-dated contracts with the exception of Cotton. The findings are also

[20] We use a somehow loose but more readable terminology in discussing the results; of course, futures prices are cointegrated, not commodities.

[21] In the restricted model, the insignificant adjustment coefficient of the unrestricted model is set equal to zero. The estimation results of the unrestricted model are available upon request; in terms of statistical significance, the results are not different.

equivalent with respect to the commodities for which no cointegration is found (Coffee and Soybean Oil) or two cointegrating vectors are identified (Lean Hogs and Orange Juice). In addition, no cointegration is found for Cocoa. It is finally worth emphasizing that the cointegration results are robust with respect to the number of lags specified in the cointegration equation.

Variance decomposition: For those 9, respectively 8, commodities where cointegration between short- and long-dated futures prices is present, the Gonzalo-Ng decomposition of the VECM-residuals is undertaken; this results in a time series with transitory shocks (TS) and a series with permanent shocks (PS) for each commodity. For illustrative purposes, the impulse response function (IRF) of the short- and long-dated Corn contracts with respect to the TS and PS are displayed in Figure [1].[22] The IRF confirms that the long contacts are largely driven by permanent shocks, and the effect is stable across lags. In contrast, the short-dated futures prices are mainly driven by transitory shocks. In the case of Corn, the transitory shocks account for 85% of total variance of the short-dated contract, which in turn implies that the permanent effect plays a minor role at the short time horizon. As the VECM suggests, the short-dated contract is mainly responsible for restoring the equilibrium, with an apparent minor effect upon the equilibrium of the price system itself. The half life of the transitory shocks implied by the adjustment coefficient of the VECM is 20 months for Corn.

The overall results of the variance decomposition are displayed on the final row,

[22]The figure is based on the estimation results for the Corn futures price series adapted to the COT-speculation data.

respectively the final two rows, of each Panel in Table [3]. The results indicate that the transitory shocks account for 69% to 100% of the variance, with values close to 100% for Soybean, Cotton, and Sugar. The half life of the transitory shocks is in the range of 10 months to 23 months (Panel A), and between 9 months and 59 months (Panel B). A rather quick absorbtion is observed for Heating Oil and Sugar, while a long absorbtion period emerges for Corn, Wheat, Live Cattle, and Natural Gas. There seems to be no commodity specific pattern in this reaction. Notice that the time series for Sugar and Natural Gas differ with respect to the starting date (05/93 and 02/94 instead of 01/90).

5.2 Granger causality between permanent and transitory price shocks and speculation

Granger causality is first examined between permanent and transitory shocks of futures prices and speculation. The results are displayed in Table [4]. Recall that speculation is measured by the levels of Working's T index which is stationary. The second and third columns of the Table display the test statistics for causality between permanent shocks (PS) and speculation. The null hypothesis of no causality running from speculation to permanent shocks cannot be rejected in any of the commodities on conventional significance levels; there are two commodities with a p-value marginally below 10% (Corn and Live Cattle). Thus, overall there is no statistical evidence for the hypothesis that speculation causes permanent price shocks. Interestingly, the null hypothesis for the reverse relationship can be rejected for three commodities, namely Corn, Soybean and Sugar.

The test results addressing Granger causality between speculation and transitory shocks (TS) are displayed in the fourth and fifth column. There is no statistically significant impact of speculation on temporary price shocks; all p-values are beyond conventional significance levels. Moreover, the estimated VAR-coefficients are mostly even lower than in the case of permanent shocks. There is again only slightly more evidence for the reverse relationship, where no causality can be rejected for three commodities (Corn, Wheat, and Heating Oil) with p-values between 0.05 and 0.1.

Thus, our evidence suggests that speculation as measured by the T index has no effect on permanent or transitory price shocks; if a relationship exists, it is rather in the reverse direction - but for few commodities only in our sample.

A reinterpretation: In the light of these findings, the cointegration results of Section (5.1) have a further interpretation. It is often argued that speculation is concentrated in short-dated contracts. Unfortunately, there is little direct evidence to verify this presumption. However, as argued in Section (2), our speculation index most likely reflects the activities in short-dated contracts because the COT database classifies (somehow erroneously) index investors as speculators; but index investors are mostly replicating major commodity indices, which are constructed from short-dated contracts. However, we have found virtually no evidence that speculation - as measured by our index - has permanent or transitory price effects (with the exception of Corn). This is fully consistent with our observation that the short-dated futures prices are mainly driven by transitory shocks.

If speculation is indeed concentrated in the short-dated contracts, our cointegration results deserve a deeper interpretation. Namely, if speculation or index investing would have permanent effects in the price formation process, if it would even destabilize the price system in extreme cases, then futures prices of long- and short dated contracts must be cointegrated with the *short*-dated contract driving the permanent shocks of the system, and the long-dated contract restoring the equilibrium following a shock. The coefficients of the VECM representation of the model as well as our variance decomposition tests clearly reject this hypothesis: Six commodities are not cointegrated at all (which excludes permanent effects of the short-dated contracts *a priori*), and where cointegration exists, the permanent shocks are driven by the long-dated contract.

We therefore conclude that our evidence is inconsistent with the hypothesis that speculation - as measured by Working's T index - has permanent effects on futures prices. It is finally worth noting that Granger causality between price shocks and speculation is not different for Cotton, the only commodity where the VECM suggests a reverse dynamic relationship between the short- and long-dated contract.

5.3 Granger causality between permanent and transitory price shocks and storage

The results of the second set of Granger causality tests, between permanent and transitory shocks of the price system and storage, are displayed in Table [5]. Recall that storage is measured by the first difference of logarithmic seasonally adjusted inventory levels and can be interpreted as inventory shocks.

The second and third columns of the Table display the test statistics for causality between permanent shocks (PS) and storage. We hypothesize that transitory price shocks are absorbed by inventory changes (or eventually the reverse), while permanent price shocks should not be reflected in inventory adjustments. The hypothesis of no causality running from permanent shocks to storage can be rejected for 2 out of the 8 commodities (Soybean and Wheat), with two commodities on the edge of significance (Heating Oil and Natural Gas). The reverse hypothesis of no causality running from storage to permanent shocks is rejected for Cotton and Wheat. So, contrary to our hypothesis, there are few commodities, notably Wheat, showing an interaction between permanent price shocks and adjustment in storage.

More directly related to our hypothesis, however, is the causal relationship between transitory shocks (TS) and storage. The test results are displayed in the fourth and fifth column of Table [5]. These results are remarkably different from those before: The absence of a causal relationship running from transitory shocks to storage is strongly rejected for 6 out of the 8 commodities; in 5 cases, the p-value is below 0.01. For a seventh commodity, Heating Oil, the value is only slightly above 0.1. Only Cotton reveals a different behavior. The reverse relationship, causality running from storage to temporary price shocks, can be found in only two cases, Wheat and Cotton.

Thus, our evidence suggests that temporary futures price distortions are largely absorbed by adjustments in inventories, while permanent price shocks affect inventories in a few cases. On the other hand, storage does typically not affect prices - except for Cotton and Wheat, where permanent as well as temporary effects are found.

5.4 Variance decomposition

Based on the VAR models estimated in the two previous sections, a variance decomposition is performed for determining the fraction of variability in permanent and transitory shocks caused by speculation and storage (and respectively, of the reverse relationships). The figures displayed in the subsequent Tables are the largest variance proportions observed across the time-lags; figures are marked in bold if the respective Granger causality tests rejects a significant relationship on the 10% level.

Table [6], Panel A, displays the results of the variance decomposition related to speculation. The most interesting results are in Column two of Panel A which displays the fraction of permanent price shocks driven by speculation. The largest value can be found for Soybean with 7.6%, followed by Cotton and Live Cattle. The impact of speculative shocks on overall price variability is furthermore tempered by the observation from Table [3] that the largest portion of futures price variability is driven by transitory, not permanent shocks. The variance proportions in Column four reveal that the impact of speculation on transitory price shocks is in the same order to magnitude. The largest impact is documented for Live Cattle with 6.5%. However, the Granger causality test indicates no significant effect for all commodities. For completeness, the variance proportions of the shocks in the reverse direction (permanent and transitory shocks on speculation) are also documented, but need no further comment.

The variance decomposition related to storage is documented in Panel B. Column two shows that the proportion of PS caused by storage is almost negligible, with the exception of Cotton (12.6%) and Corn (7.2%). Slightly larger proportions are observed in Column four for TS (some 15.8% for Wheat) as well as for the reverse relationship (Column three): As already indicated by the number of significant Granger relationships, there are a few seizable proportions of storage variability explained by TS: Soybean (12.7%), Crude Oil (11.6%), and Natural Gas (7.1%). But the overall effects are small.

We conclude from these results that, in general, the variance of PS and TS are driven by different factors than those analyzed here. Speculation has a particularly small effect.

6 Summary

This paper takes an innovative look at the relationship between the pricing of commodity futures contracts and its relation to storage and speculation. Fifteen commodities are analyzed. Contrary to most other studies, we analyze the temporary and permanent futures price innovations in a cointegrated system. To minimize estimation problems, we just include two futures maturities in our system, the nearby contract and a "long" dated contract expiring 12 months ahead of the nearby contract. The long-dated contract is not really long, but it is the longest common maturity across the selected commodities with price data covering two decades. We find that the short- and long-dated futures price series of 9 commodities are cointegrated, i.e. share a common long-term stochastic trend. The VECM reveals that except for one commodity, Cotton, the long term equilibrium is determined by the long-dated contract, while the adjustment towards equilibrium is restored by the short-dated contract. The transitory shocks account for 65% to 100% of the variance of the short-dated contract (with typical values in excess of 90%), implying half lives between one and two years.

Granger causality tests do not support the hypothesis that speculation as measured by Working's T index has a statistically significant effect on the permanent or transitory price shocks; if a relationship exists, it is rather in the reverse direction - but for a few commodities only in our sample. Under the assumption that speculation occurs mainly in short-dated contracts this finding is inconsistent with the common presumption that speculation has permanent effects on the price formation process. Notice in this context that the COT-data which are used to calculate the speculation index include, aside from traditional speculators, also the activities of various types of long-only index funds (most commodity indexes represent rolling strategies in short-dated futures) so that our speculation index is likely to be heavily weighted on short-term futures positions.

Finally, Granger causality tests indicate that temporary futures price distortions are largely absorbed by adjustments in inventories, while permanent price shocks affect inventories only in a few cases.

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A Data Sources

A.1 Speculation

The data used to calculate the T index are provided by the Commitments of Traders (COT) report released by the U.S. Commodity Futures Trading Commission (CFTC). It contains the allocation of open interest on each Thursday for markets in which 20 or more traders hold positions equal to or above the reporting levels established by the CFTC. Two main classifications are released: the Commitments of Traders Futures-Only Report contains futures market open interest only. Historical data files are available from 1986. Since March 14, 1995 the Futures-and-Options-Combined Report provides an aggregation of futures market open interest and delta weighted option market open interest. The published open interest for each market is aggregated across all contract maturities in both reports. All data are released on Friday at 3:30 p.m. However, only mid-month and month-end data were provided by the COT before September 30,

1992. We combine the data from the two Reports to construct a single time series for each commodity.

Both reports classify the positions into commercials, non commercials, and non reported. For each group, the respective number of long and short contracts is reported separately.[23] The aggregate of all long and short positions add up to the market's total open interest.

Following common practice in the empirical literature, "commercials" are considered as hedgers whereas "non commercials" are classified as speculators. However, the group of non reporting traders can not be easily classified as hedgers or speculators without strong assumptions. Sanders, Irwin, and Merrin (2010) point out that the speculation index is not particularly sensitive to the assignment of the non reporting traders. For that reason, this group is omitted in computing our T index.

A.2 Storage

We use four different data sources for our storage data:[24] The USDA releases the monthly World Agriculture Supply and Demand Estimates (WASDE) report which includes the estimated ending stocks for agriculture products based on a commodity specific crop supply and demand forecast.[25] The expected carryover projection, which is a point forecast for the end of the current marketing season, is monthly updated

[23]The non commercials also include spread positions, which however do not affect the speculation index because they are market neutral.

[24]The full names of the agencies are given in the main text, Section (4.2).

[25]The World Agricultural Supply and Demand Estimates (WASDE) report provides USDA's comprehensive forecasts of supply and demand for major U.S. and global crops and U.S. livestock. The report gathers information from a number of statistical reports published by USDA and other government agencies, and provides a framework for additional USDA reports.

until the end of April and switches afterwards into the projection of the following marketing season, whereas the old ending stocks become the new beginning stocks.[26] It is important to take this reporting practice into account when constructing monthly time series of inventory data.

A.3 Futures Prices

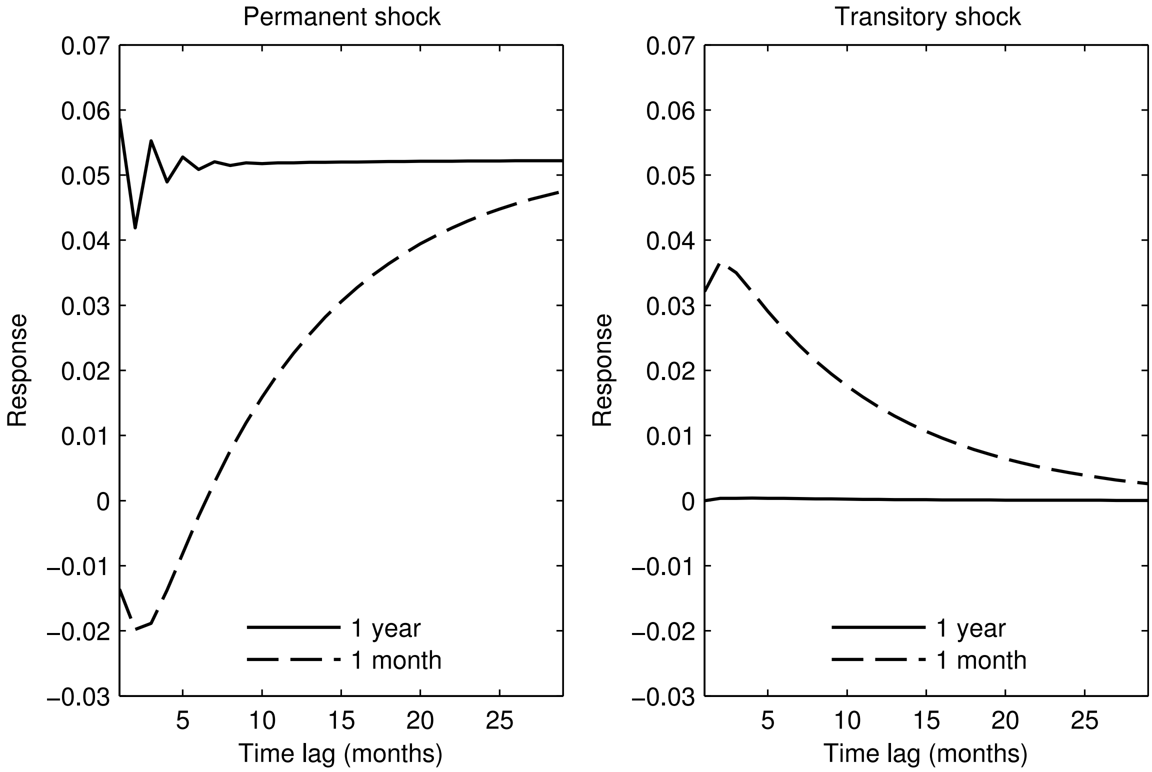
Monthly futures price series are constructed in the following way: The short-dated futures prices reflect a rolling futures strategy with the shortest available contract[27]. The long-dated futures price series is constructed analogously, but uses contracts expiring one year ahead of the nearby maturity. The contracts are rolled into the next available maturity in the month where the shortest contract expires; a fixed business day is selected for the rollover. The roll schedule applied to each commodity is available upon request. The selected time spread of exactly one year controls for seasonalities in the term structure of commodity futures prices; i.e. by rolling the contracts, seasonal price "jumps" vanish because the contracts exhibit the same expiration month. All prices are denoted in U.S. dollars and were downloaded from Thomson Reuters Datastream.

[26] Vogel (1999) provides a good understanding of these issues.

[27] The spot price is typically not observable for commodities; it is therefore common practice to use the price of the nearby contract, i.e. the contract with the shortest time to maturity, as a proxy.

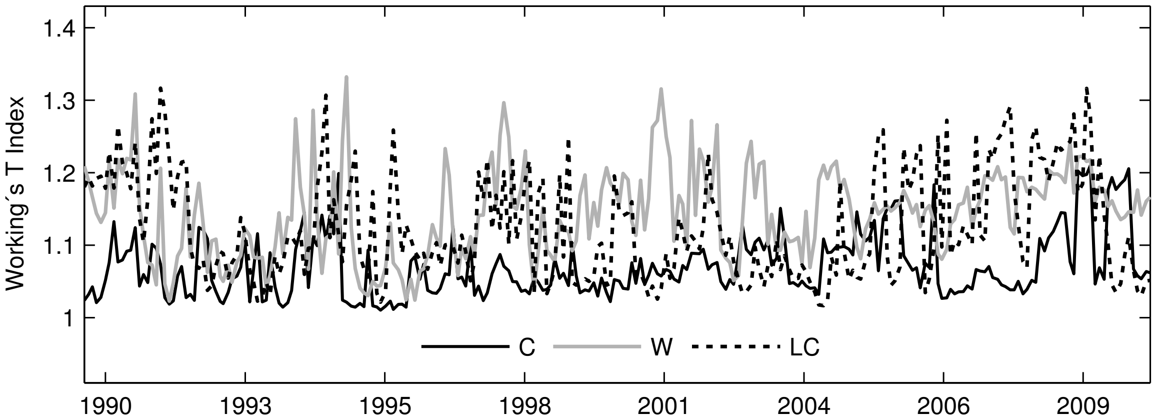
B Figures and Tables

Figure 1: Illustrative impulse respsonse function (Corn) based on the Gonzalo-Ng variance decomposition



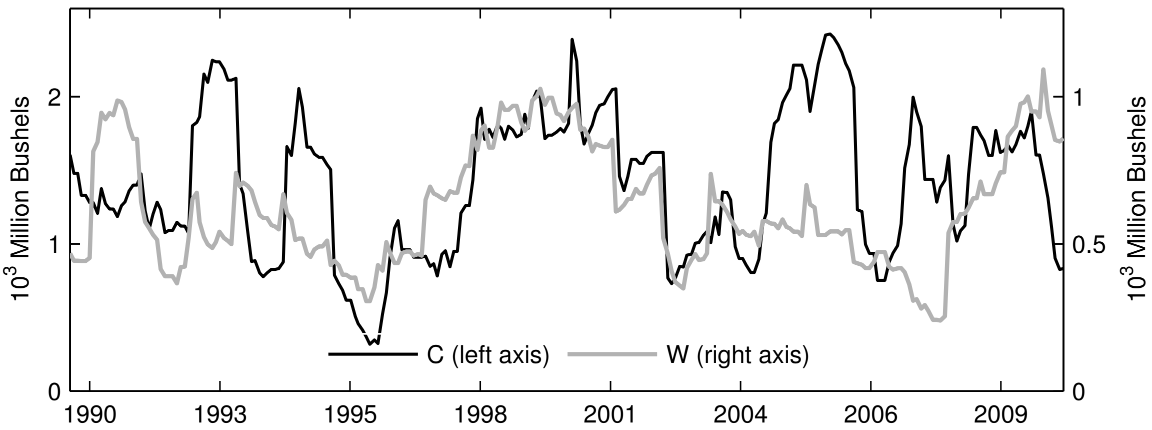
The impulse response function on the left (right) depicts the price reaction of the short- and long-dated futures contracts on a permanent (transitory) shock by one standard deviation. The P-T decomposition is based on the residuals of the VECM representation of the cointegrated futures price system.

Figure 2: Illustrative time series of Working's T Index on net speculation



Working's T Index is illustrated for Corn (C, black line), Wheat (W, gray line) and Live Cattle (LC, dotted line) for monthly observations from January 1990 to December 2010. The index is calculated using position data from the Commitments of Traders (COT) report by the CFTC.

Figure 3: Illustrative time series of USDA ending stocks



Ending stocks projections for Corn (C, black line) and Wheat (W, gray line) for monthly observations from January 1990 to December 2010. The data are from the World Agriculture Supply and Demand Estimates (WASDE) published by the United Department of Agriculture (USDA).

Table 1: The sample of selected commodity futures contracts

Sector	Commodity	Exchange	Data period	No.-Months	Expiry months
Grains (4)	Corn	CBOT	Jan 90 - Dec 10	252	3, 5, 7, 9, 12
	Soybean	CBOT	Jan 90 - Dec 10	252	1, 3, 5, 7, 8, 9, 11
	Soybean Oil	CBOT	Jan 90 - Dec 10	252	1, 3, 5, 7, 8, 9, 10, 12
	Wheat	CBOT	Jan 90 - Dec 10	252	3, 5, 7, 9, 12
Softs (5)	Cocoa	ICE US	May 99 - Dec 10	140	3, 5, 7, 9, 12
	Coffee	ICE US	Jan 90 - Dec 10	252	3, 5, 7, 9, 12
	Cotton	ICE US	Jan 90 - Dec 10	252	3, 5, 7, 9, 12
	Orange Juice	ICE US	Jan 90 - Dec 10	252	1, 3, 5, 7, 9, 11
	Sugar	ICE US	Apr 94 - Dec 10	213	3, 5, 8, 10, 12
Meat (2)	Lean Hogs	CME	Jan 90 - Dec 10	252	2, 4, 6, 7, 8, 10, 12
	Live Cattle	CME	Jan 90 - Dec 10	252	2, 4, 6, 8, 10, 12
Energies (3)	WTI Crude Oil	NYMEX	Jan 90 - Dec 10	252	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	Heating Oil	NYMEX	Jun 93 - Dec 10	211	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	Natural Gas	NYMEX	Jan 94 - Dec 10	204	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Metals (1)	Copper Spot	COMEX	Jan 90 - Dec 10	252	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
	Copper 1 Year	COMEX	Jan 90 - Dec 10	252	3, 5, 7, 9, 12

CBOT denotes the Chicago Board of Trade, ICE denotes the Intercontinental Exchange US, CME denotes the Chicago Mercantile Exchange, COMEX denotes the New York Commodities Exchange, LME denotes the London Metal Exchange, and NYMEX denotes the New York Mercantile Exchange. Expiration months are selected based on simultaneous availability of the nearby contract and the respective contract with the same expiry month one year ahead. As noted in the text, due to data limitations, an exception is made for Copper.

Table 2: Summary statistics for Working's T Index and inventories

							Unit root test (ADF)		
Commodity	No.-Obs.	Mean	Min	Max	S.D.	Source	No. lags	t-stat.	p-value[1]
Panel A - Working's T Index on net speculation									
Corn	252	1.07	1.01	1.21	0.04	CFTC	0	-8.1	0.0%
Soybean	252	1.09	1.02	1.24	0.05	CFTC	0	-7.9	0.0%
Wheat	252	1.14	1.02	1.33	0.06	CFTC	0	-8.5	0.0%
Cotton	252	1.06	1.01	1.21	0.04	CFTC	2	-4.4	0.3%
Sugar	252	1.04	1.00	1.21	0.03	CFTC	1	-5.1	0.0%
Live Cattle	252	1.12	1.02	1.32	0.07	CFTC	0	-15.7	0.0%
WTI Crude Oil	252	1.03	1.01	1.07	0.01	CFTC	1	-4.7	0.1%
Heating Oil	252	1.04	1.00	1.15	0.03	CFTC	2	-3.8	2.1%
Natural Gas	249	1.06	1.00	1.27	0.07	CFTC			
Panel B - Inventories (Descriptive statistics) resp. Inventory Changes (Unit root test)									
Corn	252	1'415	22%	171%	35%	USDA	0	-13.7	0.0%
Soybean	252	290	36%	212%	44%	USDA	0	-12.7	0.0%
Wheat	252	624	38%	175%	32%	USDA	0	-13.7	0.0%
Cotton	252	5	34%	206%	37%	USDA	0	-12.2	0.0%
Live Cattle	252	373	63%	138%	18%	NASS	0	-16.4	0.0%
WTI Crude Oil	252	322	84%	119%	7%	DOE	0	-15.6	0.0%
Heating Oil	211	52	59%	190%	23%	DOE	0	-14.1	0.0%
Natural Gas	204	2'239	58%	133%	15%	EIA	0	-12.6	0.0%

The time series cover the period from December 1990 to December 2010, with a few exceptions. Notice that only those commodities are displayed in the Table which are used in the Granger causality tests in the empirical part of the paper, i.e. for which cointegration of futures prices is found in Subsection (5.1).

Panel A displays descriptive statistics for Working's T Index. The index is calculated using the data from the Commitments of Traders (COT) report published by the Commodity Futures Trading Commission (CFTC).

Panel B displays descriptive statistics for the seasonally adjusted inventory levels. The mean is expressed in real units of the respective commodity (see belew), but for easier interpretation the maximum (Max), minimum (Min) and standard deviation (S.D.) are expressed in percentages of the respective mean. The mean for Corn, Soybean and Wheat is given in million bushels, Cotton in million bales, Live Cattle in million pounds, WTI Crude Oil and Heating Oil in million barrels, and Natural Gas in million cubic feet. USDA denotes the United States Department of Agriculture, NASS the National Agriculture Statistics Service, DOE the U.S. Department of Energy, and EIA the U.S. Energy Information Administration.

For both Panels, the lag length of the Augmented Dickey-Fuller (ADF) unit root test is based on the Schwarz Information Criterion and the estimated equation includes an intercept and a trend. In Panel A stationarity is tested for the level of the speculation index, while in Panel B stationarity is tested for the first difference of logarithmic inventories, i.e. relative inventory changes.
[1]MacKinnon one-sided p-value.

Table 3: Cointegration of 1 month and 1 year commodity futures prices: Restricted model

Commodity[1]		C	S	W	CT	SB	LC	CL	HO	NG
Estimation period		01/90	01/90	01/90	01/90	05/93	01/90	01/90	01/90	02/94
		12/10	11/10	12/10	12/10	11/10	12/10	12/10	12/10	12/10
Panel A: adapted to CTO speculation data										
Number of lags		2	2	1	1	1	1	1	2	1
Trace test (p-value)		7.5%	3.7%	2.8%	8.9%	9.3%	0.0%	0.3%	4.2%	0.1%
Cointegration vector	1 Year	1	1	1	-1.76	1	1	1	1	1
	1 Month	-0.99	-0.96	-1.14	1.00	-0.88	-1.26	-1.11	-1.10	-1.11
	Constant	-0.15	-0.26	0.77	3.24	-0.66	1.11	0.39	0.00	0.08
VEC-term[2]	1 Year				0.05					
	t-value				3.12					
VEC-term[2]	1 Month	0.07	0.12	0.10		0.13	0.13	0.14	0.10	0.18
	t-value	*3.25*	*3.96*	*4.11*		*3.26*	*5.06*	*4.91*	*3.98*	*5.08*
Variance decomp.	Fraction of TS	85%	99%	84%	99%	100%	90%	75%	69%	73%
Half life of TS	Months	20	14	21	18	12	23	16	10	22
Panel B: adapted to storage data										
Number of lags		2	1	3	1		1	2	2	1
Trace test (p-value)		9.1%	6.2%	4.3%	8.1%		0.1%	0.4%	4.2%	0.3%
Cointegration vector	1 Year	1	1	1	-1.80		1	1	1	1
	1 Month	-0.97	-0.97	-1.32	1.00		-1.27	-1.12	-1.10	-1.12
	Constant	-0.23	-0.20	1.84	3.38		1.18	0.44	0.00	0.13
VEC-term[2]	1 Year				0.05					
	t-value				*3.30*					
VEC-term[2]	1 Month	0.07	0.11	0.07			0.15	0.12	0.10	0.17
	t-value	*3.19*	*3.76*	*3.90*			*5.32*	*4.65*	*3.98*	*4.72*
Variance decomp.	Fraction of TS	84%	100%	80%	99%		94%	73%	69%	77%
Half life of TS	Months	20	11	59	20		29	9	10	25

Commodities are abbreviated by: Corn (C), Soybean (S), Wheat (W), Cotton (CT), Sugar (SB), Live Cattle (LC), WTI Crude Oil (CL), Heating Oil (HO) and Natural Gas (NG). Notice that no COT data are available for Cocoa. COT stands for the Commitments of Traders reports (published by the U.S. Commodity Futures Trading Commission), VEC stands for vector error correction and TS for transitory shocks. The time period covers monthly data from Jan 1990 to Dec 2010, except for Cocoa, SB, HO and NG.

[1]No cointegration can be found for Coffee, Soybean Oil and Copper, whereas two cointegration relationships are found for Lean Hogs and Orange Juice. [2]The coefficient which is restricted equal to zero is not displayed in the Table.

Table 4: Test for Granger causality between speculation and permanent shocks as well as transitory shocks

Com.	Est. period	No. Obs.	PS does not Granger cause speculation: VAR Coefficient lag 1	lag 2	lag 3	p-value	Speculation does not Granger cause PS: VAR Coefficient lag 1	lag 2	lag 3	p-value	TS does not Granger cause speculation: VAR Coefficient lag 1	lag 2	lag 3	p-value	Speculation does not Granger cause TS: VAR Coefficient lag 1	lag 2	lag 3	p-value
C	04/90	248	0.00			0.05	2.27			0.09	0.00			0.05	0.91			0.57
	12/10		*-1.94*				*1.68*				*1.96*				*0.57*			
S	04/90	248	0.00			0.06	1.51			0.27	0.00			0.13	1.70			0.22
	12/10		*-1.86*				*1.09*				*1.51*				*1.22*			
W	01/90	251	0.00			0.66	1.42			0.14	0.00			0.10	1.05			0.37
	12/10		*-0.45*				*1.49*				*1.67*				*0.91*			
CT	03/90	249	0.00	0.00	0.00	0.19	1.34	0.75	-0.13	0.73	0.00			0.97	-0.21			0.90
	12/10		*-1.73*	*-0.44*	*1.20*		*0.63*	*0.32*	*-0.06*		*0.03*				*-0.13*			
SB	04/93	210	0.00	0.00		0.01	1.89	0.70		0.53	0.00	0.00		0.44	3.00	0.97		0.22
	12/10		*-2.34*	*-1.95*			*0.71*	*0.26*			*0.73*	*1.07*			*1.13*	*0.37*		
LC	03/90	249	0.00	0.00		0.97	-2.39	1.69		0.07	0.00	0.00	0.00	0.32	-0.74	2.02	-1.76	0.34
	12/10		*-0.13*	*0.19*			*-2.29*	*1.62*			*-0.32*	*0.15*	*0.34*		*-0.63*	*1.56*	*-1.52*	
CL	03/90	248	0.00	0.00		0.19	5.41	-4.36		0.67	0.00	0.00		0.97	1.35	-0.89		0.99
	12/10		*1.49*	*1.09*			*0.89*	*-0.72*			*0.25*	*-0.04*			*0.17*	*-0.11*		
HO	03/90	204	0.00	0.00	0.00	0.61	-2.36	5.25	-0.94	0.36	0.00	0.00	0.00	0.08	-0.56	2.95	-1.46	0.92
	12/10		*1.29*	*-0.12*	*-0.36*		*-0.78*	*1.66*	*-0.32*		*-0.60*	*-1.43*	*2.12*		*-0.13*	*0.66*	*-0.35*	
NG	04/94	199	0.00	0.00		0.21	2.00	-1.07		0.60	0.00	0.00		0.12	2.52	-0.13		0.12
	12/10		*-0.38*	*-1.75*			*0.60*	*-0.32*			*-0.62*	*1.95*			*0.68*	*-0.03*		

Commodities (Com.) are abbreviated by: Corn (C), Soybean (S), Wheat (W), Cotton (CT), Sugar (SB), Live Cattle (LC), WTI Crude Oil (CL), Heating Oil (HO) and Natural Gas (NG). Granger tests are based on the cointegration results from Table [3]. VAR stands for vector autoregression, PS for permanent shocks and TS for transitory shocks.

[1]No cointegration is found for Coffee, Cocoa, Soybean Oil and Copper, whereas two cointegration relationships are found for Lean Hogs and Orange Juice. Therefore these commodities cannot be analyzed here.

Table 5: Test for Granger causality between storage and permanent shocks as well as transitory shocks

			PS does not Granger cause storage			Storage does not Granger cause PS			TS does not Granger cause storage			Storage does not Granger cause TS		
Com.	Est.	No.	VAR Coefficient		p-value	VAR Coefficient		p-value	VAR Coefficient		p-value	VAR Coefficient		p-value
	period	Obs.	lag 1	lag 2		lag 1	lag 2		lag 1	lag 2		lag 1	lag 2	
C	05/90	247	0.00		0.60	-0.52		0.36	0.02		0.00	-0.14		0.84
	12/10		*-0.52*			*-0.92*			*2.97*			*-0.20*		
S	04/90	248	-0.02		0.03	0.34		0.54	0.03	0.02	0.00	0.22	0.79	0.29
	12/10		*-2.20*			*0.61*			*3.84*	*3.02*		*0.40*	*1.44*	
W	06/90	246	-0.01		0.04	-1.56		0.07	-0.01	0.01	0.01	5.10	-0.49	0.00
	12/10		*-2.03*			*-1.83*			*-1.58*	*2.53*		*4.72*	*-0.43*	
CT	04/90	248	0.00		0.48	-3.91		0.00	0.00		0.43	-1.29		0.08
	12/10		*-0.70*			*-5.52*			*-0.79*			*-1.75*		
LC	04/90	248	0.00		0.69	-1.18		0.34	0.00	0.01	0.09	-1.58	0.45	0.44
	12/10		*-0.41*			*-0.96*			*0.73*	*2.08*		*-1.22*	*0.35*	
CL	05/90	247	0.00		0.73	0.60		0.81	0.01	0.00	0.00	-1.55	-3.59	0.53
	12/10		*-0.34*			*0.24*			*4.57*	*3.71*		*-0.44*	*-1.05*	
HO	10/93	206	0.01		0.12	1.25		0.17	0.01		0.13	1.27		0.35
	12/10		*1.55*			*1.37*			*1.53*			*0.94*		
NG	04/94	200	0.01		0.09	-1.18		0.44	0.01		0.00	2.17		0.23
	12/10		*1.72*			*-0.78*			*3.94*			*1.20*		

Commodities (Com.) are abbreviated by: Corn (C), Soybean (S), Wheat (W), Cotton (CT), Live Cattle (LC), WTI Crude Oil (CL), Heating Oil (HO) and Natural Gas (NG). Granger tests are based on the cointegration results from Table [3]. VAR stands for vector autoregression, PS for permanent shocks and TS for transitory shocks.

[1]No cointegration is found for Coffee, Cocoa Soybean Oil and Copper, whereas two cointegration relationships is found for Lean Hogs and Orange Juice. Therefore these commodities cannot be analyzed here. This also applies to Sugar because of limitations in storage data.

Table 6: Variance decomposition: Largest explained variance

Panel A: Speculation

Commodity	[1] speculation driven by PS	[2] PS driven by speculation	[3] speculation driven by TS	[4] TS driven by speculation
	Percentage of variation in ...			
C	**1.46**	**4.69**	1.44	2.74
S	**1.30**	7.63	0.89	2.92
W	0.78	3.66	**1.06**	6.35
CT	1.44	6.69	0.00	0.62
SB	**7.89**	4.32	1.13	1.36
LC	0.01	**5.10**	0.92	6.49
CL	2.32	0.49	0.02	2.81
HO	0.76	2.63	**1.45**	2.30
NG	1.70	0.81	0.77	4.01

Panel B: Storage

Commodity	[1] storage driven by PS	[2] PS driven by storage	[3] storage driven by TS	[4] TS driven by storage
	Percentage of variation in ...			
C	0.11	7.23	**3.28**	18.1
S	**13.25**	0.14	**12.67**	**0.92**
W	**1.66**	**1.48**	**3.05**	**15.81**
CT	0.18	**12.64**	0.27	1.40
LC	0.07	1.06	**1.93**	0.67
CL	0.97	0.05	**11.63**	3.87
HO	1.16	2.00	1.14	6.22
NG	**1.45**	3.84	**7.12**	10.72

The table displays the results of a variance decomposition based on the VAR models used for the Granger causality tests in Tables [4] and [5]. Shown is the percentage variance of permanent and transitory shocks caused by speculation and storage (Columns two and four), and respectively, of the reverse relationships (Columns one and three). The figures are the largest variance proportions observed across the time-lags. Bold figures refer to statistically significant Granger causality.
Commodities are abbreviated by: Corn (C), Soybean (S), Wheat (W), Cotton (CT), Sugar (SB), Live Cattle (LC), WTI Crude Oil (CL), Heating Oil (HO) and Natural Gas (NG). Figures are marked in bold if the respective p-values of the Granger causality test, displayed in Tables [4] and [5] is less then 10%.