Speculative Influences on
Commodity Futures Prices 2006-08

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Initial draft: 12 August 2009
This revision: 24 October 2009

Abstract

This note examines the possible price impact of speculative bubbles and index-based investment activity on commodity futures prices over 2006-08. I look specifically at crude oil, three non-ferrous metals (aluminium, copper and nickel) and three agricultural commodities (wheat, corn and soybeans). There is only modest evidence for the behaviour characteristic of extrapolative bubbles but the impact of index-based investment may have been substantial and bubble-like.

This paper has been prepared under contract with UNCTAD. The views expressed are, however, those of the author and not of UNCTAD itself. I am grateful to Jörg Mayer for comments on an earlier draft, to Isabel Figuerola-Ferretti and Roderick McCrorie for collaboration on econometric issues, to Elena Corazzolla for research assistance and to Paul Giunti and Maria Mohammadian-Molina for help with data. All errors are my own.
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1. Introduction

Were high commodity prices in 2006-08 a speculative bubble? This was the view expressed by the British peer Lord Meghnad Desai who claimed that 2008 oil price rises were speculative and appeared to be a financial bubble.[1] Phillips and Yu (2009) reach the same conclusion econometrically and observe bubble behaviour in the crude oil market starting in March 2008 and collapsing in August 2008. A U.S. Senate subcommittee has argued that the wheat market was affected by excessive speculation in 2008 (United States Senate Permanent Subcommittee on Investigations, 2009).

The consensus view among market commentators is that high prices for oil and non-ferrous metals were driven primarily by rapid demand growth in China and other parts of Asia in the context of more modest growth in oil supply. Slow supply growth is seen as the consequence of low exploration and investment over the low price two decades from 1985 and in part because of finiteness of oil reserves (although there is less agreement as to whether this was important). However, it is difficult to quantify the impact of Chinese demand growth with any precision.

Turning to agricultural commodities, China is less important, although it is a major importer of soybeans, used as an animal feedstock. Many commentators have argued that, nevertheless, China was the indirect cause of high food prices via its impact on the crude oil price which increased the attractiveness of biofuels production. Mitchell (2008) argued that diversion of food commodities into use as biofuel feedstocks was the major cause of higher food prices in 2008. However, this is a residual-based argument. Gilbert (2009) puts a dissenting view and attributes only a modest proportion of food price rises to biofuels demand.

The 2006-08 rise in dollar commodity prices took place against the backdrop of a decline in the value of the U.S. dollar against other major currencies. This has led to the claim that higher dollar prices at least partially reflect shrinkage of the measuring rod. That is true, but if this were the only cause of changes in dollar prices, we should expect commodity prices in to have risen in terms of the euro and yen, currencies which have both appreciated against the dollar.[2] They have not. Exchange rate changes cannot therefore be the entire story.

[1] "Act now to price the bubble of a high oil price", *Financial Times*, 6 June 2008.

[2] Exchange rate changes redistribute purchasing power among commodity consumers and competitive advantage among producers. Production should rise and consumption fall in countries with depreciating currencies with the opposite in countries whose currencies appreciate. The effects on aggregate production and consumption should net to zero. Local currency prices should therefore rise in depreciating countries and fall in appreciating countries.

Overall, although it is possible to argue that the recent commodity price spikes were driven entirely by fundamental factors, this involves something of an act of faith in relation to the unquantifiable impacts of Chinese growth (metals and energy commodities) and biofuels demand (agricultural foods). These explanations therefore leave room for alternatives perhaps involving futures market factors. In this paper, I look at two routes through which futures market activity may have amplified or distorted commodity price movements. These are trend-following speculation and index-based investment which I discuss in section 2 of the note.

2. The actors

Edwards and Ma (1992, p.11) state "Futures contracts are bought and sold by a large number of individuals and businesses, and for a variety of purposes". We may delineate five broad classes of actors:

a) Hedgers: These are "commercials" in CFTC terminology. They have an exposure to the price of the physical commodity (long in the case of producers and merchants with inventory, short in the case of consumers) which they offset (usually partially) by taking an opposite position in the futures market.
b) Speculators: They take positions, generally short term based on views about likely price movements. Speculators may be divided between those who trade on market fundamentals and those who trade on a technical basis, i.e. on the basis of past trends or other, more complicated, price patterns. Hedge funds and CTAs (see below) typically fall into this category. Many speculative trades are "spread" rather than "outright" trades, that is to say they involve taking offsetting positions on related contracts (generally different maturities for the same future).
c) Investors: Investors take positions (usually long and usually indirectly) in commodity futures as a component of a diversified portfolio. This is the class of actors which appears to have grown dramatically over the two most recent decades.
d) Locals: Originally pit traders with modest capital but now mainly screen traders often operating from trading "arcades", locals provide liquidity by "scalping" high frequency price movements driven by fluctuations in trading volume and size. Many of their positions will also be spreads rather than outrights. Locals may also arbitrage across markets or exchanges.
e) Index providers: Banks or other financial institutions who facilitate commodity investment by providing suitable instruments, typically ETFs, commodity certificates

or swaps. These institutions will generally offset much of their net position by taking offsetting positions on the futures markets.

These categories are easier to separate in principle than in practice. A producer or consumer who chooses not to hedge, or who hedges on a "discretionary" basis, is implicitly taking a speculative position. Some locals may hold significant outright positions over time. Long term investors will take speculative views on commodities versus other asset classes, and on specific groups of commodities (metals, energy etc.). Some agents have mixed motives.

Although commodity speculation has traditionally been thought of as undertaken by individuals (the proverbial New York cab drivers and Belgian dentists), the greatest share of non-hedge futures market positions in value terms are held through intermediaries.

- US legislation defines a commodity pool as an investment vehicle which takes long or short futures positions. A Commodity Pool Operator (CPO) operates a commodity pool. Commodity Trading Advisors (CTAs) advise on and manage futures accounts in CPOs on behalf of investors. A CPO investment is a straightforward means of investing in a portfolio of commodity futures.
- Hedge funds invest on behalf of rich individuals. Some of these investments are likely to be in commodity futures or swaps. "Funds of funds" are hedge funds, or CPOs which invest in other hedge funds or CPOs, generating greater diversification albeit at the cost of a second level of fees. A small number of hedge funds are focussed specifically on traditional commodities, generally with an emphasis on energy and non-ferrous metals.
- Exchanges offer Exchange Traded Funds (ETFs) defined either in terms of specific commodities or commodity indices. Banks offer certificates with returns tied to or related to the same indices.
- Index–based investments typically involve floating-for-fixed swap structure in which an intermediary, often a bank, pays the investor a return related to the returns on a commodity index. The intermediaries, known as swap providers, will offset some or all of the resulting short exposure through purchase of futures contracts.

Within the commodity class, energy futures have traditionally had the highest weight and agricultural futures the lowest weight. Metals are intermediate. Fabozzi *et al.* (2008b) state that in 2007 there were around 450 hedge funds with energy and commodity-related trading strategies.

The remainder of this paper divides in two. I look at speculative bubbles, possibly associated with the activities of CTAs, in sections 3-5, and price inflation, possibly resulting from index-based investment, in sections 6-9.

3. Speculative bubbles

Commodity Trade Advisors (CTAs) form a major group of non-commercial traders on futures markets, including commodity futures markets. They are obliged, under the U.S. Commodity Exchanges Act (CEA), to disclose their investment strategies. The most important distinction among CTAs is between the majority, which follow "passive" allocation strategies and the much smaller minority which adopt discretionary strategies. Passive strategies rely on trend identification and extrapolation – once an upward trend is identified, the fund will take a long position in the asset and *vice versa* for a downward trend. Trends are generally identified by application of more or less sophisticated moving average procedures – see Taylor (2005, ch. 7). CTAs compete on the predictive power of their trend extraction procedures and also on the extent of their activity – whether they always take a position in a particular future or whether they can be out of the market for that future for extended periods.[3] A natural concern is that CTAs may themselves create the trends that they subsequently follow resulting in herd behaviour and bubbles.

Friedman (1953) famously argues that speculation will stabilize prices since otherwise speculators will lose money and thence find some better way to employ their time and resources. Although influential, this argument has not generally been regarded as convincing. It is noted that clients regularly lose money in casinos, but casinos nevertheless remain in business. Similarly, many CTAs give advice which result in CPOs losing money. Some of these CTAs go out of business but others replace them. It is difficult to assess whether CPO investments have been net profitable.

Modern finance theory distinguishes between informed and uninformed speculation (Bagehot, 1971; O'Hara, 1995, ch.3). According to this view, informed speculation is the channel through which private information becomes impounded in publically-quoted prices. Uninformed speculation should either not have such effects, or in less liquid markets, should not have persistent effects. If uninformed trades do move a market price away from its fundamental value, informed traders, who know the fundamental value of the asset, will take

[3] Hedge funds are both more diverse and less transparent than CTAs. They are not obliged to report their investment strategies which must therefore be inferred from performance. They will also typically be opportunistic and hence may not follow consistent strategies over time.

advantage of the profitable trading opportunity with the result that the price will return to its fundamental value.

In other words, if a non-fundamental price movement emerges, informed investors should take contrarian positions. In practice, the informed investors are likely to sit on the sidelines until sense returns to the market since there is no easier way to lose money than to be right but to be right too early. De Long *et al* (1990) showed that, if informed traders have short time horizons (perhaps as the result of performance targets or reporting requirements) and if there are sufficiently many uninformed trend-spotting speculator, they may choose to bet on continuation of the trend even though they acknowledge it is contrary to fundamentals. The 1999-2000 internet equities bubble appears to fit this description. The view can also make concrete which the Diba and Grossman (1988) concept of a "rational bubble" in which explosive asset prices satisfy the first order (Euler) condition equating the expected rate of appreciation to the return on assets of similar riskiness through the rationally perceived possibility of the bubble bursting generating a large negative return.

4. Testing for bubble behaviour

The existence and extent of trend-following behaviour may in principle be ascertained by regressing CTA-CPO positions on price changes over the previous days. These data are not, however, publically available. Using confidential CFTC data, Irwin and Holt (2004) found that the net trading volume of large hedge funds and CTAs in six of the twelve futures markets they consider was significantly and positively related to price movements over the previous five days. However, the degree of explanation was low. Irwin and Yoshimaru (1999) report very similar results for CTA-CPO positions. The empirical evidence is consistent with the existence of trend-following behaviour but also indicates that this will generally be swamped by other influences.

An alternative approach, which I adopt here, is to look for the evidence of trend-following behaviour in the price process itself. The underling idea is that if tend-following behaviour is important, an upward movement in prices will tend to be extrapolated. The view that there is trend in an asset price will itself generate the momentum which validates this belief. (The argument holds equally for a negative trend).

Phillips, Wu and Yu (PWY, 2009) have devised a procedure which allows the investigator to test for bubble-type behaviour in a financial time series. The test uses the first order Augmented Dickey-Fuller (ADF) regression

$$\Delta \ln f_t = \mu + \delta \ln f_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta \ln f_{t-j} + \varepsilon_t \quad (2)$$

where the parameter p is chosen such that the residuals from the regression are uncorrelated. The standard ADF test is based on testing the null hypothesis of non-stationarity $H_0 : \delta = 0$ against the alternative hypothesis $H_1 : \delta < 0$ which implies stationarity. Instead, PWY test the same null hypothesis against the alternative $H_1^* : \delta > 0$ implying explosive behaviour.[4] The t statistic $t_{\hat{\delta}}$ associated with the least squares estimate of the coefficient δ follows the Dickey-Fuller distribution but the relevant critical values for the test against H_1^* are the right-hand values. I refer to this as the Positive Augmented Dickey-Fuller (PADF) test.

There are at least two approaches possible to testing for apparently explosive behaviour. The first is to apply the PADF test on a month by month basis. This gives a sequence of test outcomes. There are two problems. The first is that bubbles m ay span months with the result that, although no bubble is found in either month m or in m+1, an undetected bubble may have been present in the final two weeks of m extending into the first two weeks of m+1. The second problem is that, with a 5% test size, it is to expected that bubbles will be found in 5% of months even if no bubbles were in fact present.

The second approach, based on a single recursively estimated regression, is that proposed by PWY (2009) who argue that it enables the dating of the start and end of bubbles. PWY suppose that this weakly explosive behaviour is only present over a subsample $[T_1{:}T_2]$ of the entire sample $[1{:}T]$ and that $\delta = 0$ for the remainder of the sample. PWY attempt to estimate the two dates T_1 and T_2 from recursive least squares estimates of the ADF equation (2). Write $\hat{\delta}(\tau)$ for the estimate of δ over the sample $[1{:}\tau]$ and $t_{\hat{\delta}}(\tau)$ for the associated t-value. PWY propose to estimate T_1 as the first date τ_1 for which $t_{\hat{\delta}}(\tau) \geq cv_{t_{\hat{\delta}}}$, the test critical value, and to estimate T_2 as the first date $\tau_2 > \tau_1$ for which $t_{\hat{\delta}}(\tau) < cv_{t_{\hat{\delta}}}$ the same critical value.

There are a number of complications in this procedure.

a) The results appear slightly sensitive to the start date of the sample.
b) Bubbles need to persist for a significant time to warrant this identification. It is necessary to have a convention to deal both with isolated or short intervals in which the criterion

[4] A series cannot explode indefinitely without reaching infeasible values. PWY therefore follow Phillips and Magdalinos (2007) in supposing that the series is "weakly explosive" in the sense that δ tends to zero as the sample size increases.

$t_{\hat{\delta}}(\tau) \geq cv_{t_{\hat{\delta}}}$ is satisfied and with isolated or short "hole" intervals in which the criterion $t_{\hat{\delta}}(\tau) < cv_{t_{\hat{\delta}}}$ is satisfied.

c) Recursive estimation requires an initialization of sample, say of τ_0 observations. (Typically, one takes τ_0 as around ten per cent of the total sample). The statistic $t_{\hat{\delta}}(\tau)$ is therefore unavailable over the period [1:τ_0].

d) Multiple bubbles are a possibility. If a bubble has been identified terminating at T_2, the investigator can re-initiate the exercise over the sample [T_2+1: T]. In practice, since the dating remains somewhat uncertain, it is probably better to restart at T_3+1 where $T_3 > T_2$. This creates a further "blind" period over the sub-sample [T_2+1: T_3+1+:τ_0'] where τ_0' is the initialization period for the second recursion.

PWY (2009) use these procedures to investigate the NASDAQ internet bubble. Using the same methods, Phillips and Yu (2009) claim that there was on oil price bubble between March and September 2008.

The PADF test procedure is new and relatively untested. It has yet to be sanctioned either by practical experience or by peer group review. It tests for a narrowly defined class of bubble phenomena – those that can be characterized as rational bubbles. This class is, however, interesting in the commodities context as this is exactly the type of price response which one might expect to arise expect out of the activities of trend-following CTA speculators as described in section 3 of this paper. The procedure aims to be able to date, retrospectively, the start and end of periods of explosive behaviour. However, the experience discussed below suggests that the procedure is less automatic than PWY imply and requires significant judgemental input. Furthermore, it is unclear whether the PWY procedure should be interpreted as dating bubble episodes, as PWY claim, or as indicating the dates at which one can be sure (at the specified level of confidence) that a bubble has started or terminated. These two concepts differ because the date at which one can be confident that an explosive episode has taken place will tend to be later, and perhaps substantially later, than the start of the bubble itself.

Even if an apparent bubble is found, this cannot be taken as sufficient evidence that this was caused by futures market activity since it is also possible that the market is reacting to a bubble in the underlying fundamental. Looking at NASDAQ prices, Phillips and Yu (2008) confirm that there is no bubble in the dividend process, which drives equity prices, and hence conclude that the NASDAQ bubble is a financial markets bubble. The analogous argument in the commodities sector would require the analyst to determine the underlying fundamental, perhaps either convenience yield or consumption, and to demonstrate that the associated process is non-explosive.[5]

5. Bubble behaviour in commodity markets

In what follows, I look at seven commodities – crude oil (WTI, first nearby), aluminium, copper and nickel (all LME three month prices) and corn, wheat and soybeans (CBOT, first nearby). I consider both real monthly averages (nominal U.S. dollar prices deflated by the US PPI), using the sample January 1990 – December 2008 (228 observations), and nominal (US dollar) daily closing prices, using the sample 3 January 2006 to 31 December 2008 for crude oil and the three grains (753 and 755 observations respectively on account of differences in holidays) and the longer sample 4 January 2000 to 31 December 2008 for the three non-ferrous metals, reflecting the earlier start of the metals boom (2271 observations). I roll the CBOT and WTI prices on the first day of the final month of trading with the result that monthly prices are based on averages of prices from a single contract.[6]

The monthly regressions used and ADF specification (2) with $p = 1$ estimated over the 226 months March 1990 to December 2008. The initialization value for the recursion was $\tau_0 = 22$ giving estimates of $t_{\hat{\delta}}(\tau)$ from January 1992 to December 2008. In none of the seven cases did the forward PWY test indicate the presence of a bubble. Overall, therefore, the analysis of monthly data does not provide any evidence for bubble behaviour in the prices considered.

I now turn to the recursive daily analysis where the results are more complicated. The tests again adopt an ADF(1) specification. I adopt the rule that a bubble must persist for ten working days if it is to count as economically interesting. I look for significance using a constant critical value of 1.4603 taken from PWY (2009).[7] I divide the seven commodities in to three groups.

[5] Convenience yield plays the same role in the pricing of commodity options as do dividends in the pricing of options on equities with the difference that it is ownership of the physical commodity and not the future which earns convenience yield. This implies that convenience yield is irrelevant if one is considering prices of a specific future but may be important if one is working with a continuous (i.e. rolled) future.

[6] The roll issue does not arise with LME prices since each day effectively corresponds with a different contract. My rolling convention implies that my "first nearby" will correspond to the second position in more normal parlance for all but the final days of the month.

[7] I acknowledge the argument that the critical value should decline as τ increases.

i) For one of the seven commodities under consideration (corn), there is unequivocally no evidence for a bubble from the recursive estimates – see Figure 1.

ii) For four commodities – aluminium, crude oil, nickel and wheat – there are isolated days or short periods in which $t_{\hat{\delta}}(\tau) \geq cv_{t_{\hat{\delta}}}$ but these are insufficient to qualify as bubbles. For aluminium, the recursive estimates show ADF statistics in excess of the critical value for a group of four days in May 2006 (9-12 May) – see Figure 2. In the case of crude oil it is exceeded a five day period including a one day hole (21-23 May plus 28 May)[8] – see Figure 3. For nickel, the critical value is exceeded respectively for a two day period (10-11 April 2007) – see Figure 4. Similarly, for wheat, the critical value is exceeded for three days at the end of September 2007 and again on a single day in February 2008 – see Figure 5.[9]

iii) There is clear evidence for bubbles periods for two of the seven commodities – copper and soybeans. For soybeans, the threshold is exceeded on 26-27 December 2007, again from 2-16 January 2008 and from 4 February to 6 March 2008. The soybean price ran up from \$1200/bshl to \$1450/bshl over this latter ten week period. There is no evidence for a subsequent bubble in soybeans. The copper analysis finds a first bubble from 17 February 2004 to 5 April 2004. Subsequently, a second bubble is identified over the period 11 April 2006 to 9 June 2006. There is some evidence that this second bubble may have continued into July 2006 since $t_{\hat{\delta}}(\tau) \geq cv_{t_{\hat{\delta}}}$ for a four day period from 11 to 14 July 2006. The third set of recursive estimates starting 14 August 2006 produces a group of four days in which $t_{\hat{\delta}}(\tau) \geq cv_{t_{\hat{\delta}}}$ over New Year 2006-07, but this fails to meet the length criterion. The criterion is again exceeded starting 1 December 2008 and extending to the end of the sample, albeit with a two day hole on 4 - 5 December – see Figure 7.

The interpretation of these results is not straightforward. The negative results for aluminium, corn, crude oil, nickel and wheat may be taken as implying that we can dismiss explosive bubble behaviour in these markets. The evidence from the soybeans market is that there was at most a short explosive bubble in January 2008. Copper shows the strongest evidence for explosive bubble behaviour with positive bubbles in 2004 and 2006 and a negative bubble in 2008.

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[8] 24 and 25 May 2008 were weekend days.

[9] 27-28 September and 1 October 2007 (29-30 September was a weekend) and 27 February 2008.

Figure 8 graphs copper three month prices and provides visual confirmation of these findings. The three bubble episodes are indicated in red while the line in blue in non-bubble periods. The initial bubble, identified as starting on 17 February 2004, came after a year in which the copper price had risen steadily. The price continues to rise over the estimated bubble period, but more modestly. Similarly, the second bubble, estimated as staring on 11 April 2006, came after two further years of rapidly rising prices. The copper price continued to rise for the first month of the bubble, but thereafter tended to decline albeit in a volatile manner. The December 2008 bubble follows a steady five month decline in the copper price.

PWY (2009) wish to interpret the start and end dates as the dates at which bubble periods started and ended. This interpretation may be mistaken. The start date is the first date at which, going forward, once can be confident that the price process has a root in excess of unity. That finding will necessarily be based on data from the preceding days (or periods) and will therefore come sometime after the start of the explosive period. This is apparent in all three copper bubbles – the price had been rising for a full year prior to the estimated start date of the 2004 bubble and for more than a year prior to the estimated start of the 2006 bubble. It has been falling for more than three months prior to the estimated start of the (negative) 2008 bubble. Similarly, the estimated end date will be based on data from days in which the price process has been non-explosive. It will also come after the end of an actual bubble. By contrast, using the backward recursive estimates, the estimated end date is the most recent date at which, looking backwards from the present, one can be confident that the price process had a root in excess of unity. This is apparent in the 2006 bubble where the price was falling for a month prior to the estimated bubble termination date. Significant ADF test statistics may therefore be confidently taken as indicating that there have been bubble episodes, but, contrary to the claims made in PWY (2008), they should not be taken as accurate estimates of bubble dates

If the price was indeed weakly explosive in the estimated bubble periods, this should be clear from estimating a standard ADF equation over the period in question. The results of this exercise are reported in Table 1. Notable are the facts that

a) The ADF(1) statistics are all negative over the estimated bubble periods, indicating a departure towards stationarity. In the case of the 2004 copper bubble, the statistic would allow rejection of the null of non-stationarity against the alternative of stationarity.

b) The ADF(1) statistics are positive in the pre-bubble periods for three of the four bubbles indentified by the PWY procedure consistent with the estimated bubble start coming after the actual start of the bubble.

Table 1
ADF statistics, before, during and after estimated bubble periods

	Estimated start	Estimated end	Length (days)	ADF(1) Before	ADF(1) Bubble	ADF(1) After
Soybeans	26/12/2007	06/03/2008	49	0.68	- 0.86	- 3.29
Copper	17/02/2004	05/04/2004	35	1.11	- 3.35	- 2.28
	11/04/2006	09/06/2006	40	1.45	- 2.31	- 1.06
	01/12/2008	31/12/2008	21	- 1.48	- 1.80	n.a.

The table gives ADF(1) statistics for the logarithmic prices over the *n* days prior to the estimated bubble (including the estimated start date), the bubble period itself and the *n* subsequent days (including the estimated end date) where *n* is equal to the number of days in the estimated bubble (forward recursive estimates) or 60 (backward recursive estimates).

Overall, the results reported in this section provide some evidence for possible explosive, bubble-type, behaviour in a number of important commodity futures markets over recent years. This evidence is strongest for copper followed by soybeans, but is absent in aluminium, crude oil, corn, nickel and wheat. Additionally, the analysis has posed important questions about the instruments currently advocated to discover the presence of bubbles. It is important that more effort be devoted to the refinement of these instruments prior to using them to make policy recommendations.

6. Futures speculation and futures investment

Transactors in futures markets are generally classified as either hedgers or speculators and the exchanges are seen as transferring price exposure from the hedgers to speculators in exchange for a risk premium. Speculators take a view, either on the basis of information or through the use of more or less sophisticated trend-spotting procedures, on the prospects of the particular commodities in which they take positions.

The CFTC requires brokers to report all positions held by traders with positions exceeding a specified size, and also to report the aggregate of all smaller ("non-reporting") positions. These positions are published in anonymous and summary form in the weekly CFTC *Commitments of Traders* (COT) reports. The CFTC classifies reporting traders as either "commercial" or "non-commercial" depending whether or not they have a commercial interest in the underlying physical commodity. Commentators, both academic and in the industry, routinely interpret commercial positions as hedges, non-commercial positions as large speculative positions and non-reporting positions as small speculative positions – see Edwards and Ma (1992, pp.15-17). Upperman (2006) provides a guide to trading on the basis of the COT reports.

In what follows, I distinguish between speculation in commodity futures and investments in commodities which use futures contracts, directly as indirectly, as investment vehicles. The distinction depends on the motivation of the actor in question. A speculator takes a view about the likely returns on a particular commodity future, say in crude oil, in relation to the riskiness of that return and takes a positive, zero or negative position accordingly. An investor takes a view on the effects of adding a commodity component to an investment portfolio on the basis of the risk-return characteristics of the overall portfolio. In practice, commodity investors take long positions and tend to track one of two widely quoted commodity futures indices. For this reason, they are generally referred to as "index investors". Index investments are most commonly implemented through swap structures negotiated through a number of banks and brokers referred to as "index providers".

Intermediate positions are possible between the speculative and index investment positions characterized above. One can think of an investor adding, for example, a long or short crude oil futures position to an equity or bond portfolio. I simplify the discussion by regarding all non-commercial positions which are not held by, or on behalf of, index investors as speculative positions.

It is widely perceived that, as the consequence of the increased diversity of futures actors and the increased complexity of their activities, the COT data may fail to fully represent futures market activity. Many institutions reporting positions as hedges, and which are therefore classified as commercial, are held by index providers to offset swap positions which, if held directly as commodity futures, would have counted as non-commercial. As the CFTC has itself noted "… trading practices have evolved to such an extent that, today, a significant proportion of long-side open interest in a number of major physical commodity futures contracts is held by so-called non-traditional hedgers (e.g. swap dealers) … This has raised questions as to whether COT report can reliably be used to assess overall futures activity …" (CFTC, 2006, p.2).

7. Index investment in commodity futures

The driving rationale of investment in commodity futures is that commodities may be considered as a distinct "asset class", and seen in this light, have favourable risk-return characteristics. The claim that commodities form a distinct asset class, analogous with the equity, fixed interest and real estate asset classes, supposes that the class is fairly homogeneous so that it may be spanned by a small number of representative positions. Specifically, this requires that the class have a unique risk premium which is not replicable by combining other asset classes – see Scherer and He (2008). Given this premise, the claim that commodities form an asset class which is interesting to investors relies on their exhibiting a sufficiently high excess return and sufficiently low correlations with other asset classes such that, when added to portfolio, the overall risk-return characteristics of the portfolio improve – see Bodie and Rosansky (1980), Jaffee (1989), Gorton and Rouwenhorst (2006), and for a summary, Woodward (2008).

Index funds set out to replicate a particular commodity futures index in the same way that equity tracking funds aim to replicate the returns on an equities index, such as the S&P500 or the FTSE100. The most widely followed commodity futures indices are the S&P GSCI and the DJ-UBS index (previously the DJ-AIG index). The S&P GSCI is weighted in relation to world production of the commodity averaged over the previous five years.[10] These are quantity weights and hence imply that the higher the price of the commodity future, the greater its share in the S&P GSCI. Recent high energy prices imply a very large energy weighting – 71% in September 2008. The DJ-UBS Index weights the different commodities primarily in terms of the liquidity of the futures contracts (i.e. futures volume and open interest), but in addition considers production. Averaging is again over five years. Importantly, the DJ-AIG Index also aims for diversification and limits the share of any one commodity group to one third of the total. The September 2008 energy share fell just short of this limit.[11] September 2008 weightings of these two indices are charted in Figure 9.

The sums of money invested by this third group of commodity investors may be very substantial. Using official non-public information, the CFTC estimated the notional value of positions held by index-funds to the $146bn at end December 2007as $146bn ($118bn on U.S. exchanges) rising to $200bn at the end of June 2008 ($161bn on U.S. exchanges). See CFTC (2008). Table 2 summarizes these data for the eleven commodities covered in the CFTC's special call on commodity swap and index providers, reported in CFTC (2008).[12] Of the $161bn of commodity index business in U.S. markets at the end of June 30 2008,

[10] http://www2.goldmansachs.com/gsci/#passive
[11] http://www.djindexes.com/mdsidx/index.cfm?event=showAigIntro
[12] Twelve contracts since wheat is traded on both the Chicago Board of Trade and the Kansas City Board of Trade.

approximately 24% percent was held by index funds, 42% by institutional investors, 9% by sovereign wealth funds and the remaining 25% by other traders (CFTC, 2008). The table also gives the shares of the index funds' net positions in total open interest. These average 26%-27%, but are much higher for copper, crude oil, wheat, live cattle and lean hogs.

Table 2
Index Fund Values and Shares

	31 December 2007		30 June 2008	
	$bn	Share	$bn	Share
Crude oil	39.1	31.1%	51.0	26.6%
Gasoline	4.5	22.9%	8.0	23.9%
Heating oil	7.8	34.8%	10.0	34.5%
Natural gas	10.8	16.8%	17.0	14.7%
Copper	2.8	49.9%	4.4	41.7%
Gold	7.3	15.9%	9.0	22.7%
Silver	1.8	15.5%	2.3	20.1%
Corn	7.6	25.8%	13.1	27.4%
Soybeans	8.7	26.1%	10.9	20.8%
Soybean oil	2.1	24.8%	2.6	21.7%
Wheat	9.3	38.2%	9.7	41.9%
Cocoa	0.4	11.3%	0.8	14.1%
Coffee	2.2	26.0%	3.1	25.6%
Cotton	2.6	33.0%	2.9	21.5%
Sugar	3.2	29.0%	4.9	31.1%
Feeder cattle	0.4	23.2%	0.6	30.7%
Live cattle	4.5	48.4%	6.5	41.8%
Lean hogs	2.1	43.6%	3.2	40.6%
Other U.S. markets	0.7		1.4	
Total (U.S. markets)	117.9	26.8%	161.5	25.8%
Non-U.S. markets	28.1		38.4	
Overall total	146.0		199.9	

Source: columns 1 and 3 CFTC (2008) valued at front position closing prices; columns 2 and 4, CFTC, *Commitment of Traders* reports. The wheat figures aggregate positions on the Chicago Board of Trade and the Kansas City Board of Trade. Open interest is valued at the closing price of the front contract. The aggregate share relates to positions on U.S. exchanges for the listed commodities. Except in the final two rows, figures relate only to positions held on U.S. exchanges.

In what follows, I report an estimate of the quantum of index investment across the range of commodity futures over the period 2006-08. A large literature relates changes in futures prices to the net positions of non-commercial traders, often identified as "large speculators", identified in the CFTC's weekly *Commitments of Traders* (COT) reports.

Commercial traders ("hedgers"), who are the counterparts of the non-commercials, are interpreted as not taking a view on prices. However, the increased complexity of the modern futures industry implies that the division of futures positions into commercial and non-commercial categories may have become arbitrary and that the standard COT net non-commercial positions variable is likely to be less informative in the current environment than it may previously have been.

Responding to these concerns, the CFTC has, starting in January 2006, issued a supplementary report for twelve agricultural futures markets which distinguish positions held by institutions identified as index providers. However, they have chosen not to provide this additional information for energy and metals futures, at least for the present, on the grounds that offsetting may involve taking positions on non-US exchanges and because many swap dealers in metals and energy futures have physical activities on their own account making it difficult to separated hedging from speculative activities – see CFTC (2006).

I have used this information in the CFTC's COT Supplementary Reports to construct a quantum index of total net index-related futures positions on U.S. agricultural markets from the start of 2006.[13] The resulting "Corazzolla index" is graphed in Figure 10.[14] The index rose sharply in the first five months of 2006 but was then broadly flat until the final months of 2007. A second sharp rise brought it to a peak at the end of April 2008. It then fell steadily (precipitately in September and October 2008) to reach a low in February 2009, at which point it was slightly beneath its value at 2006. There has subsequently been a modest recovery.

The Corazzolla index was calculated using data on index provider positions on agricultural futures markets, which is the only information that CFTC has made available on a consistent basis. This poses the question of the extent to which this index may also be taken as measuring total index provider positions. Since index composition only changes slowly (DJ-UBS) or not at all (S&P-GSCI) one might suppose the agricultural index to be representative of total index positions. From Table 2, we find that index positions on U.S. agricultural futures markets accounted for 36.6% of total index provider positions on U.S.

[13] Data are taken from the CFTC's *Supplementary Commitments of Traders Reports.* The markets covered are corn (maize), soybeans, soybean oil and soft wheat (Chicago Board of Trade), hard wheat (Kansas Cit Board of Trade), cocoa, coffee, cotton and sugar (New York Board of Trade) and feeder cattle, lean hogs and live cattle (Chicago Mercantile Exchange). Positions are measured in contracts. The index uses value weights as of 31/12/2007 to weight the net position (in contracts) on each exchange.

[14] The index is named for Elena Corazzolla who performed the calculations as part of her Trento laurea dissertation.

exchanges on 31 December 2007 and 34.9% on 30 June 2008. Weekly variations in this share are, however, more important than its trend evolution. Two factors indicate that the index may be less than fully representative of the total

a) Index provides now offer a variety of sub-indices with the result that index investment has assumed a greater judgemental component.
b) The CFTC figures relate to the futures positions taken by the index providers to offset their index exposure. Offsetting may be discretionary, in particular in relation to timing, even if index investment is not.

It is therefore difficult to make an *a priori* judgement on the representativeness of the Corazzolla index for total index positions. However, one might suggest that the test of the adequacy of the index is its ability to explain movements in commodity prices. This is the subject of section 8.

8. Index investment in commodity futures markets

In this section, I explore the results obtained by relating the Corazzolla index, discussed in section 7, to change in commodity prices over 2006-08. The econometric methodology employed in testing for the effects of index investment, or any other set of futures markets positions, is standard. Granger-causality analysis may be employed to relate futures returns at any specified level of temporal aggregation (daily, weekly, monthly etc.) to changes in positions. Consider the first equation of a bivariate VAR(*p*) (i.e. a *p*th order Vector AutoRegression) linking futures returns $\Delta \ln f_t$ to changes in positions Δx_t

$$\Delta \ln f_t = \alpha + \sum_{j=1}^{p} \beta_j \Delta \ln f_{t-j} + \sum_{j=1}^{p} \gamma_j \Delta x_{t-j} + u_t \qquad (1)$$

The Granger-causality test (strictly a non-causality test) is the standard Wald test $H_0 : \gamma_1 = \cdots = \gamma_p = 0$ against the alternative of its negation. The order p of the VAR is determined by testing down from a general specification employing a large value of *p*. Note that equation (1) excludes the current period value Δx_t so, while on the one hand there are no simultaneity issues which complicate inference, on the other hand. The test is silent with respect to contemporaneous causation. A favourable result from a Granger causality test establishes a *prima facie* case that there is a causal relationship between the two variables.

Table 3 gives the results of Granger-causality tests linking weekly logarithmic changes in the Corazzolla measure of net index positions on U.S. agricultural futures markets and logarithmic changes in the seven commodity futures prices already considered in section 5 above. The first two columns of the table ask whether the changes in the futures prices Granger-cause changes in the Corazzolla index while the final two columns reverse the question and ask whether index positions Granger-cause changes in the futures prices. In columns 1 and 3 I take $p = 3$ (tested down from an initial value of $p = 6$) while in column 4 I reduce to $p = 2$, except in the case of copper, where this reduction is rejected by the Wald statistic (not reported). A distributed lag of length 3 is always required in explaining changes in the Corazzolla index, but it is possible to reduce the length of the futures price distributed lag to one (column 2).

Table 3
Granger-causality tests

Null hypothesis	"Row variable Granger-non-causes Net Index Positions"		"Net Index Positions Granger-non-cause row variable"	
Model Statistic	ADL(3,3) $F_{3,159}$	ADL(3,1) $F_{1,161}$	ADL(3,3) $F_{3,159}$	ADL(2,2) $F_{2,161}$
Crude oil (NYMEX, WTI)	1.01 [38.9%]	0.04 [84.6%]	**3.35** **[2.06%]**	**6.07** **[0.03%]**
Aluminium (LME, 3 month)	0.29 [83.6%]	0.10 [75.7%]	2.52 [6.02%]	**4.09** **[1.85%]**
Copper (LME, 3 month)	1.29 [27.9%]	0.01 [94.2%]	**2.96** **[3.40%]**	-
Nickel (LME, 3 month)	0.45 [71.5%]	0.35 [55.4%]	1.39 [24.8%]	2.51 [8.46%]
Wheat (CBOT, 1st nearby)	**2.84** **[4.00%]**	**7.41** **[0.72%]**	1.13 [33.9%]	0.99 [37.3%]
Corn (CBOT, 1st nearby)	**3.30** **[2.20%]**	**9.27** **[0.03%]**	1.28 [28.3%]	2.37 [9.70%]
Soybeans (CBOT, 1st nearby)	1.72 [16.4%]	**4.94** **[2.76%]**	0.56 [64.0%]	0.96 [38.4%]
Dollar exchange rate index	1.99 [11.7%]	**5.56** **[1.95%]**	0.99 [40.0%]	-
Equity index (average S&P and Hang-Seng)	**2.71** **[4.73%]**	**-**	1.27 [28.6%]	2.42 [9.23%]

The table reports Granger-non-causality tests in relation to logarithmic changes in the Net Index Positions variable, defined in the text, and logarithmic changes in the seven futures prices under consideration and also an index of the value of the U.S. dollar. In columns 2 and 4, the tests are performed on restricted versions of the ADL(3,3). For copper and the exchange rate index, no test is reported in column 4 since the implied restrictions are rejected. Data are weekly from 31/01/2006 (columns 1 to 3) or 24/01/2006 (column 4) to 31/03/2009. Tail probabilities are given parenthetically. Bold face indicates rejection of the null hypothesis of Granger-non-causality at the 5% level (i.e. "acceptance" of Granger-causality).

Looking initially at the first two columns, we see that changes in the Corazzolla index are Granger-caused by changes in the three agricultural futures prices (most evidently, that of corn), but there is no evidence of a Granger-causal link either from the crude oil price or from the non-ferrous metals prices. This is consistent with the view that the Corazzolla index does indeed represent positions in agricultural futures markets and may not be representative of positions in energy and metals markets. However, the test results reported in columns 3 and 4 tell a different story: changes on the Corazzolla index Granger-cause changes in crude oil, aluminium and copper futures prices as well as changes in wheat futures prices but they do not Granger-cause changes in corn or soybean futures prices. The fact that the index does have predictive power for energy and non-ferrous metals markets demonstrates both that it is to some extent representative of index positions in non-agricultural futures markets and that the changes in these positions have been associated with some price impact.

Granger-causality tests establish the presence of a causal link (at the specified level of confidence) between the posited causal variable and the variable of interest, but do not imply that this link is direct. Specifically, there is the worry that the variable of interest and the posited causal variable may be jointly caused by some third variable, may be intermediated by such a variable or may simply exhibit a high sample correlation with this third variable. There are three variables that cause particular concern –the U.S. dollar exchange rate, levels of economic activity and the physical supply and demand conditions in the markets in question.

I have constructed an index of the value of the U.S. dollar against a basket of major currencies[15] for conformable dates with those of the COT Supplementary Reports. This index is graphed in Figure 11 from which it is clear that the movements are inverse those of the Corazzolla net index positions index. The correlation between the two indices is – 0.76 in levels and – 0.29 in differences The penultimate row of Table 3 reports that changes in the U.S. dollar exchange rate Granger-cause changes in index positions, consistent with the view that dollar-based investors take positions in commodity index investments to protect themselves against possible dollar depreciation. (There is no evidence that index investments Granger-cause changes in the value of the dollar consistent with the fact that the forex flows are an order larger than commodity index investments).

Indices of economic activity are not available at higher than monthly frequencies. It would be possible to interpolate monthly indices to a weekly or daily basis but such a

[15] The Eurozone, Japan, U.K., Switzerland, Australia and Canada with weights 4:4:1:1:1:1, Data source: European Central Bank.

procedure runs the danger of allowing commodity futures returns to depend on measures of activity relating to the future. A further problem is that commodity futures prices reflect anticipated level of economic activity and hence tend to lead actual changes in activity. As an alternative, I include returns on stock exchange indices, which are available at the weekly frequency and which also reflect growth expectations rather than growth itself. Specifically, I look at the returns on the Standard and Poors 500 index of U.S. equity prices $\Delta\ln SP_t$ and, to reflect the importance of Chinese growth, returns on the Hang Seng index $\Delta\ln HS_t$. Use of the average equity return $\Delta \ln EQ_t = \frac{1}{2}\left[\Delta \ln SP_t + \Delta \ln HS_t\right]$ appears generally acceptable in place of the two original returns. The final row of Table 3 shows that changes in equities prices Granger-cause changes in index-based investments by not *vice versa*.

Thirdly, market analysts typically analyze commodity price changes primarily in terms of the supply-demand balance for the commodity. To the extent that these fundamentals are correlated across commodities, they may also be correlated with index investments. If this is the case, index investors, along perhaps with traditional speculators, would be the transmission mechanism whereby information on market fundamentals become impounded in futures prices. The final row of Table 3 gives the results of Granger causality tests which show that equity returns Granger cause changes in index positions but not *vice versa*.

In a number of markets, exchange warehouse stocks provide a convenient measure of the state of market fundamentals, although it is never clear how representative these stock levels are of total availability of the commodity. In practice, these variables do not contributed to the explanation of commodity returns once equity returns and index investment are included in the equations.

The second important qualification with regard to Granger-causality analysis is that it is silent with respect to contemporaneous correlation. This is important in the current context since both liquidity and information al considerations suggest that index-based transactions, in common with all other futures market transactions, will impact prices at the time of the transaction. Granger-causality analysis will capture this impact only in so far as past value of index-based positions predict current changes in these positions. Test power may therefore be weak. At the same time, week-on-week changes in index-based positions may reflect price movements within the week in question (particularly since these are offsetting positions taken by the index providers) establishing the possibility of bidirectional causality.

The correlations between the contemporaneous price changes and change in the net index positions are high for crude oil (0.412), aluminium (0.517) and copper (0.460). The cross-plots are graphed in Figures 12, 13 and 14 respectively. (The crude oil correlation rises to 0.469 if the post-Lehman week ending 23/09/2008 is omitted). The high correlations for these three commodities suggest that contemporaneous links should be ignored. The correlations (not illustrated) for nickel and the three agricultural commodities are much lower (0.25 to 0.31).

I explore two approaches to analyzing the impact of changes in index positions on futures prices taking into account the contemporaneous interactions. In both cases, I also control for market fundamentals. In the first case, I suppose that all effects are contemporaneous and estimate equations of the form

$$\Delta \ln f_t^j = \alpha^j + \beta^j \Delta \ln NIP_t + \gamma^j \Delta \ln EQ_t + u_t^j \qquad (3)$$

where f_t^j is the *j*th futures price, NIP_t is the Corazzolla index of net index positions, $\Delta \ln EQ_t$ is the equity returns index defined above and measured contemporaneously with the futures prices. The seven equations are estimated by instrumental variables (IV) taking the change in net index positions $\Delta \ln NIP_t$, the change in equities prices $\Delta \ln EQ_t$ and the change in warehouse stocks to be either endogenous or measured with error. The instrumental variables are implied by the Granger-causality tests reported in Table 3: three lags each of $\Delta\ln NIP$, three lags each of $\Delta\ln NIP$, $\Delta\ln EQ$, $\Delta\ln ER$ and the *VIX* volatility index and the lagged returns on wheat, corn and soybean futures and the lagged returns on wheat, corn and soybean futures. Estimation results are reported in Table 4.[16]

The $\hat{\beta}$ coefficients of the change in net index positions are large for crude oil and the three non-ferrous metals, although they are imprecisely determined. The Sargan tests reject instrument validity only for aluminium.[17] By contrast, the $\hat{\beta}$ coefficients do not differ significantly from zero for the three grains. Using the system SUR (Seemingly Unrelated Regressions) estimator, joint restriction of these three coefficients to zero is not rejected for

[16] I also explored inclusion of the contemporaneous change in the dollar exchange rate index $\Delta \ln ER_t$ discussed above and, for crude oil and the three metals, changes in deliverable stocks (Cushing for WTI, LME warehouses for the three metals). The coefficients of these variables were non statistically significant, although the exchange rate coefficient was generally significant in the absence of the variable $\Delta \ln EQ_t$. This latter variable is also dollar-denominated and so it is possible that exchange rate effects enter via this route. The restriction of the coefficients of $\Delta \ln SP_t$ and $\Delta \ln HS_t$ to be equal is always satisfied. The results reported in Table 4 are not sensitive to relaxation of this constraint or inclusion of additional controls.

[17] This appears to be due to lagged changes in the Corazzolla index affecting returns.

the three grains but is rejected for the metals.[18] It is notable that the Corazzolla index, constructed on the basis of agricultural futures markets, appears to explain movements in industrial commodity prices better than it does movements in agricultural prices. This lends support to the view that the Corazzolla index may be taken as representing total index-related investments, not just those in agriculture. On this view, the high coefficients for the non-agricultural commodities reflect the greater presence of these investments in energy and metals futures markets – see Table 2.

Table 4
Instrumental variables estimates of equation (3)

Coefficient / Variable	$\hat{\beta}$ / $\Delta \ln NIP_t$	$\hat{\gamma}$ / $\Delta \ln EQ_t$	Standard error	Instrument validity $\chi^2(13)$	Joint significance $\chi^2(3)$
Crude oil	0.702 (1.76)	1.300 (3.59)	5.20%	8.15 [83.4%]	
Aluminium	0.645 (2.91)	0.480 (2.38)	2.90%	26.6 [1.43%]	10.6 [1.4%]
Copper	0.863 (2.36)	1.068 (3.21)	4.79%	11.9 [53.5%]	
Nickel	1.126 (2.41)	0.413 (0.97)	6.12%	19.3 [11.4%]	
Wheat	0.584 (1.51)	0.490 (1.30)	5.41%	10.9 [61.8%]	3.01 [38.9%]
Corn	0.371 (0.91)	0.469 (1.27)	5.32%	15.2 [29.8%]	
Soybeans	0.441 (1.47)	0.501 (1.85)	3.91%	16.6 [21.6%]	

The table reports Instrumental Variables estimates of the return on the row *j* futures price $\Delta \ln f_t^j$ on a constant (coefficient $\hat{\alpha}$ not reported), and the three column variables (two for wheat, corn and soybeans) as specified in equation (3) in the text. Both the net index positions $\Delta \ln NIP_t$ and the change in equity values $\Delta \ln EQ_t$ are treated as endogenous. The instruments are three lags each of $\Delta\ln NIP$, $\Delta\ln EQ$, $\Delta\ln ER$ and *VIX* and the lagged returns on wheat, corn and soybean futures. The $\chi^2(3)$ tests for joint significance test exclusion of $\Delta \ln NIP_t$ from the three non-ferrous metals and grains equations respectively in the model estimated by SURE. Data are weekly from 31/01/2006 to 31/03/2009. Tail probabilities are in square "[.]" parentheses and *t* statistics in round "(.)" parentheses.

The second approach I explore is based on the efficient markets view that only innovations should affect asset price returns. A standard methodology is that of regressing changes in futures prices on measures of trading activity. Finance theory implies that these measures only be associate with a price impact to the extent that the trading activity conveys

[18] Since the equations contain the same regressors, unrestricted SURE gives the same estimates as the IV estimates reported in the first two columns of the table.

information into the market. Informed traders may attempt to disguise themselves as uninformed traders, or simply to hide behind the activities of uninformed traders. This may make it difficult for counterparties to accurately infer whether a particular trade is or is not informed. However, any price impact from uninformed trades should be transient.

Illiquidity may counteract information considerations. In an order book trading system, such as that approximated by commodity futures markets, large transactions will inevitably push into the order book and hence have at least a transient price impact. If a market becomes unbalanced, as when index-based investment creates a predominance of buy-side interest, counterparties are likely to require an enhanced risk premium if they are to take on the off-setting short exposure. This can create a situation analogous to a speculative bubble in which potential counterparties are disinclined to take short positions in the knowledge that index-based buying may push prices to higher levels. In this way, the effects of index-based investment may become observationally equivalent to those of trend-following extrapolative expectations.

This discussion motivates examination of equations of the form

$$\Delta \ln f_t^j = \alpha^j + \sum_{i=0}^{p} \beta_i^j \hat{\varepsilon}_{t-i} + \sum_{i=0}^{1} \gamma_i^j \hat{\nu}_{t-i}^j + u_t^j \tag{4}$$

where the $\hat{\varepsilon}_t$ are the residuals from the regression of $\Delta \ln NIP_t$ on the complete set of variables used as instruments in the estimates reported in Table 4 and the $\hat{\nu}_t$ are the residuals from the regression of $\Delta \ln EQ_t$ on three lags of itself and three lags of the *VIX* volatility index.[19]

Estimation results are given in Table 5. For the three grains, it is possible to set the entire equity return distributed lag to zero – see bottom panel. Using these restricted estimates fro the grains, the estimated lead coefficient $\hat{\beta}_0$ on the net index investment variable differs significantly from zero for all seven commodities. In all seven cases, the sum of the estimated β coefficients exceeds the initial coefficient β_0 although this sum is less precisely determined than the initial impact The market efficiency condition (final column), which sets the coefficients of all the lagged innovations to zero, is rejected only for crude oil and copper. These results therefore both confirm the claim that index investment impacted the range of commodity futures prices and, at the same time, contradict a market illiquidity interpretation

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[19] A Wald block exogeneity test on the remaining nine variables in the equation for $\Delta \ln NIP_t$ indicated that these could be dropped from this equation: $F_{9,150} = 0.51$ with tail probability 86.7%.

of the effects of index investment and instead are consistent with the view that these transactions convey information.

Table 5
Innovation regression results

Coefficient / Variable	$\hat{\beta}_0$ / $\hat{\varepsilon}_t$	$\sum_{j=0}^{5}\hat{\beta}_j$ / $\hat{\varepsilon}_t \ldots \hat{\varepsilon}_{t-5}$	$\hat{\gamma}_0$ / $\hat{\nu}_t$	$\sum_{j=0}^{5}\hat{\gamma}_j$ / $\hat{\nu}_t,\ldots,\hat{\nu}_{t-5}$	R^2 and Standard error	Wald test $\gamma_1 = \ldots = \gamma_5 = 0$, $\beta_1 = \ldots = \beta_5 = 0$; $F_{10,152}$
Crude oil	0.905 (3.25)	2.126 (3.24)	0.479 (3.55)	0.989 (2.91)	0.279 4.93%	2.47 [0.91%]
Aluminium	0.785 (4.66)	1.233 (3.10)	0.165 (2.02)	0.475 (2.31)	0.240 2.98%	1.43 [17.2%]
Copper	0.894 (3.55)	2.600 (4.37)	0.247 (2.01)	0.470 (1.53)	0.233 4.46%	2.00 [3.74%]
Nickel	0.847 (2.42)	1.433 (1.74)	0.394 (2.32)	1.187 (2.78)	0.174 6.19%	1.70 [8.53%]
Wheat	0.681 (2.25)	1.836 (2.57)	0.126 (0.86)	0.166 (0.45)	0.152 5.36%	1.69 [8.81%]
Corn	0.913 (3.05)	0.730 (1.03)	0.134 (0.93)	0.701 (1.91)	0.136 5.31%	1.11 [31.5%]
Soybeans	0.422 (1.91)	0.673 (1.29)	0.197 (1.84)	0.638 (2.37)	0.145 3.91%	1.38 [19.5%]
						$F_{5,158}$
Wheat	0.759 (2.62)	2.012 (2.99)	-	-	0.101 5.42%	1.88 [10.1%]
Corn	0.954 (3.36)	1.186 (1.80)	-	-	0.101 5.31%	1.32 [25.7%]
Soybeans	0.501 (2.37)	1.122 (2.29)	-	-	0.091 3.95%	1.98 [8.52%]

The table reports OLS estimates of the return on the row j futures price $\Delta \ln f_t^j$ on a constant (coefficient $\hat{\alpha}$ not reported), a distributed lag of the innovations $\hat{\varepsilon}_t \ldots \hat{\varepsilon}_{t-5}$ from the Net Index Positions equation, the log change in the exchange rate index and the innovation in the log of warehouse stocks (not wheat, corn or soybeans). See equation (4). Data are weekly from 31/01/2006 to 31/03/2009. Tail probabilities are in square "[.]" parentheses and t statistics in round "(.)" parentheses.

Overall, the Granger-causality tests reported in Table 3 and the regression results reported in Tables 4 and 5 confirm that index-based investment in commodity futures has a price impact, and that this impact is permanent. The Corazzolla measure of index-based investment, constructed from the CFTC's Supplementary COT Reports, is based solely on data on positions in U.S. agricultural futures markets. It is therefore remarkable that this measure explains movements in energy and metals futures prices better than it does movements in the agricultural futures prices themselves. It is known that index-based investments tend to concentrate in energy and metals markets and these results therefore encourage the contention that the Corazzolla index is representative of changes in the entire range of commodity futures markets.

The results appear to favour an informational explanation of the price impact of index-based investment over a liquidity-based explanation. This is despite the fact that, at least according to its proponents, index-based investment in commodities is motivated by portfolio diversification rather than informational considerations. This suggests that index-based investors may possess information on the likely prospects of the entire "commodity asset class" and that their transactions impound this information in the various futures prices entering the indices.

9. Extent of price impact

We can use the estimated price impacts from Tables 4 and 5 to estimate the extent to which index investment may have raised commodity futures prices. Table 6 reports the estimates based on the results reported in Table 5 but with the lagged coefficients set to zero in line with the test results reported in the final column of the table.[20] The estimated price impacts, presented in the table as annual averages, are proportional to the estimated β_0 coefficients. The table also gives the maximum extent to which prices were increased. The final three columns of the table confront the counterfactual prices with the maximum prices over the 2006-08 period. Figures 15-21 chart actual and counterfactual prices.

Table 6
Estimated average price impact

	Average impact				Maximum impact
	2006	2007	2008h1	2008h2	
Crude oil	6.4%	5.4%	13.6%	3.4%	16.1%
Aluminium	6.8%	5.8%	14.3%	3.5%	17.0%
Copper	6.3%	5.3%	13.4%	3.3%	15.8%
Nickel	5.4%	4.6%	11.5%	2.8%	13.6%
Wheat	6.1%	5.1%	12.9%	3.2%	15.3%
Corn	6.8%	5.8%	14.4%	3.6%	17.1%
Soybeans	3.8%	3.2%	8.1%	2.0%	9.6%

Estimated annual price impact of index-based investment in commodity futures based on the estimated coefficients in Table 5 but with restrictions imposed as described in the text.

[20] For crude oil and copper only the lagged β coefficients are set to zero.

The estimated price impacts are remarkably uniform across all seven commodities considered at around 5% to 8% on average but rising to 10%-17% over the initial six months of 2008 with soybeans showing increases of only around half of this level. Overall, it is possible to judge these effects as modest through 2006 and 2007 but relatively severe in the first half of 2008. Over these six months it is reasonable to conclude that index-based investment generated a bubble in commodity futures prices even if the use of term bubble is somewhat different from that currently being considered in the econometric literature.

10. Conclusions

In this paper, I have attempted to quantify the extent to which high commodity futures prices over 2006-08 resulted either from bubble behaviour, possibly resulting from extrapolative expectations on the part of CTAs and other traditional speculators, and index-based investment in commodity futures. I find limited evidence of speculative bubbles of this type. Contrary to the findings of Phillips and Yu (2009), there is no evidence of the behaviour characteristic of extrapolative bubbles in the crude oil market. However, there is such evidence for the copper market over the same period.

In that context, I also note that the bubble detection procedure proposed by Phillips, Wu and Yu (2008) raised a number of methodological issues which to be resolved. In particular, I suggest that the start and end bubble dates generated by their procedure should be interpreted as the dates at which the econometrician can be sure that a bubble has started or ended and not, as they suggest, the dates at which the bubble did start or end.

Contrary to the negative results obtained for speculative bubbles, the results reported in sections 8 and 9 of the paper indicate that index-based investment in commodity futures may have been responsible for a significant and bubble-like increase of energy and non-ferrous metals prices, although the estimated impact on agricultural prices. These estimates derive from use of an index, developed in conjunction with Elena Corazzolla, of index-based investments in U.S. agricultural futures markets using data from the CFTC's Supplementary Commitments of Traders reports. Although only a modest proportion of total index-based investment goes to agricultural futures, this measure may nevertheless be representative of the entirety of index-based investment if the proportions in which these investments are distributed across markets is formulaic. Perhaps remarkably, the measure proposed by Corazzolla, and previously employed in Gilbert (2009), explains changes in energy and non-ferrous metals prices as well as in agricultural futures prices.

The estimated price impact of index-based investment on energy and metals prices is of the order of 5%-10% but rises to 15% in the first half of 2008. When oil peaked in July at over $140/bl, the price in the absence of index-based investment might have been slightly around $130/bl. When three months copper was at $8200/ton in April 2008, it would have been at $7400 absent index-based investment. According to these estimates, it would be incorrect to argue that high oil, metals and grains prices were driven by index-based investment but index investors do appear to have amplified fundamentally-driven price movements.

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Figure 1: PWY recursive ADF(1) statistics, corn

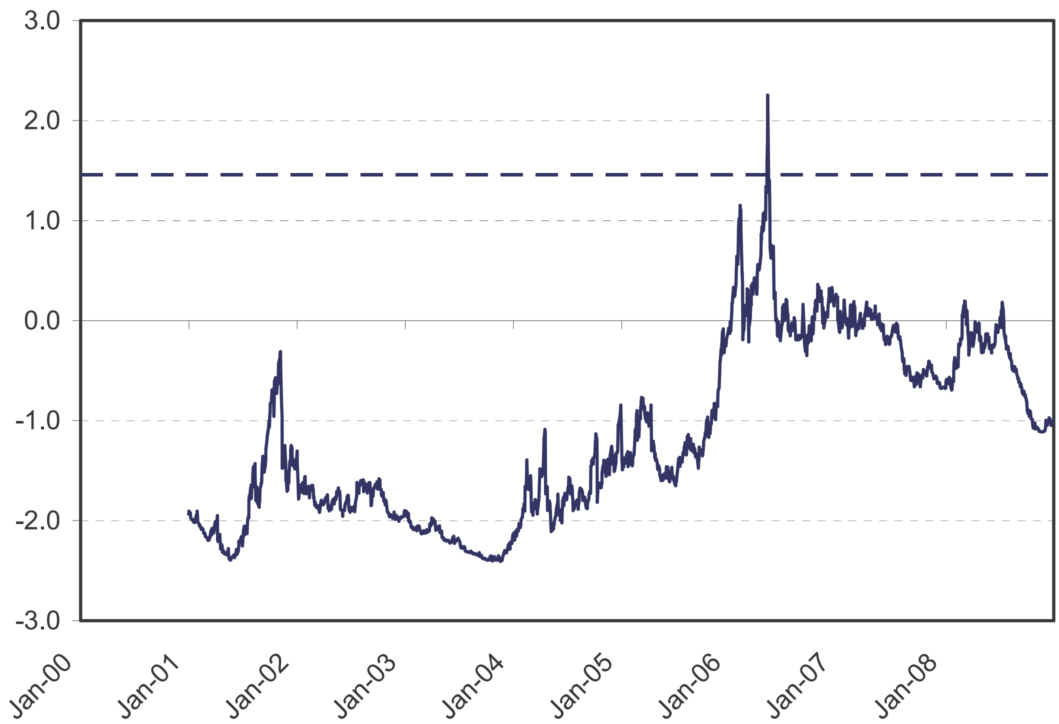

Figure 2: PWY recursive ADF(1) statistics, aluminium

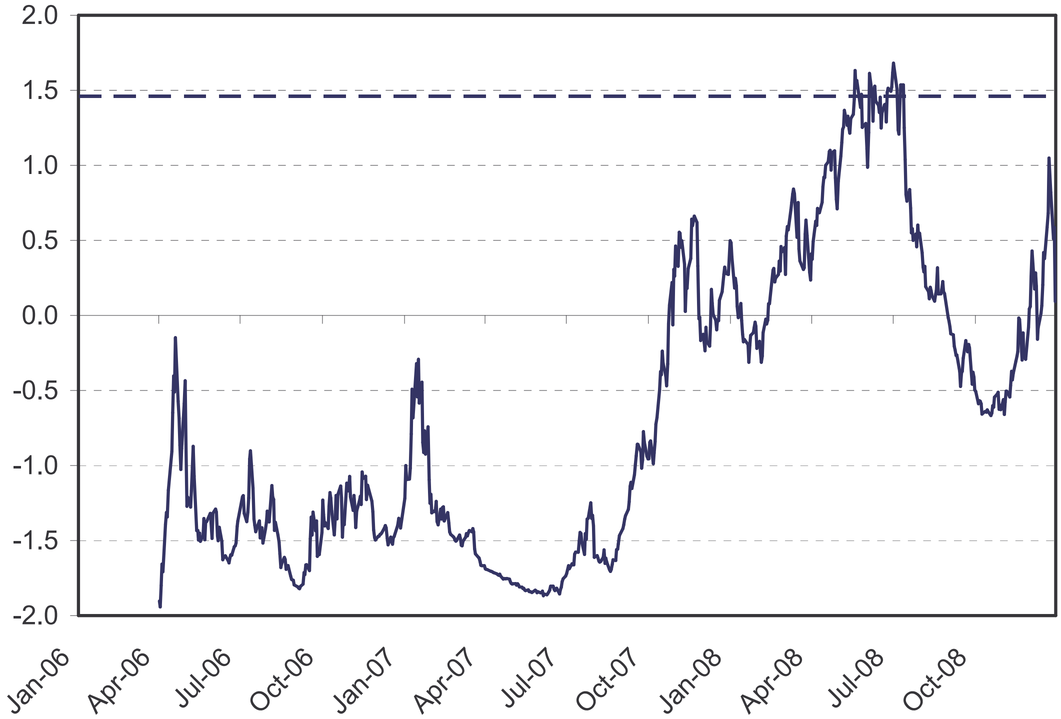

Figure 3: PWY recursive ADF(1) statistics, WTI crude oil

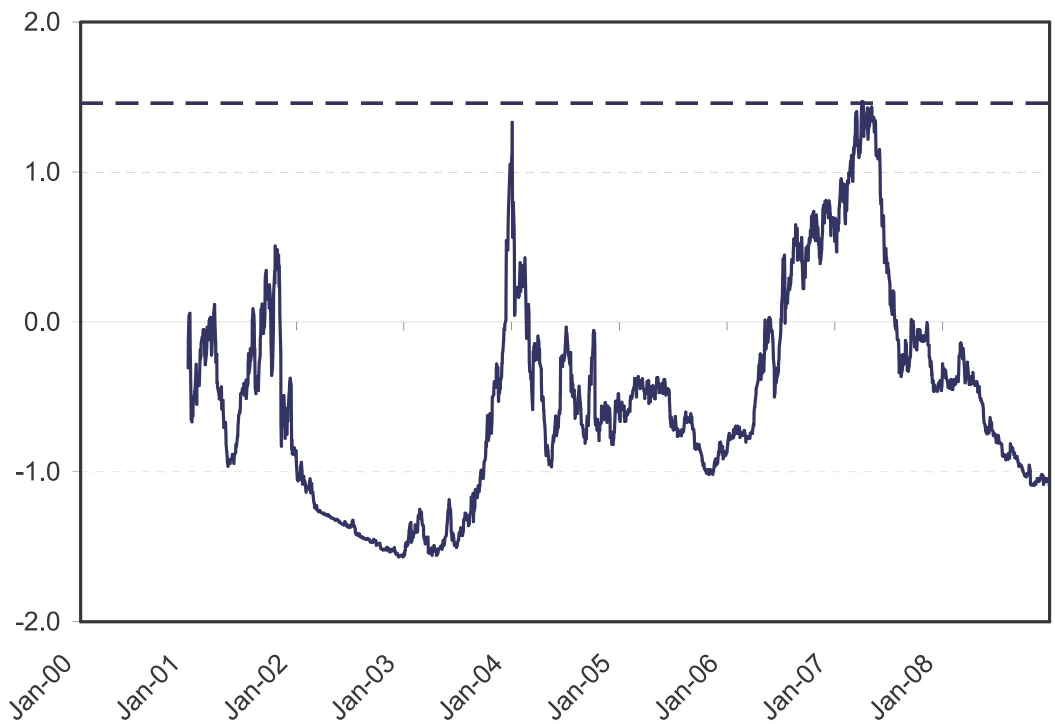

Figure 4: PWY recursive ADF(1) statistics, nickel

Figure 5: PWY recursive ADF(1) statistics, wheat

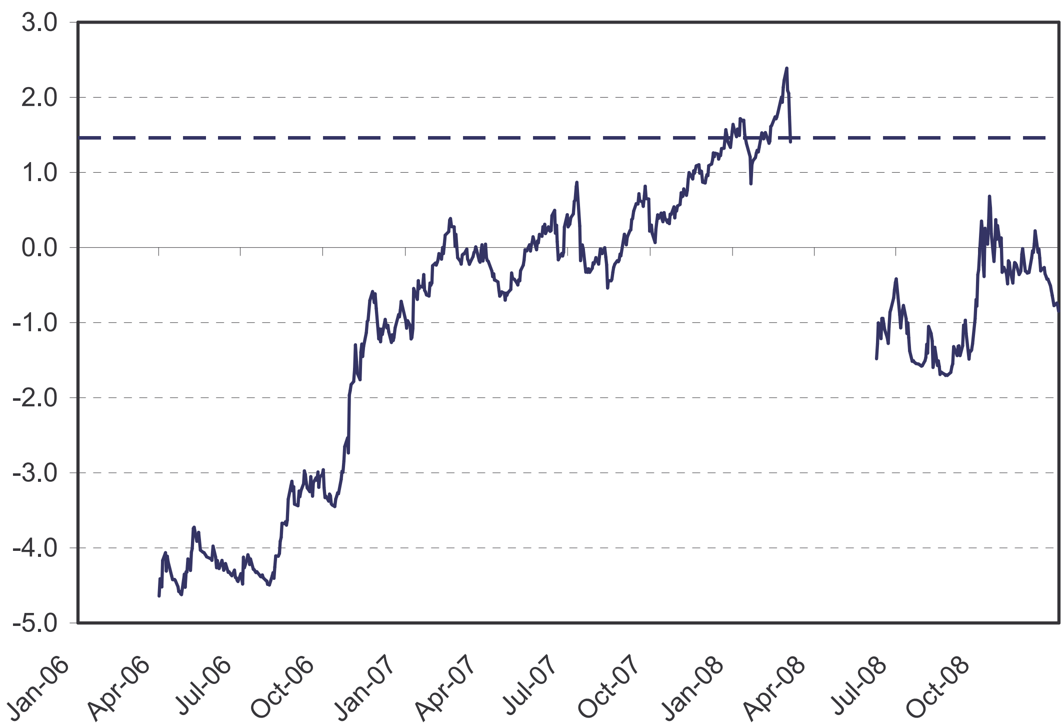

Figure 6: PWY recursive ADF(1) statistics, soybeans

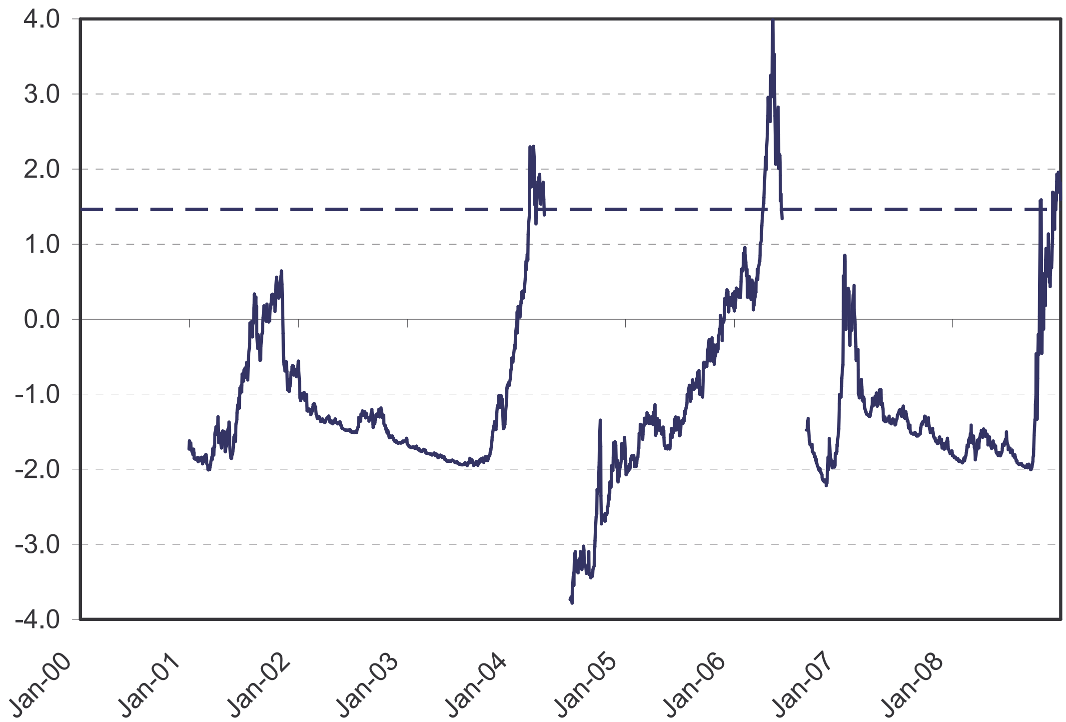

Figure 7: PWY recursive ADF(1) statistics, copper

Figure 8: Copper "bubble periods"

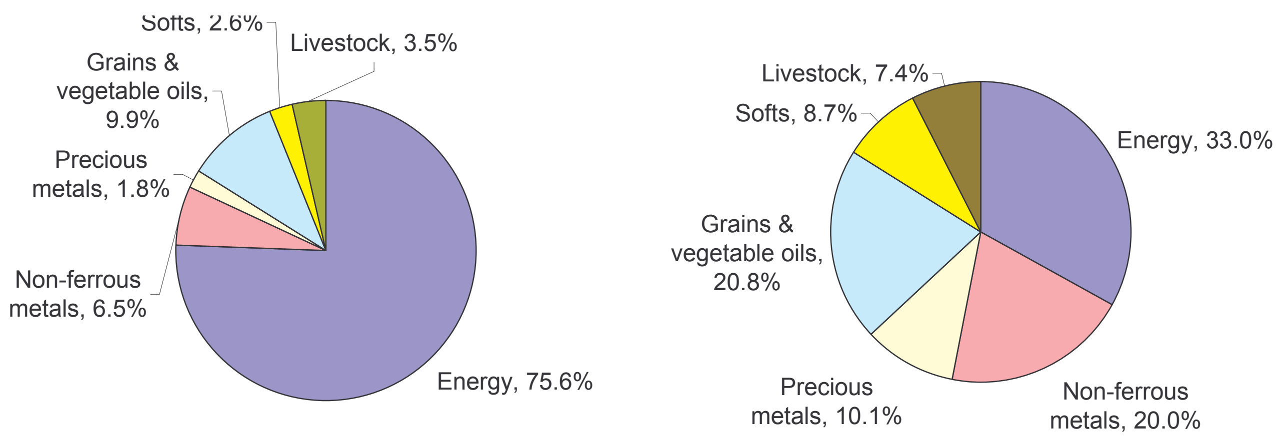

Figure 9: Commodity Composition, S&P GSCI (left) and DJ-UBS Commodity Indices, September 2008

Figure 10: Quantum index of net positions taken by index providers on U.S. agricultural futures markets (03/01/2006 = 100)

Figure 11: Index of the value of the U.S. dollar against a basket of currencies (03/01/2006 = 100)

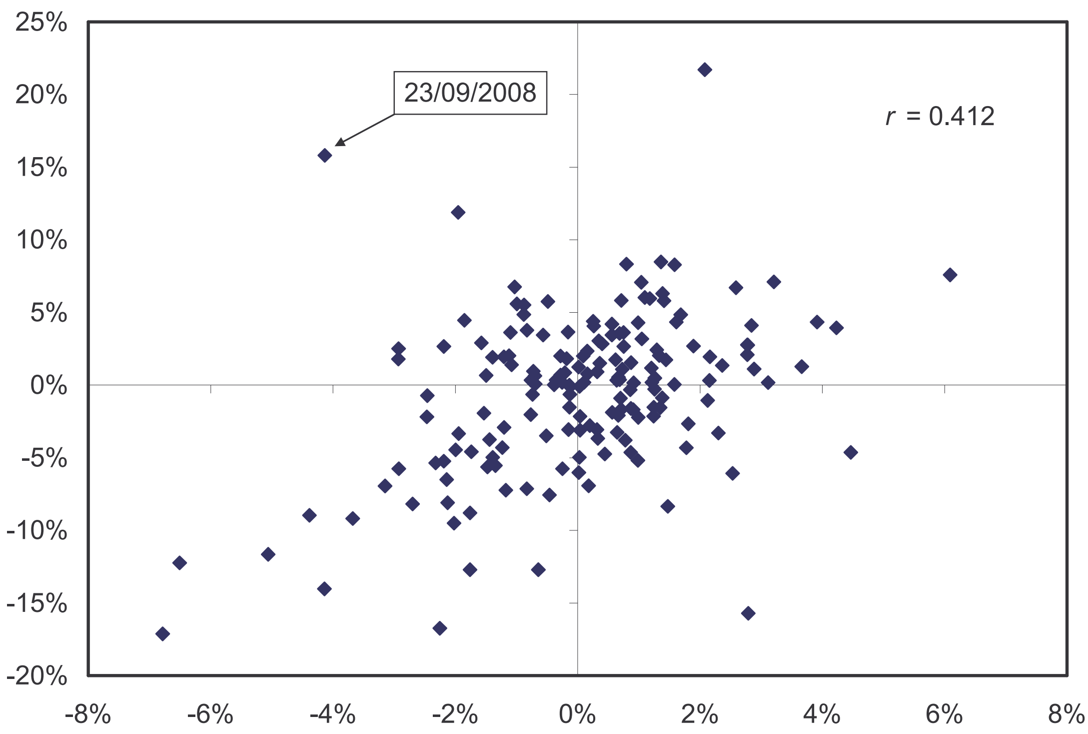

Figure 12: Cross-plot, weekly changes in NYMEX WTI front contract against change in net index positions, 10/01/2006 – 31/03/2009

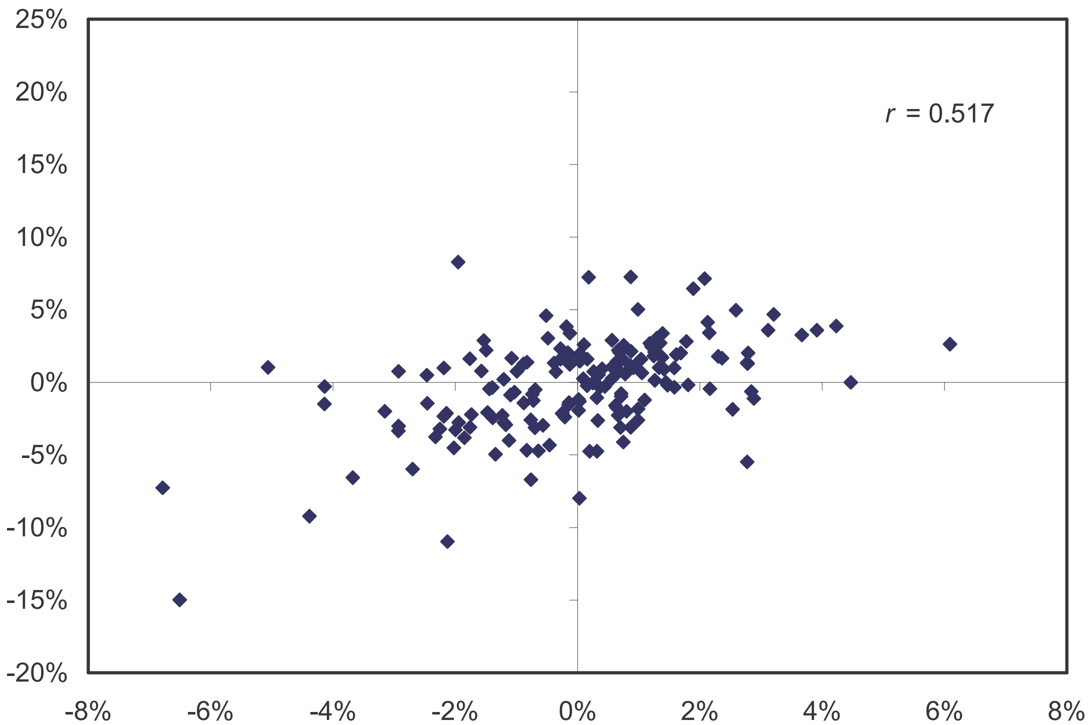

Figure 13: Cross-plot, weekly changes in LME 3 month aluminium settlement price against change in net index positions, 10/01/2006 – 31/03/2009

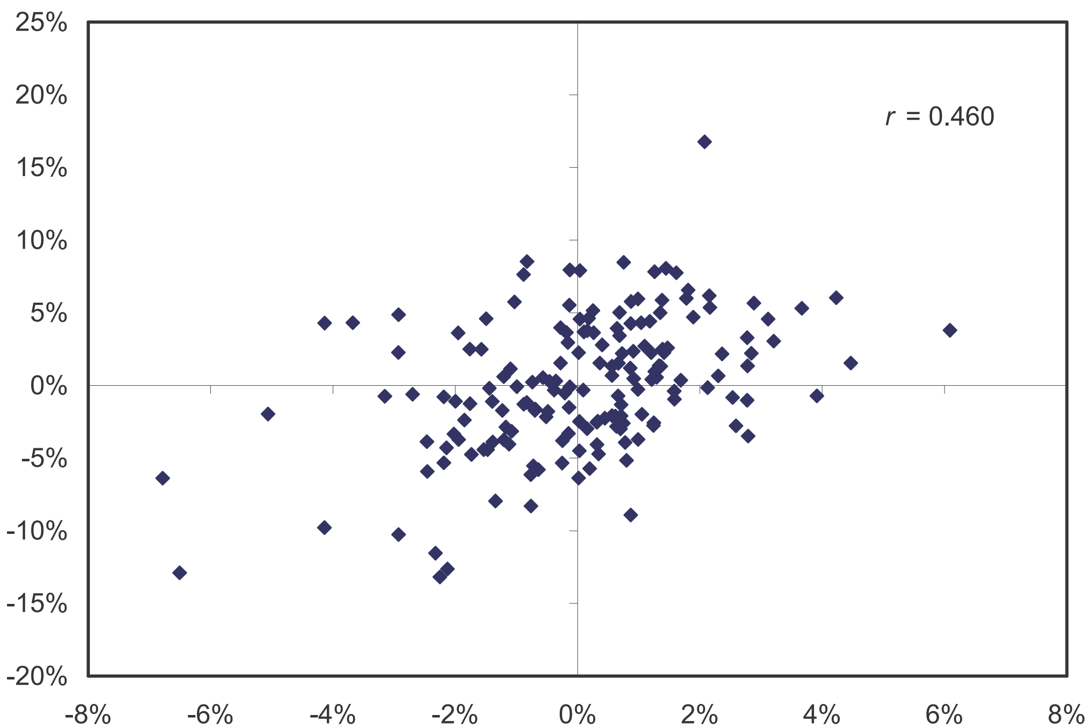

Figure 14: Cross-plot, weekly changes in LME 3 month copper settlement price against change in net index positions, 10/01/2006 – 31/03/2009

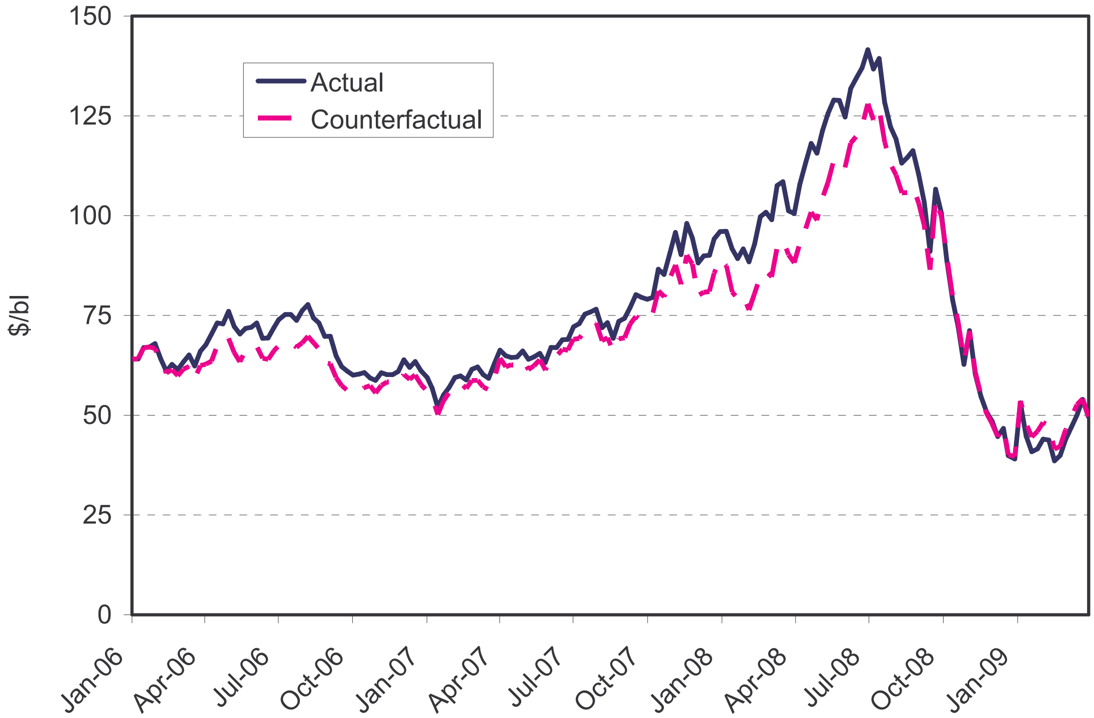

Figure 15: Actual and counterfactual WTI crude oil prices

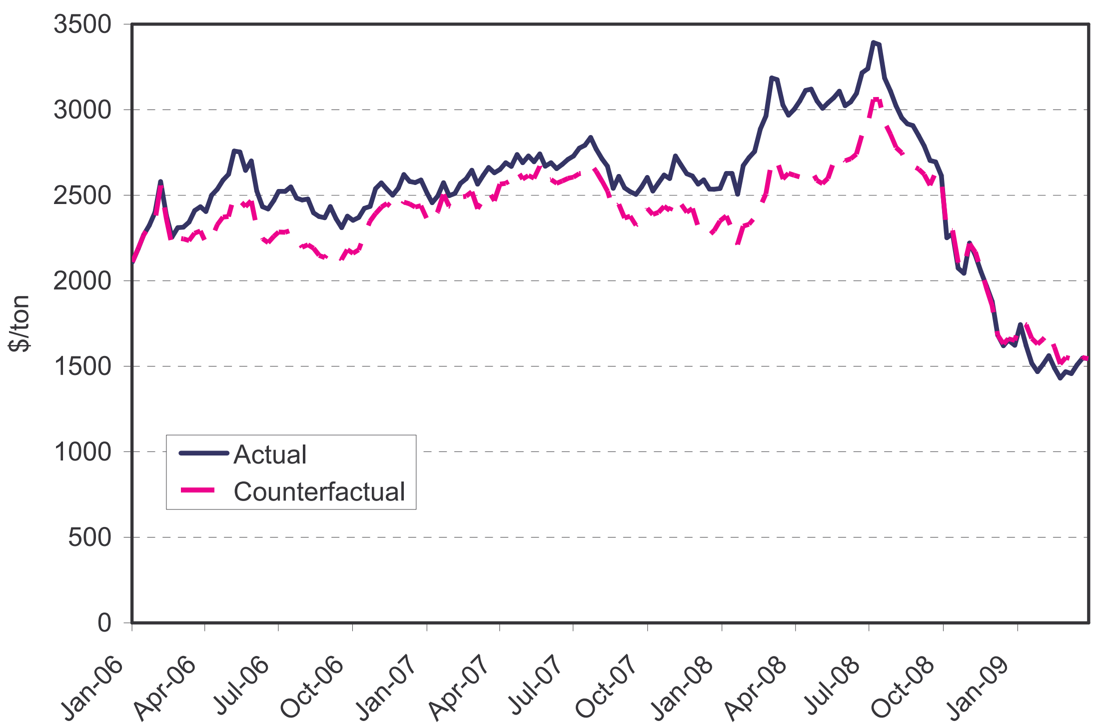

Figure 16: Actual and counterfactual LME aluminium prices

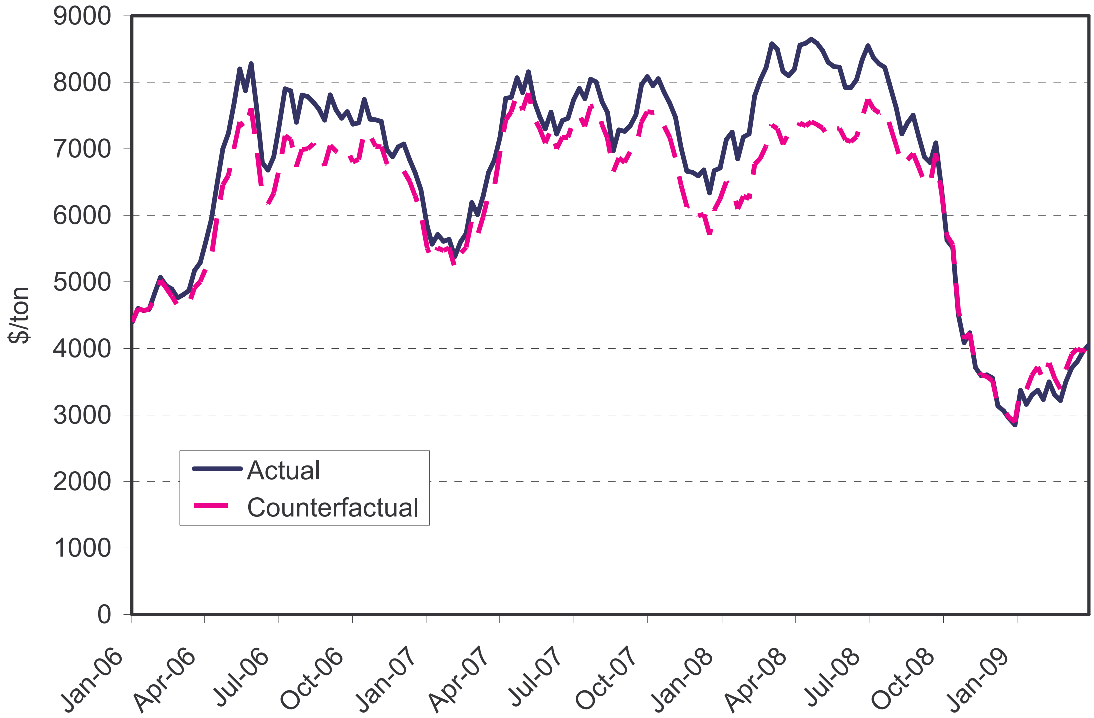

Figure 17: Actual and counterfactual LME copper prices

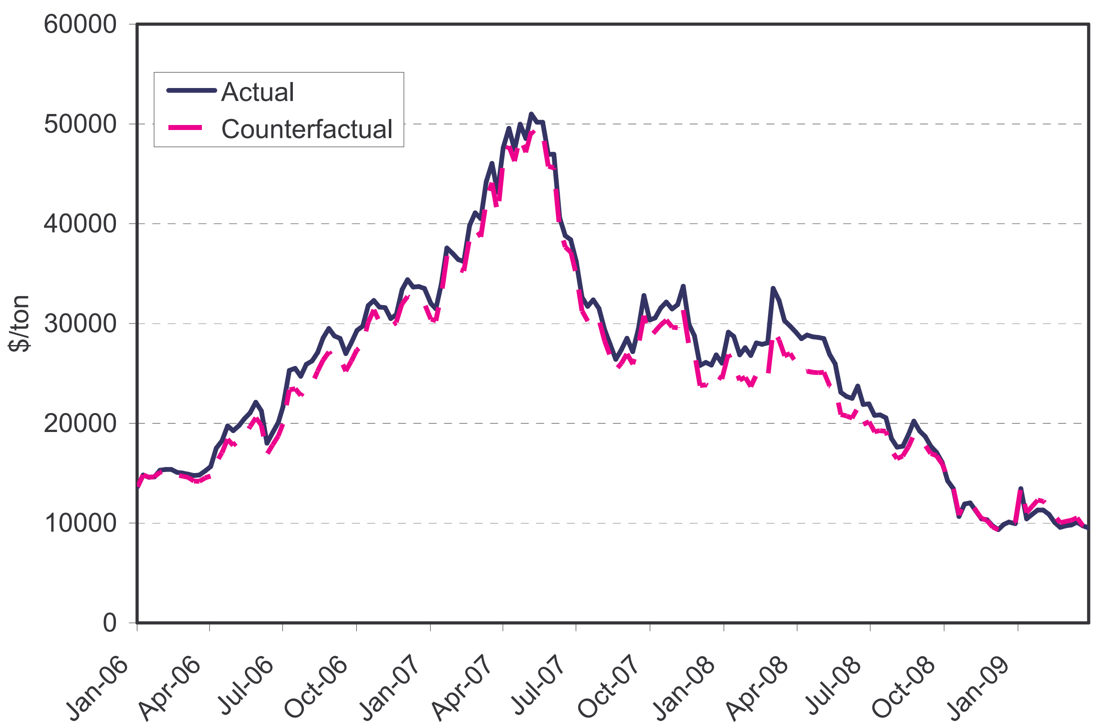

Figure 18: Actual and counterfactual LME nickel prices

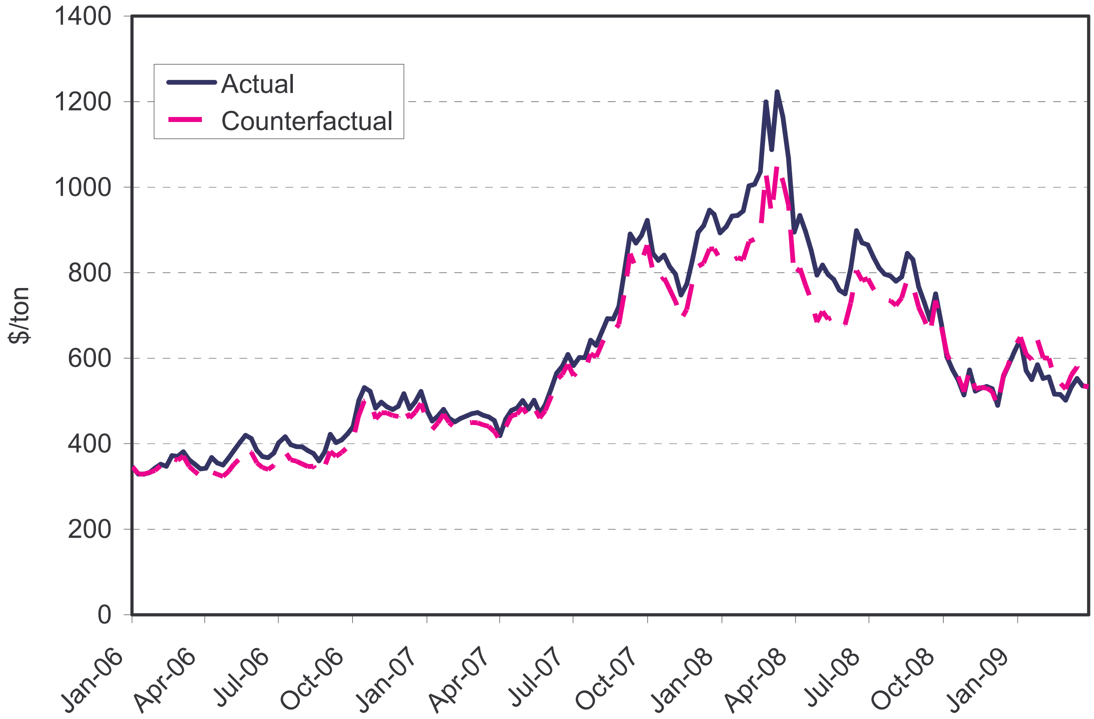

Figure 19: Actual and counterfactual CBOT wheat prices

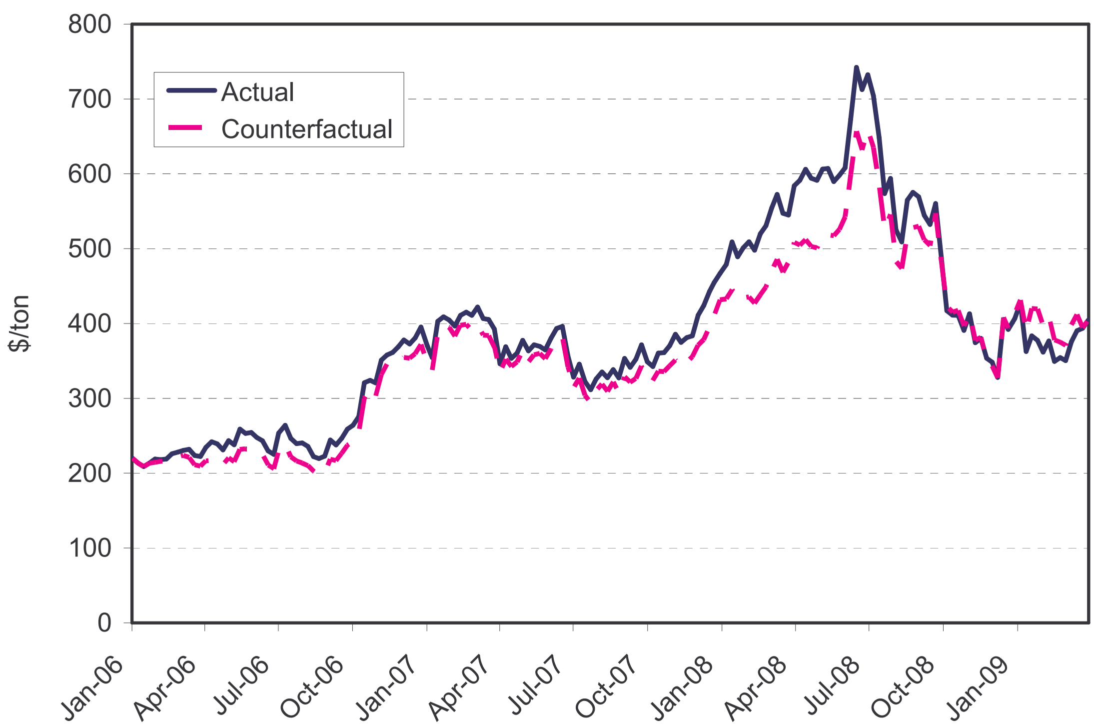

Figure 20: Actual and counterfactual CBOT corn prices

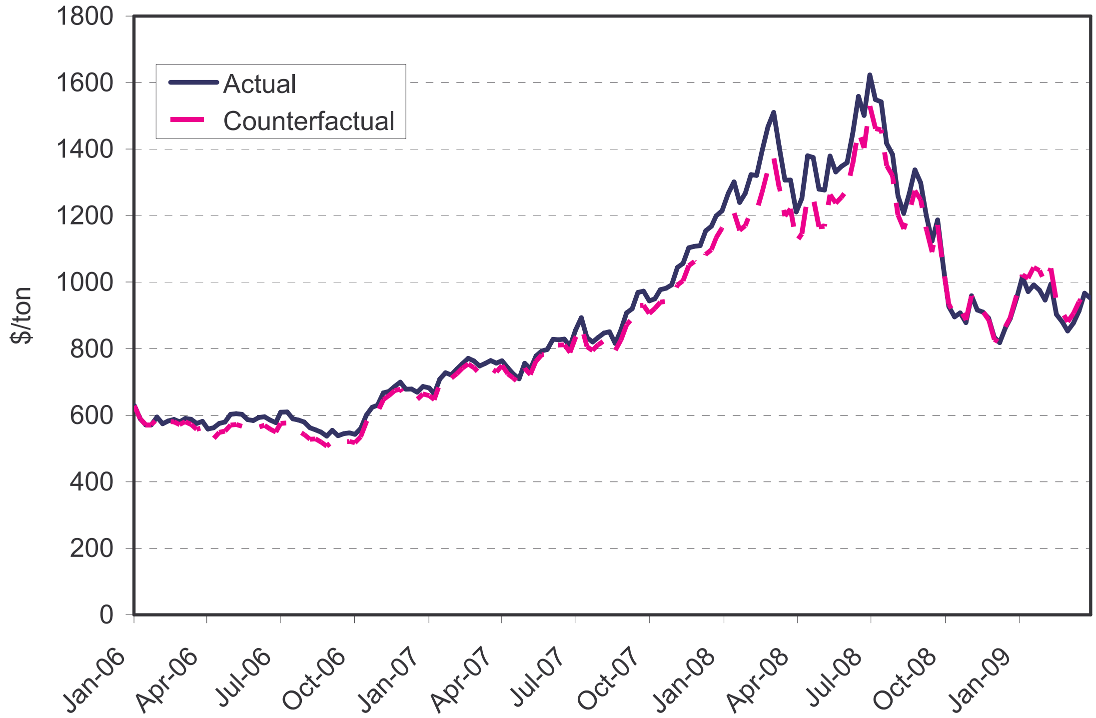

Figure 21: Actual and counterfactual CBOT soybean prices