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Commodity Price Dynamics in the 21st Century.
Fundamentals or Speculation?

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1. Introduction

The diploma thesis at hand reevaluates the influence of speculation on commodity prices dynamics between 2003 and 2009.

The author obtained the image of elaborating a study on this topic during an internship in Mexico in 2008. Similar to developing countries, the large number of poor people in Mexico was strongly affected by the increases of agricultural commodity prices. The dynamics of the latter not only caused food insecurity of millions, but also affected political stability. It was the strong effects of commodity prices on global economies and political stability that aroused the author's interest in this field, in particular in the question whether prices between 2003 and 2009 fully reflected their "true" fundamental value or whether they were distorted by destabilizing speculation.

The commodity bull market between 2003 and mid 2008 was the most pronounced in decades, not only in its length but also in its magnitude. Prices of nearly every important agricultural and energy commodity increased considerably. The IMF commodity price index nearly quadrupled over little more than five years (<http://www.imf.org>).

A comprehensive reconsideration of those dynamics is of great contemporary importance for several reasons.

First, especially crude oil has constituted a major input factor for large parts of industries. The strong crude oil bull market between 2003 and mid 2008 therefore boosted production costs considerably. Especially when the outbreak of the global financial crisis became apparent, the high price of crude oil not only deteriorated expectations, but also more importantly directly decelerated economic growth.

Second, price hikes of major agricultural commodities (especially wheat, corn and rice) had a great impact on net food importing developing countries. The Food and Agriculture Organization of the United Nations (FAO) estimated a record high of over one billion undernourished people worldwide in 2009 (FAO 2009). As a result, food riots broke off in several developing countries.

The rising food and energy inflation also affected overall consumption in industrialized countries since a larger proportion of income had to be spent on food, heating etc. Last but not least, rising commodity prices accelerated the increase of overall inflation and thereby constricted the monetary policy of central banks (Schulmeister 2009).

The purpose and central question of the study is to analyse whether recent price hikes can be explained without destabilizing speculation in commodity futures markets. Academic economists and practitioners have still not reached a consensus regarding the question whether speculation has (at least partly) caused price increases. For decades the discourse on the formation of commodity prices has been shaped by the predominant belief in the efficiency of commodity spot and futures markets. Recent price dynamics, however, challenged this position and call for a comprehensive reconsideration of commodity price dynamics in the 21st century.

This study shall try to contribute to the discourse on commodity price formation by opposing the efficiency hypothesis to a speculation hypothesis.

In chapter 2 the analysis begins with an overview of relevant theoretical aspects. The main problem with commodity price theory is the lack of useful models as to the recent price dynamics. The emphasis of this paper's theoretical part is therefore placed on modelling different perceptions of financial markets, rather than on elaborating one testable model. Predictions of the Efficient Market Hypothesis (EMH) will be opposed to predictions of inefficient market positions. This shall advocate a better understanding of the dependence of the efficiency hypothesis on assumptions that might not hold in real commodity futures markets.

Chapter 3 analyses the empirical behaviour of the prices of copper, corn, crude oil, gold and wheat after 2003. The aim of this part is to empirically evaluate the propositions presented in chapter 2, i.e. whether the efficiency- or the speculation hypothesis is more suitable to describe commodity price dynamics in the 21st century. Several aspects will be discussed, whereby the approach will be from general to specific.

Chapter 4 finally concludes this study.

2. Theoretical Aspects of Commodity Price Formation

2.1. Hotelling's Rule¹

In his classic text *The Economics of Exhaustible Resources*, Harold Hotelling formulated the fundamental principle underlying the economics of natural resources (Solow 1974). Although the paper was written back in 1931, already at that time the author dedicated himself to the question of the optimal depletion of commodities. Although his paper deals with exhaustible resources, certain deductions are equally valid for agricultural commodities such as wheat and corn, as they are also storable to a certain extent.²

An inventory of a commodity, be it stored in a stash or underground, can be regarded as a capital asset for its owner (Solow 1974: 2). The possibility of storage provides producers with two options, either to sell the product or to postpone (part of) its sales to a future period and keep underground inventories. The first step of Hotelling was to detect the determinants of the decision between selling and holding (Hotelling 1931: 140).

Assume that producers of commodities want to maximize the present value of their future profits.

A producer will be indifferent between receiving a net price p_0 now and a price $p_0 e^{\tau t}$ at time t , if the net price p_0 of the commodity increases over time at a rate equal to the interest rate factor τ ³. Under perfect competition the net price denotes the market price of the good minus marginal extraction costs.

Inventories left underground can only produce a return for their owner, if the net price is increasing over time. The market can therefore only be in equilibrium if net price and interest factor are growing at the same rate. If the net price increased too slowly, then producers would augment their supply of the good, as the rate of interest would yield a higher utility than underground storage or even a constant remaining supply. If on the other hand the net

¹ All mathematical expressions in this chapter were obtained from Hotelling (1931).

² One would have to adjust calculations to the costs of storing a commodity in a stash rather than underground.

³ Note that this applies only to perfectly competitive markets.

price increased at a rate greater than the rate of interest, producers would have incentives to cut back on supply and increase underground storage.

This simple statement determines the condition for market efficiency and as Robert Solow called it, constitutes the fundamental principle of the economics of exhaustible resources (Solow 1974: 3).

Within the discussion about rising oil prices between 2007 and mid 2008, an argument was brought up that was based on exactly the above- described logic. Media often reported that one of the reasons for the strong oil price increases was the cutback of supply by the OPEC. The incentives to reduce their supply of oil resulted from the strong price increases, at a higher rate than the growth rate of the interest rate factor. However, we will see later on that this should theoretically not be possible.

The condition for the market to be in equilibrium under perfect competition at any point in time is therefore that $p_t = p_0 e^{rt}$, with p_0 determined by supply and demand conditions at that time. Let the supply of the commodity be denoted by a and the demand by $q_t = f(p_t, t)$. As it is the condition for the market to be in equilibrium, the net price grows at an equal rate as the rate of the interest factor.

Therefore we obtain the following expression:

$$\int_0^T q dt = \int_0^T f(p_0 e^{rt}, t) dt = a^4$$

Since we are discussing exhaustible resources, the upper limit T denotes the time when the resource will finally be exhausted and demand will be zero.

Assume furthermore that demand is diminishing in the price and the demand function has a unique solution at any point in time.

Suppose, for example, that the demand function is given by $q = 5 - p$, independent of the time. Then, if the price of the resource is equal to or higher than five, demand will be zero. With demand approaching zero, the price will increase to the value of five, which is the highest price any consumer in the market would pay. Therefore the condition at time T will be that $p_0 e^{rT} = 5$ and supply and demand will be

⁴ The price consumers face does include extraction costs.

$$a = \int_0^T (5 - p_0 e^{\tau t}) dt = 5T - p_0 (e^{\tau T} - 1) / \tau$$

After eliminating p_0 Hotelling obtained the following result:

$$e^{-\tau T} = 1 + \tau(a / 5 - T)$$

If this equation is plotted as a function of T , an exponential curve will be obtained.

What has just been described formally are the effects of the resource being exhaustible. At some point in time, the commodity will become significantly scarce and the market price for the commodity will have to rise steeply. This will be due to an increase in the net price, which Solow called the scarcity rent (Solow 1973: 3). However, it can also be that extraction costs increase with the advancing depletion of the resource.

Due to the increasing market price, demand will accordingly fall, until at some point (time T) the market price will be sufficiently high to cut off demand entirely. In this moment, if producers behaved rationally over time, the resource would be exhausted (Hotelling 1931).

The logic of prices increasing due to the advanced depletion of the resource takes an important place in the fundamental valuation of commodities. The accelerating depletion of existing oil fields and the rising costs of discovering new oil resources, denoted as *peak oil*, constitute major fundamental factors that influence prices (Soros 2008: 2). Furthermore, they strengthen optimistic expectations of (strongly) rising future prices.

However, the concept of *backstop technology* could provide a ceiling for the price increases of exhaustible resources (Solow 1974: 4).

This term denotes a technology capable of substituting an exhaustible resource by another (abundant) technology, however, at high costs. As the depletion of (underground) stocks of an exhaustible resource advances, the scarcity rent will increase exponentially until at some point the market price will exceed the costs of the backstop technology. Although this concept might become essentially important for some commodities such as crude oil, it is not of major importance for this paper's topic.

Let us return to Hotelling's fundamental principle, which is the equilibrium condition between net prices and the rate of interest. According to Robert

Solow, the flow markets of the commodities could easily become unstable (Solow 1974: 6). If net prices were considered to rise too fast compared to the rate of interest, producers would increase their underground inventories and cut back supply.

In accordance to demand exceeding supply, the market price of the good would increase. This would then strengthen the optimistic beliefs of producers, which in the end could lead to a self-reinforcing speculative run-up of prices.

However, the knowledge of the existence of a long run equilibrium value of the good would correct the disequilibrium in the flow market. If net prices increased at a rate considered too high, this would not lead to a strong cutback of supply but rather to a revaluation of existing stocks of the good (Solow 1974: 6).

The discussion of the fundamental principle of the economics of exhaustible resources was rather perfunctory. However, already after taking a quick look at the arguments proposed by Harold Hotelling and Robert Solow, it becomes clear that the equilibrium conditions in commodity flow markets cannot be analysed segregated from other financial and macroeconomic factors. In order to fully understand spot price dynamics, also the conditions of other financial markets, most importantly commodity futures markets, have to be taken into consideration.

For that reason the Efficient Market Hypothesis (EMH) will be discussed in a next step. It constitutes the fundament of the belief in efficiently functioning financial markets (as commodity futures markets).

2.2. The Efficient Market Hypothesis

The theoretical benchmark model of the efficiency hypothesis builds up very strongly on the Efficient Market Hypothesis (EMH), as formulated by Eugene Fama in 1970.

Fama defines a financial market as efficient, if security prices always *fully reflect* all available information (Fama 1970: 383).

Stating that real world financial markets, such as commodity futures markets, are efficient according to the before mentioned definition, the EMH rules out the possibility of trading systems based only on currently available information that have expected returns in excess of equilibrium return (Shleifer 2000).

According to the EMH, market participants are assumed to be rational and they therefore value securities rationally, based on their fundamental values.

Notational, an efficient market can be described as follows:

Assume that all events take place at discrete points in time, $t - 1, t, t + 1$ etc.

The term ϕ_{t-1} denotes the information set available at time $t - 1$, which is relevant for determining security prices at time $t - 1$.

ϕ_{t-1}^m is the set of information the market uses at time $t - 1$ to determine security prices. Thus ϕ_{t-1}^m is a subset of ϕ_{t-1} and contains at most the information ϕ_{t-1} , however, it could also contain less.

The price of a security j at a discrete point in time is denoted by $p_{j,t+\tau}$, with $j = 1, 2, \dots, n$, where n is the number of securities available in the market.

The joint probability density function for security prices at time $t + \tau$ ($\tau \geq 0$) assessed by the market at time $t - 1$, conditionally on the information set ϕ_{t-1}^m is denoted by $f^m(p_{1,t+\tau}, \dots, p_{n,t+\tau} | \phi_{t-1}^m)$.

The “true” joint probability density function that follows from the information set ϕ_{t-1} equals $f(p_{1,t+\tau}, \dots, p_{n,t+\tau} | \phi_{t-1})$.

The set of information ϕ_{t-1} can be described as the state of the world at time $t - 1$, as it includes current and past values of relevant variables like consumer tastes or the political climate in general (Fama 1976).

Additionally, the above- described information set also includes whatever is known about the evolution of the state of the world throughout time (Fama 1976).

The process of price formation at time $t - 1$ then happens as follows.

Based on the information used in the market at time $t - 1$, ϕ_{t-1}^m , market participants assess a joint distribution of security prices for the next period (t)

$f^m(p_{1,t}, \dots, p_{n,t} | \phi_{t-1}^m)$. Following this distribution, current security prices $p_{1,t-1}, \dots, p_{n,t-1}$ are then determined by the market, based on a model of market equilibrium which defines equilibrium prices according to the characteristics of the joint distribution of prices (Fama 1976: 135).

As common in economics, the term “market equilibrium” implies a set of market-clearing prices, at which demand for securities meets supply.

The main point of this notation, that a capital market is efficient, is then stated as follows:

$$\phi_{t-1}^m = \phi_{t-1} \quad (2.1)$$

This indicates that the information market participants use to determine security prices at time $t-1$ includes all available information at that point in time.

Since ϕ_{t-1} includes everything that is known about the evolution of the state of the world throughout time, equation (2.1) implies:

$$f^m(p_{1,t}, \dots, p_{n,t} | \phi_{t-1}^m) = f(p_{1,t}, \dots, p_{n,t} | \phi_{t-1}) \quad (2.2)$$

Because current prices are determined on the basis of the joint density function, they fully reflect all available information at time $t-1$ (Fama 1976).

This simple statement that prices reflect all information and markets are therefore efficient already implicates crucial assumptions. Fama stated that equilibrium prices are determined by market participants based on one “true” model of market equilibrium. However, why should all traders in the market assume the same equilibrium model? Whether market prices really reflect their fundamental values, this crucially depends on the assumptions of market participants what the equilibrium values really are. An infinite number of these models used by traders might exist and furthermore not all of them necessarily have to be based on the information set ϕ_{t-1}^m .

Fama additionally assumed that ϕ_{t-1}^m includes all information from the past up to the present. Loosely speaking, traders do their job rationally and are well informed (equipped with perfect knowledge) about the past. However, the important question arises why the future should continue the past! Behind that proposition there is the assumption of one single probability system governing prices. It is constant over time and therefore does not change even if prices

exhibit high variances. John Maynard Keynes denotes the assumption of one probability system as a convention, however, one based on weak grounds (Keynes 1967: 152). Keynes will be discussed in more detail later on.

To be able to make the model empirically testable, however, the term “fully reflect” must be defined. Many empirical models state the conditions of financial market equilibrium in terms of expected returns. Conditional on the relevant information set, the equilibrium return on a security is a function of its risk.

The outcome of the model strongly depends on the defined relationship between risk and return. However, the above described “strong” version of the Market Efficiency Hypothesis can only serve as a benchmark for the efficiency hypothesis, as it implies that information and trading costs are zero (Grossman and Stiglitz 1980).

The model underlying the commodity efficiency hypothesis obviously relaxes the (unrealistic) assumptions of zero trading- and information costs. However, it is still closely related to the main propositions of the EMH, although to a more “sensitively” formulated version, stating that earning above equilibrium returns is not possible without accepting above average risk (Malkiel 2003: 59).

Market participants are again assumed to act fully rationally and use the same information set to form their beliefs, however, they do not know the expectations of the other actors (Schulmeister 2009).

Investors are fully rational, that means that they value each security for their fundamental value, i.e. the net present values of their future cash flows, discounted by their risk characteristics.

When new information arrives, investors in the market quickly respond to this information by bidding prices up if the news arrived is good, or by bidding them down if the news suggests prices to fall.

As this new information is incorporated into prices, they adjust quickly to their new levels corresponding to their fundamental values.

In contrast to the strong version of the EMH discussed before, prices do not jump immediately to a new equilibrium, but reach it through a gradual price discovery process.

If all actors are rational, a financial market is efficient by definition. However, efficiency does not live or die with the rationality of all actors. Assume that irrational investors trade randomly in the market. If their trading strategies are not correlated, their trades are likely to cancel each other as not all irrational traders share the same expectations. Therefore, prices will still be close to their fundamental values, although the trading volume will increase (Shleifer 2000).

Surprisingly, a market can be considered efficient even if irrational actors' trading strategies are correlated. This case is based on the argument of arbitrage and is, according to Andrei Shleifer "(...), one of the most intuitively appealing and plausible arguments in all of economics" (Shleifer 2000: 3).

Arbitrage defines the simultaneous purchase and sale of the same, or essentially similar security in two different markets at advantageously different prices (Alexander and Sharpe 1990).

Assume, due to correlated trading strategies of irrational actors, the price of a security overshoots its fundamental value and exceeds the properly risk adjusted net present value of future cash flows.

Observing this, a rational investor will sell (short) this security in the market and simultaneously buy (go long on) an adequate substitute to hedge his risk. By doing so, the rational investor is able to earn a return above the equilibrium return.

If arbitrage happens quickly enough, sufficient adequate substitutes are available and rational actors are competing to earn the above equilibrium profits, security prices will not deviate much from their fundamental values and arbitrageurs will not be able to earn much of abnormal returns (Shleifer 2000).

Additionally to bringing prices back in line with their fundamental values, arbitrage will also result in irrational investors losing money. They will become less wealthy and eventually disappear from the market.

In the long run, market efficiency will not only be achieved by arbitrage, but also by competitive selection (Shleifer 2000).

The empirical consequences of rational markets (the term "market" of course used as a metaphor to summarize the decisions made by individuals) are remarkable.

First, it somehow eases the argument that high transaction volumes indicate inefficient markets. As mentioned before, irrational trades can either be uncorrelated or compensated by arbitrage. Both cases will lead to an increase in the transaction volume in a market; however, prices will stay in line with their fundamental values.

Second, and even more important, rational behaviour and arbitrage rule out the possibility of an endogenous overshooting (in both directions) of prices due to excessive speculation in the market.

Speculation on securities provides the market with the necessary liquidity and is, according to the EMH and the commodity efficiency hypothesis, an essential part of the price discovery process. Arbitrage even smoothens prices towards their fundamental equilibrium values.

As a consequence, any (long run) deviation of prices from their fundamental equilibrium values must be attributed to exogenous shocks and cannot be caused by excessive speculation.

2.3 The Random Walk Hypothesis

The Efficient Market Hypothesis is often linked with the idea of asset price changes following a Random Walk without drift.

In this context, the term “Random Walk” denotes a series of security prices, where all subsequent prices depart randomly from previous prices (Fama 1970, Malkiel 2003).

The first Scientist to formulate the idea that equity prices follow a stochastic process was Louis Bachelier (a French mathematician) in 1900.

In his doctoral thesis “Théorie de la Speculation” he elaborated the train of thought, that for each price, there exists a buyer and a seller, whose expectations about future price developments diverge. While the buyer expects future prices to further increase, the seller expects them to fall. In total, as Bachelier deduced, the anticipations of all market participants even out. Therefore their expected value equals zero and asset prices are not predictable (Fama 1970: 389).

Formally a Random Walk without drift can be described as:

$$X_t = X_{t-1} + \varepsilon_t \text{ with } \varepsilon_t \sim iid (0, \sigma^2)$$

Since the expected value of the error term equals zero, it follows that:

$$E(X_t) = X_{t-1}$$

Prices will follow a Random Walk if the price changes are independently and identically distributed. This means daily commodity prices are independent over time.

Assume that the conditions of market equilibrium can be stated in terms of expected values and all available information on fundamental values is incorporated into prices.

Then one can define the excess market value of a security j at time $t + 1$ as:

$$x_{j,t+1} = p_{j,t+1} - E(p_{j,t+1} | \phi_t)$$

The excess value equals the difference between the observed price of security j at time $t + 1$ and the expected price at $t + 1$, conditional on the available information at time t .

Then

$$E(\tilde{x}_{j,t+1} | \phi_t) = 0$$

The tildes indicate that $x_{j,t+1}$ is a random variable at time t .

Let $\beta(\phi_t) = [\beta_1(\phi_t), \dots, \beta_n(\phi_t)]$ be a trading system based on the information available at time t , which suggests the investment of a certain amount on each of the n securities. The total excess market value at time $t + 1$ is then determined by

$$V_{t+1} = \sum_{j=1}^n \beta_j(\phi_t) [p_{j,t+1} - E(\tilde{p}_{j,t+1} | \phi_t)]$$

Since $p_{j,t+1} - E(\tilde{p}_{j,t+1} | \phi_t) = 0$, it follows that

$$E(\tilde{V}_{t+1} | \phi_t) = \sum_{j=1}^n \beta_j(\phi_t) E(\tilde{x}_{j,t+1} | \phi_t) = 0$$

The logic of this idea, which underlies the efficiency hypothesis, suggests that the emergence of news and exogenous shocks follow a Random Walk.

If new information is nearly immediately reflected in security prices, then price changes in the next period will only reflect the news (changes in the

fundamental values) of the next period and will be independent of the news of the current period.

Prices will therefore be independently distributed. Since new information and shocks are by definition not predictable, also future price changes are unpredictable and therefore random (Fama 1970).

The implications of the statement that security prices follow a Random Walk are striking, as they rule out the systematic profitability of trading strategies only based on past prices (and information).

The statement therefore postulates that no investor, be it a hedge fund or an individual amateur, can consistently beat the market, neither by technical analysis (the study of past prices) nor by fundamental analysis (the study of financial information) (Shleifer 2000).⁵ This is due to prices being independent over time and only responding to random shocks, which by definition cannot be forecasted.

Regarding empirical studies, however, measuring the profitability of trading strategies is still very controversial.

To test whether it is possible to earn above equilibrium profits, a researcher has to define a reasonable relationship between the returns that can be earned and risk.

A considerable amount of studies found “money making” opportunities in financial markets, they therefore contradict the EMH. However, whenever money making opportunities, based on past prices and (also current) information were found, the opposition did not take long to formulate a model of risk, reducing above equilibrium profits to a fair compensation for the risk born by investors (Shleifer 2003).

The relationship between risk and returns could therefore be seen as the very controversial part in measuring the efficiency of a financial market.

One broadly accepted concept is the Capital Asset Pricing Model (CAPM), as formulated by Sharpe (1964).

⁵ Beat the market in the sense of earning above equilibrium returns.

To summarize the empirical predictions of the efficiency hypothesis, financial markets (rational individuals) are expected to incorporate new information on fundamental values of securities both quickly and correctly (Shleifer 2000).

Although prices will not jump immediately to their new equilibrium value, they should follow a gradual discovery process, so that investors discovering the news too late should not be able to profit from it (or even lose).

Also rational individuals should incorporate new information adequately. Prices should neither over- nor under react to new information, nor should they follow a particular trend.

Due to this behaviour, market participants should not be able to earn above equilibrium returns when they base their strategies on past information.

2.4. Theoretical Challenges of the Efficient Market Hypothesis

The position of inefficient markets seizes on trading behaviour and price dynamics in financial markets considerably different from the efficiency hypothesis.

It is the central theoretical assumptions in which the two hypotheses vary in, and which lead to the different empirical views of the characteristics of real world financial markets, as in this case commodity futures markets.

To begin with, the first difference regards an assumption every (under)graduate student of economics is taught to use in order to capture the rational, utility maximizing behaviour of economic agents - the rational behaviour of the “homo oeconomicus”.

It is exactly the rational behaviour of economic agents in financial market, which the inefficiency hypothesis challenges.

According to the latter, an actor’s conduct is not only governed by rational calculations, but also by emotional and social factors. Also for that reason, financial markets themselves are often characterized as in a *manic* or *depressive* phase (Keynes 1936, Schulmeister 2009).

While the efficiency hypothesis assumes that only relevant information is used by market participants to form their price expectations (and demand), others

argue that investors also react to irrelevant information and are not equipped with full knowledge.

Trading based on irrelevant rather than relevant information, and therefore not rational according to the normative model is called *noise trading* (Shleifer 2000: 12).

The deviation of economic agents away from the standard decision making model, however, takes place in a number of areas.

First, in assessing risky speculations, not all individuals follow the maxims of the von Neumann-Morgenstern rationality (Kahneman and Riepe 1998, Shleifer 2000). While a perfectly rational decision maker should consider the amount of final wealth that can be obtained, many actors rather account for the gains and losses along the way.

Investors also tend to show a strong loss aversion, which means that the function for losses is steeper than the function for gains (Kahneman and Riepe 1998).

Consider for example the manager of an investment fund, who gets evaluated on a regular basis. In order to look good and justify his own position, the manager might have incentives to add stocks to his portfolio that have recently done well, and sell stocks that have recently done rather poorly.

Individuals also violate maxims of probability theory, as Bayes law, when they assess the outcomes of uncertain events.

For example, as in technical trading systems, speculators often try to predict future price movements by analyzing price dynamics in the recent past.

By doing so, investors might perceive patterns that do not exist, and therefore generate an incorrect model. The information sets used in the formation of price expectations, which are often formed only in regard to the direction of price movements, are additionally heterogeneous.

For example, due to overconfidence in their own misjudgement, investors could carry recent price increases (generated by chance) too far into the future, therefore overpricing a security.

To summarize this point, market participants might perceive patterns where there are none and by carrying them into the future forget that “trees do not grow into the sky” (Kahneman and Riepe 1998, Shleifer 2000: 11).

The different ways how investment options are presented to people may also influence investors decisions. This problem is called (*narrow*) *framing* (Shleifer 2000: 10).

Consider the following pairs of concurrent decisions⁶:

Decision 1.

- a) sure gain of 2.400\$
- b) 25% chance to gain 10.000\$ and a 75% chance to gain nothing.

Decision 2.

- a) sure loss of 7.500\$
- b) 75% chance to lose 10.000\$ and 25% chance to lose nothing.

A majority of people would chose (a) in decision one and (b) in decision two.

Now consider the following third decision problem:

Decision 3.

- a) 25% chance to win 2.400\$ and a 75% chance to lose 7.600\$
- b) 25% chance to win 2.500\$ and a 75% chance to lose 7.500\$

Easy to answer, one would choose answer (b) in this decision. However, returning to the first two decisions, one will discover that the answers most people would pick (a and then b), together yield the inferior option (a) in problem three.

The superior option (b) in problem three is obtained by conjoining the two options of the first two problems, which most people would reject (Kahneman and Riepe 1998).

This example illustrates a problem of real world financial markets, where investors often fail to develop a broader frame on decision-making problems. However, even if some market participants act irrationally, the ultimate argument of the EMH states that arbitrage will ensure the market to stay in equilibrium.

The next chapter will therefore elaborate possible deviations of security prices from their fundamental equilibrium values due to shortcomings of real world arbitrage.

⁶ Based on Kahneman and Riepe (1998).

2.5. Limitations of Arbitrage

In chapter 2.2 it was stated that the immediate sales (purchases) of overpriced (underpriced) securities by arbitrageurs cause security prices to stay in line with their fundamental values, at least that is what the EMH predicts. This is so, because the EMH assumes that arbitrage entails no risk and trader's net returns will be at least zero (Shleifer 2000).

In reality, however, arbitrage implies a considerable risk due to several reasons. Adequate substitutes may not always be available, making risk free hedges impossible. Arbitrageurs also bear the risk that the price distortions caused by irrational (noise) traders increase even further over the short or medium run. If prices for example decrease due to a pessimistic market mood, which continues to last for several time periods, an arbitrageur may sustain severe losses if he has to liquidate the obtained positions before prices recover. Risk-averse arbitrageurs might therefore prefer not to behave as aggressively as the EMH suggests in order not to lose money (Shleifer 2000).

Besides these important shortcomings of arbitrage, this chapter's emphasis is on what can be described as the agency relationship between arbitrageurs and the investors in arbitrage (Shleifer and Vishny 1997).

Most arbitrage is performed by relatively few professionals, who trade using the resources of several other, less informed investors. The dependence of arbitrage on outside resources constitutes the main problem of the following model. Investors or lenders, who provide arbitrageurs with money, might be subject to irrational expectations as described in chapter 2.4. If for example the mispricing of a security becomes more severe over the short- or medium run, arbitrage opportunities increase. However, less informed investors might only perceive that the arbitrageur is losing money and refuse to provide more capital, exactly when it would be needed. So arbitrage would become most constrained when the opportunities are best and market efficiency would not be secured. The responsiveness of arbitrage to investor's expectations is denoted as performance based arbitrage (Shleifer 2000: 89).

The following model discusses an irrational underpricing of a specific asset over the short run, however, the price will for sure return to its fundamental equilibrium value in the long run.

2.5.1 A Model of Agents in Limited Arbitrage⁷

During three time periods, $t = 1, 2, 3$, three types of agents participate in the market. Noise traders represent irrational behaviour (as described in chapter 2.4.), rational arbitrageurs who only trade in this specific market, and rational investors who allocate their capital across arbitrageurs also in other markets. The fundamental value of the asset is denoted by V and is only known by arbitrageurs during period one and two. At time three also noise traders gain knowledge on the fundamental value and therefore the price of the asset at time three will equal its fundamental value V .

The reduced form demand function of noise traders during period one and two equals $QN_t = [V - S_t] / p_t$.

S_t denotes the undervaluation of the asset by noise traders, so to say the pessimistic shock at time t . Arbitrageurs know the first period's pessimistic shock in period one. However, they can only anticipate the second period's shock, which might be either stronger or weaker. By using their capital endowment F_t (provided by the investors) arbitrageurs take positions against the underpricing of noise traders. F_1 is assumed to be given exogenously but F_2 will be based on investor's evaluation of the performance of arbitrage.

If at time $t = 2$ the price of the security equals its fundamental value, arbitrageurs will invest in cash, but if the mispricing continues in period two, arbitrageurs will want to invest F_2 solely in the underpriced asset and accordingly the demand will equal $QA_2 = F_2 / p_2$, with p_2 denoting the market price of the asset at time $t = 2$.

For the market to be cleared, unit supply has to equal demand:

$$p_2 = V - S_2 + F_2 \quad (2.3)$$

⁷ The presentation of the model is based entirely on chapter 4 in Shleifer (2000).

It is assumed that $F_2 < S_2$, so arbitrageurs are not able to bring the price in period two back in line with its fundamental value. In period one, arbitrageurs do not necessarily want to invest their whole resources F_1 in the asset, as the mispricing might deepen in the next period, therefore $QA_1 = D_1 / p_1$. In accordance the equilibrium condition for period one can be stated as:

$$p_1 = V - S_1 + D_1 \quad (2.4)$$

Again the demand stemming from arbitrageurs in the first period is not sufficient to fully correct the misperceptions of noise traders.

Within the specific market for the asset, many arbitrageurs are competing for investor's capital (which is distributed among different markets) in the price they charge. It is assumed that for each arbitrageur there exists at least one other market participant who can be viewed as a perfect substitute. In addition all arbitrageurs face the same marginal costs, regardless of the strategy they use. Therefore Bertrand competition causes the price for the service of an arbitrageur to be equal to the marginal costs.

Bayesian investors form beliefs of the expected returns of different arbitrage strategies. The heterogeneity of those beliefs assures that total investors resources are allocated across all operating arbitrageurs. Investors are not equipped with full knowledge of specific arbitrage strategies and therefore update their beliefs by looking at past performances. To be precise, an investor forms his expectations of future returns of an arbitrage strategy ex ante, by looking at the past performance of arbitrageurs.

If an arbitrageur obtains poor returns and cannot live up to the expectations of investors, they will be provided with less capital from investors. Since in the specific market segment described in this model all arbitrageurs take the same positions, all of them will lose or gain simultaneously.

Regarding the model, investor's supply of capital to arbitrageurs is an increasing function of the arbitrageurs obtained gross return between the first and the second period. Denoting this function by G , the supplied funds in period two, F_2 , can be described by:

$$F_2 = F_1 \cdot G[(D_1 / F_1) \cdot (p_2 / p_1) + (F_1 - D_1) / F_1] \quad (2.5)$$

The ratio between the second period's price and the first period's price yields the return of the asset and the function G satisfies: $G(1)=1$, $G' \geq 0$, $G'' \leq 0$. If arbitrageurs in this special market segment perform better than a benchmark set by investors (based on arbitrage returns in other markets), they will be supplied with more funds and vice versa. Present funds provided for arbitrageurs therefore respond (exclusively) to past performance, which is why one can speak of performance-based-arbitrage.

Note that the withdrawal of funds when mispricing (caused by noise traders) worsens is a perfectly rational response of investors to the problem of inferring jointly from past returns on the ability of an arbitrageur and future opportunities.

Let us turn back to equation (2.5) and assume a linear function G :

$$G(x) = ax + 1 - a, \quad a \geq 1 \quad (2.6)$$

With x denoting the arbitrageur's gross return, a linear function G yields a second period capital supply of:

$$F_2 = a[D_1(p_2 / p_1) + (F_1 - D_1)] + (1 - a)F_1 = F_1 - aD_1(1 - p_2 / p_1) \quad (2.7)$$

According to this equation, the arbitrageur neither gains nor loses funds if net returns equal zero. If the second period's price is higher than the first period's price, the arbitrageur will be provided with more funds and vice versa.

The variable a characterizes the sensibility of provided resources to past performance. The case $a > 1$ for example means that funds will be withdrawn by investors in response to a poor past performance, whereas $a = 1$ simply means that poor past returns will be met by investors by not supplying any additional funds.

The main point of this modelling is that arbitrage might be most constraint when the opportunities (expected returns) are the best. A temporary underpricing of the asset due to irrational noise traders yields temporarily low returns. Investors observe only the low returns and withdraw their capital, not considering that expected future returns have actually increased, since the asset price will eventually return to its fundamental value.

To finalize the structure of the model, the optimization problem of arbitrageurs has to be considered. Arbitrageurs want to maximize expected profits of time $t = 3$, which is equivalent to maximizing the funds they will be provided with in

the third period. Since the second period's noise trader shock is unknown in the first period, there is some probability q that $S_2 > S_1$. The probability that noise traders will recognize the fundamental value of the asset already in the second period, meaning that $S_2 = 0$, is denoted by $(1 - q)$. If this is the case arbitrageurs will already liquidate their positions at $t = 2$ and third period's provided funds will equal:

$$W = a(D_1 \cdot V / p_1 + F_1 - D_1) + (1 - a)F_1$$

If $S_2 > S_1$, third period's funds will be given by:

$$W = (V / p_2) \cdot [a(D_1 \cdot p_2 / p_1 + F_1 - D_1) + (1 - a)F_1]$$

and arbitrageurs maximize:

$$\begin{aligned} E(W) = (1 - q) \{ & a[(D_1 \cdot V / p_1) + F_1 - D_1] + (1 - a)F_1 \} \\ & + q(V / p_2) \cdot \{ a[(D_1 \cdot p_2 / p_1) + F_1 - D_1] + (1 - a)F_1 \} \end{aligned} \quad (2.8)$$

2.5.2. Limited Arbitrage and Efficient Markets

Let us consider that $a = 1$, so poor past returns obtained by arbitrage will cause investors to not supply any additional funds to arbitrageurs. After differencing equation (2.8) with respect to D_1 , the first order condition is given by:

$$(1 - q)(V / p_1 - 1) + q(p_2 / p_1 - 1)(V / p_2) \geq 0 \quad (2.9)$$

The first term in (2.9) can be interpreted as the marginal benefit to arbitrageurs from one extra dollar supplied by investors if the market price recovers at time $t = 2$. The second term describes the forgone investment option for arbitrageurs if the mispricing continues during the second period and the market recovers at time $t = 3$.

The first order condition will be strictly equal to zero if q is high enough and the price deviation away from the fundamental value severe enough, so that arbitrageurs decide to hold back some capital in the first period to invest it in the second period. For (2.9) to hold as a strict inequality, the price deviation in the first period must be already large enough, q low enough and the second period's price shock not too large relative to the shock in the first period. In the

latter case, when arbitrageurs expect the price in $t = 2$ to recover rather than to decline further, they will choose to fully invest their capital in the first period.

Proposition 1: For any given V, S_1, S_2, F_1, a , there exists a probability q^* so that for any $q > q^*$ it holds that $D_1 < F_1$ and for $q < q^*$ it holds that $D_1 = F_1$.

Therefore, if the first order condition holds with equality, the market equilibrium is given by equations (2.3), (2.4), (2.7) and (2.9). If on the other hand (2.9) holds with a strict inequality, the equilibrium will be constituted by arbitrageurs fully investing their capital endowment at $t = 1$, $p_1 = V - S_1 + F_1$ and equations (2.3) and (2.7).

According to Shleifer, both equilibriums are quite plausible (Shleifer 2000: 98). The next proposition describes the fact that noise trader shocks will cause inefficient market prices.

Proposition 2: For the corner solution (when arbitrageurs are fully invested in the first period) it holds that $dp_1 / dS_1 < 0$, $dp_2 / dS_2 < 0$, $dp_1 / dS_2 = 0$. Equally for the interior solution it holds that $dp_1 / dS_1 < 0$, $dp_2 / dS_2 < 0$, $dp_1 / dS_2 = 0$.

In both cases the prices will move the further away from the fundamental equilibrium value, the larger are the price shocks caused by irrational (noise) traders. At the interior solution, when arbitrageurs hold back some capital in the first period to invest it when the mispricing caused by noise traders deepens, prices will deviate more strongly during $t = 1$. Remember that at the beginning of chapter 2.5 it was argued that risk-averse arbitrageurs might not fully invest their resources if they fear losses due to further price deviations away from the fundamental equilibrium. The agency relationship can therefore be regarded as an alternative explanation to the risk aversion approach for why arbitrage may be limited under these conditions (Shleifer 2000).

In the remaining part of the model, however, it will be assumed that arbitrageurs fully invest their resources in the first period. Full investment at

$t = 1$ can be seen as a sufficient condition for arbitrageurs having to liquidate (part of) their positions in the second period, when noise traders' pessimism causes prices to further decline.

Proposition 3: Assume that arbitrageurs are fully invested at $t = 1$ and noise traders' misperceptions worsen at $t = 2$. Then if $a > 1$, meaning that investors withdraw (part of their) funds for arbitrageurs, it holds that $F_2 < D_1$ and $F_2 / p_2 < D_1 / p_1$.

Proposition three therefore describes the case when arbitrageurs have to partly bail out of the market (since their cash holdings are not sufficiently high) because investors withdraw capital. The price of the asset in period two can be described in accordance by:

$$p_2 = [V - S - aF_1 + F_1] / [1 - aF_1 / p_1] \quad (2.10)$$

if $aF_1 < p_1$, which simply states that in equilibrium arbitrageurs do lose funds but still do not bail out of the market completely. The last proposition is obtained by differencing (2.10) with respect to S .

Proposition 4: At the equilibrium where arbitrageurs are fully invested at $t = 1$, $dp_2 / dS < -1$ and $d^2 p_2 / (dS)^2 < 0$.

If arbitrageurs invest their total capital at $t = 1$ then prices will fall more than one by one in the second period.

This result is the exact opposite of the assumption that arbitrageurs become most aggressive when prices deviate furthest away from their fundamental value. When prices move the furthest away from their fundamental values, then arbitrageurs hold the smallest positions.

The implications of the model of performance- based arbitrage are strong in regard to the efficiency of financial markets. It describes conditions under which arbitrage is not able to ensure prices to stay in line with their fundamental values (over the short- or medium run). When prices move far away from their fundamentals, arbitrageurs even lose money and are unable,

due to the agency relationship with investors, to secure market efficiency. The limits of arbitrage discussed in this model also seem plausible in the evaluation of real world financial markets. Investors in arbitrage funds usually have the option to withdraw their capital on relatively short notice. If investors believe that an arbitrage fund performs poorly, they can withdraw their resources and force the fund to liquidate its positions if it lacks cash. If creditors finance arbitrage positions, then poor performance can also cause forced liquidations. Creditors usually demand quick repayments or otherwise force the liquidation of collaterals, when they move near to the debt level. Last but not least, a possibility that is not captured in this model is that arbitrageurs voluntarily liquidate part of their positions. They might do so because of the fear that investors will withdraw large amounts of resources later on, due to temporarily bad performances or that at some point creditors might force liquidations (Shleifer 2000). Of course several other limitations to arbitrage that are compatible with this model could be discussed in more detail here. However, the reason for including this model within the theoretical part of this paper was only to point out that the perfect functioning of arbitrage in real world financial markets cannot be always assumed. In a next step, one could raise the question whether or how arbitrageurs have operated in commodity markets. Have arbitrageurs been avoiding operating in commodity markets, maybe because the calculation and the forecast of fundamental values have been too difficult? Or has arbitrage been especially limited in commodity markets and prices have therefore exhibited such strong increases?

2.6. A Keynesian View of Financial Markets

More than 60 years have passed by since John Maynard Keynes died, however, the recent worldwide financial crisis has led to a re-evaluation of his concepts.

The reason why his ideas⁸ are also included in this paper is that his view of speculation and financial markets present sort of the opposition to the

⁸ Stemming from the General Theory of Employment, Interest and Money (1936).

efficiency hypothesis (as presented in this chapter earlier on). While the EMH emphasises the forces causing the efficient functioning of markets, Keynes elaborates possible detrimental effects of speculation.

The expectation of future yields of an asset is based on two parameters. Partly our prospects depend on some present facts (as current demand) and partly on uncertain future events (for example changes in demand or supply conditions).

The latter are what Keynes denotes as the *state of long-term expectations* (Keynes 1967: 147). Since the knowledge of the factors that will determine future yields is very low, the confidence with which we make our forecast is especially important. However, the problem with this parameter is that even if it governs investor's decisions, it is hard to measure. Nonetheless, Keynes identifies the importance of investor psychology, which is the main focus of contemporary behavioural economics (Keynes 1967: 149).

In addition to the very little knowledge we have of future asset price changes, another factor can possibly cause some instability of the financial system.

The daily revaluation of asset prices on Stock Markets greatly influences the formation of (long-term) expectations and therefore the current rate of investment. However, daily revaluations of assets in well-organized markets are based on the (average) expectations of traders rather than on the professional opinion of the entrepreneur. In the case of commodities, the prices of futures contracts are determined by the demand in the respective futures markets. However, the average expectation of the commodity traders actually determining the prices of commodity futures may be based on weaker grounds than the professional expertise of producers of the physical commodities.

So how does this revaluation work in practice, if performed by agents that may be less informed than others?

Agents' uncertain expectations are based on a convention that implies the continued existence of the present state of the world, as long as no specific reasons to believe otherwise appear (Keynes 1967: 152).

This convention can be compared to the proposition of the EMH that the best forecast for tomorrow's price is today's price. The convention is therefore based on the belief that the market, in relation to the present information set,

truly knows best. Over the short run (or a sequence of short periods) investments therefore are considered rather safe.

However, Keynes identifies several factors that lead to the instability of the above described convention.

First, short run fluctuations of returns tend to have an excessive influence on the evaluation of assets. Also in the commodity price boom it could have very likely been the case that market participants invested in commodities due to recent price increases, rather than due to a careful consideration of long (medium) run prospects.

Second, he emphasizes the (irrational) influence of the prevailing market mood on asset prices. Valuations of the latter that are based on a (mass psychological) convention are subject to sudden changes due to alterations of the prevailing opinion, which may result from other influences than fundamental changes. Especially during times when the continuous persistence of the present state of the world seems less realistic, financial markets will be characterized by optimistic or pessimistic phases (Keynes 1967: 154).

This argument usually constitutes an important factor in the line of argument used by supporters of the inefficiency hypothesis.

The last factor (that is presented in this paper) brought up by Keynes to challenge the stability of the before described convention, refers to the argument of arbitrage. In the efficiency hypothesis prices stay in line with their fundamental values because rational investors would react quickly to irrational deviations of prices from their equilibrium values. If an asset is priced too high, rational investors (arbitrageurs) will react and quickly sell their holdings of this asset and thereby bring back the price to its fundamental value. However, what if rational investors do not act as just described but rather wait for further price increases to obtain even higher profits? Then prices could systematically deviate from their fundamental equilibrium price.

According to Keynes this is the case, as rational investors are not concerned about an investment's real value, but rather how the average opinion of market participants will value this investment a certain period hence:

Thus the professional investor is forced to concern himself with the anticipation of impending changes, in the news or the atmosphere, of the kind by which experience shows that the mass psychology of the market is most influenced. This is the inevitable result of investment markets organised with a view to so-called liquidity (Keynes 1967: 154).

According to this logic, the argument goes as far as describing this behaviour not as irrational (as the EMH does), but rather as rational (within an irrational environment). However, the existence of rational investors, basing their expectations on fundamental factors, is not denied but still the dynamics of how arbitrage works are questioned: "There is no clear evidence from experience that the investment policy which is socially advantageous coincides with that which is most profitable" (Keynes 1967: 157).

Potential deviations from rationality are further aggravated by the human nature, the urge for action rather than passivity and the preference for quick returns.

Summing up all of these arguments, the term speculation as it is used in this paper is defined with a little help by Keynes as the activity of forecasting the psychology of the market (Keynes 1967: 158).

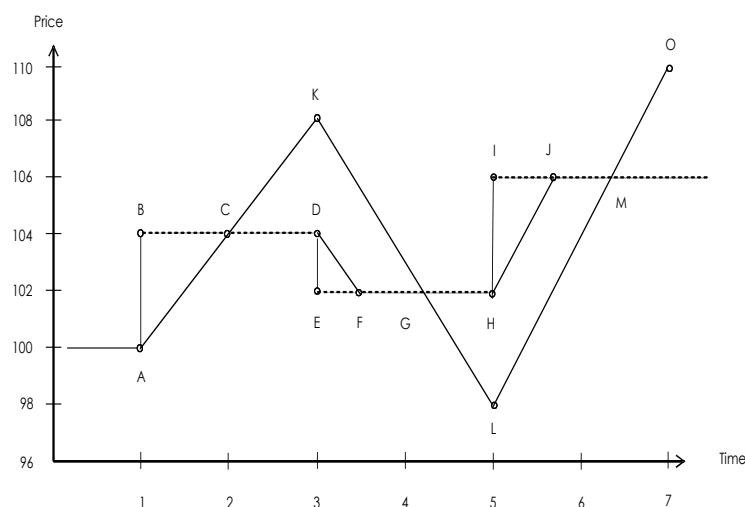
2.7. Price Dynamics Predicted by the EMH and its Critics

The perception of financial markets and therefore of asset price dynamics differs greatly between the efficient market hypothesis and what can be denoted as the inefficiency hypothesis. In efficient markets, where traders are fully rational and equipped with full knowledge, prices always stay in line with their fundamental values. At most, price deviations can occur over the short run, since positive trading and information costs cause a (very small) lag of prices reacting to new information (Schulmeister 2009). However, an

endogenous overshooting of prices over the medium- and long run, caused by traders' misperceptions, irrational trading or in short by destabilizing speculation is impossible. In contrast to the belief in efficient financial markets, its critics propose that irrational behaviour and the effects of limited arbitrage exert a substantial influence on asset price dynamics. For example, traders often forecast future price movements by simply assuming that price dynamics of the near past will continue, which was described by Keynes (1967). However, by doing so traders violate maxims of probability theory (see chapter 2.4) and simply perceive patterns and models where there are no patterns. In commodity futures markets, technical trading models are widely used. These models try to predict future price dynamics by constructing a forecast based on past prices and so might well be subject to the irrational behaviour just described. Price runs are therefore not only be lengthened by speculation, but traders might even construct (future) price models that are based rather on traders' psychology than on fundamental factors. As a result, (commodity) prices constantly overshoot their fundamental equilibrium values in both directions (Schulmeister 2009).

The following graph finally illustrates the theoretical differences between the assumptions of the classical formulation of the EMH, the more sensitively formulated efficiency hypothesis and the inefficiency hypothesis.

Figure 1: Different Scenarios of Price Dynamics



Source: Schulmeister (2009)

This graph illustrates three different paths of asset price dynamics, based on the predictions of the before mentioned hypotheses. Scenario 1 equals the dynamics according to the EMH, assuming perfect knowledge, rational behaviour and no transaction/information costs. Scenario 2 illustrates the price dynamics as predicted by the fundamentalist hypothesis, relaxing the assumptions of no transaction/information costs and traders do not know the expectations of the other market participants.

Finally in scenario 3, according to the bull-bear hypothesis, not all traders are equipped with full knowledge and behave fully rational. Furthermore, expectations are often formed only qualitatively (regarding the direction of the price move) (Schulmeister 2009).

At time $t=1$, news about the fundamental value of a security hits the market. In scenario 1, the new information is immediately reflected in the price, which therefore jumps instantaneously from 100 to the new fundamental equilibrium value 104. The price stays there, until at $t=3$ new information again reaches the market, leading again to an immediate price jump from 104 to the new equilibrium 102.

Finally at time $t=5$, the price again instantaneously jumps due to the arrival of new information.

In scenario 2, the price reaches its new equilibrium, after new information arrived at time $t=1$, only gradually after a series of transactions took place, leading to a time lag of one period (from point A to C).

However, the price then stays at its new equilibrium value. After new information arrived at point D, again it takes one period for the price to reach the new fundamental equilibrium (from D to F).

Also after new information arrives for the third time (at point H), it takes a gradual discovery process for the price to reach the new fundamental equilibrium. Again, after a series of transactions, the price then sticks at the new fundamental value.

In scenario 3, contrary to the other scenarios, traders exhibit a “trending behaviour” and artificially lengthen price runs, due to their bullish expectations (Schulmeister 2009).

After new information arrives at time $t=1$, the price gradually increases, however, the price increase does not stop at the new fundamental equilibrium value (at point C), but overshoots up to point K.

At point K news again hit the market, initiating a price decrease. Since once again (some) traders base their expectations on the most recent development (a price decrease), they lengthen the downward price run to overshoot the fundamental equilibrium value like before (of course into the other direction).

At time $t=5$, the same patterns are observed again. Traders incorporate the new information, however, overshooting the equilibrium again due to strengthening the price trend.

Therefore, while in scenario 1 and scenario 2 the price (in the latter case gradually) reaches its fundamental equilibrium and stays there (until new information arrives), the price in scenario 3 is constantly overshooting its fundamental equilibrium (in both directions) due to traders lengthening price runs according to their bullish (or bearish) expectations (Schulmeister 2009).

To summarize the results of the above discussed scenarios, short term price volatility is zero in the EMH scenario, only low in the fundamentalist scenario, however, considerably high in the bull-bear scenario.

Over the long run, scenarios 1 and 2 predict prices to stay in line with their fundamental values, as trades are governed by full rationality and knowledge. Scenario 3 on the other hand yields high volatility also over the long run, with the price overshooting the equilibrium price in both directions.

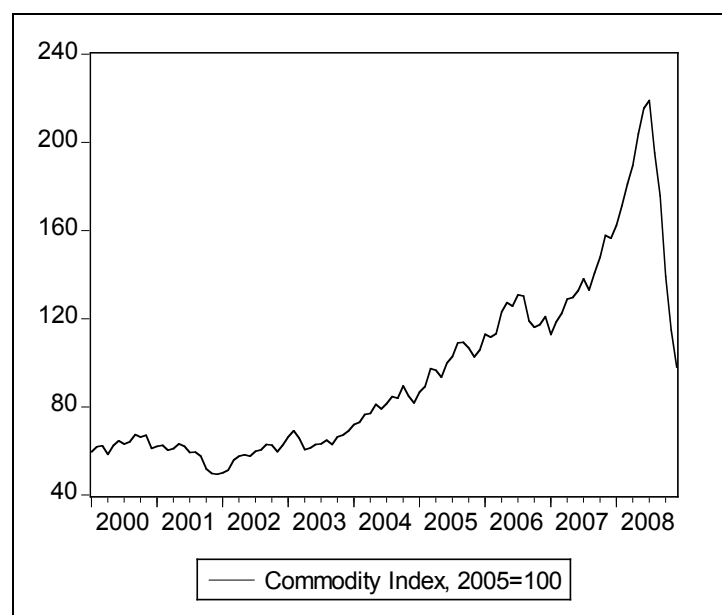
3. On the Empirics of Commodity Price Dynamics

The sharp increase in commodity prices, beginning already in 2003, has raised serious doubts about the efficiency of commodity markets and calls for a careful reconsideration of the dynamics of those prices.

Prices of nearly every important agricultural commodity tripled between 2006 and mid 2008, only to then collapse impressively.

The spot price for West Texas Intermediate (WTI) crude oil skyrocketed from around 60 US dollars per barrel at the beginning of 2007 to a peak of over 140 US dollars per barrel in mid 2008. Few months later the spot price for WTI crude oil was back at around 60 dollars per barrel.

Figure 2: IMF Commodity Price Index



Data Source: International Monetary Fund (IMF)

Not only do the impressive commodity price dynamics attract attention regarding the question of market efficiency as such, but they do have strong impacts on countless people worldwide, especially the poorest.

Although agreeing over these strong external effects, economists still have not reached a consensus on the causes of the sharp price hikes of commodities between 2006 and mid 2008.

In a survey conducted by the Wall Street Journal, the majority of economists saw the cause of the price dynamics in fundamental factors, an opinion based on the Efficient Market Hypothesis (Wall Street Journal, May 8, 2008). However, also scepticism has arisen regarding the efficiency of commodity futures markets.

So was it really the shifts in fundamental factors that caused prices to increase so strongly between 2007 and mid 2008 and then crash over just a very short period? Or was it speculation that led to the formation of a commodity price bubble, condemned to burst at some point in time?

Could it be that a realistic characterization of the price dynamics of the last years includes both fundamental changes and the price driving effects of speculation?

The hypothesis that will be elaborated over the next pages characterizes the commodity price dynamics as a bubble like movement, which was linked strongly to other macroeconomic and financial factors, particularly the recent economic crisis.

Some price increases, for example of corn and wheat, may have emanated from changes in fundamental factors. The demand for wheat and especially for corn increased due to the production of biofuel out of these commodities. Supply shocks, as severe droughts in Australia in 2006/2007 and stagnating yields in other major producing countries also played a role in the price hike.

The costs for discovering new oil repositories rose and the advanced depletion of this exhaustible resource obviously led to price increases. Additionally the demand for crude oil from emerging economies constantly rose over the preceding years.

Prices of crude oil as well as of the other commodities were also affected by the continuing depreciation of the US dollar after 2002.

However, the enormous dimension of the boom was caused by overconfidence and a misconception by investors, or to make a long story short, by excessive speculation.

At the beginning of the 21st century, financial market participants were in search of new investment opportunities. Although real estate was the more popular investment choice, financial institutions also increasingly started to use commodities as an asset class.

Up to that point, commodity futures markets mainly served the purpose of risk hedging for producers and consumers of the actual physical commodity and even more important, futures prices have been used also as a benchmark for spot prices. According to the CFTC:

Futures contracts are often relied on for price discovery as well as for hedging. In many physical commodities (especially agricultural commodities), cash market participants base spot and forward prices on the futures prices that are “discovered” in the competitive, open auction market of a futures exchange.
(<http://www.cftc.gov/educationcenter/economicpurpose.html>).

The additional demand for commodity futures stemming from speculators therefore contributed to price increases already between 2003 and 2007.

From 2007 on, it was mainly speculation that was driving up prices.

Based on the fundamental changes, investors developed excessive bullish expectations. Additionally the outbreak of the financial crisis became apparent. Both reasons provoked investors to channel considerably more money into commodity futures, rocketing futures prices to fundamentally not justifiable levels. Because futures prices have been used as benchmarks for spot prices, the price dynamics in futures markets spilled over to spot markets, where prices also rocketed from 2007 on.

As many investors tended to allocate their capital across different commodities by investing in indices, also the prices of several other commodities, especially metals, increased.

Speculation was not the causation, but the moving spirit of the tremendous price dynamics between 2007 and 2009.

Before taking the first steps of the data exploration, one essential distinction has to be clarified.

What is the actual difference between *speculation* and *investment*?

According to John Maynard Keynes, speculation is the activity of forecasting the psychology of the market, and the term enterprise (which can be regarded as conservative investment) denotes the activity of forecasting the prospective yield of an asset (Keynes 1967: 158). Speculation essentially differs from investment in regard to the risk of the transaction and the time scale. Speculation incurs the risk of losses in order to earn above average returns. Also the time horizon of speculative activities is smaller than the one of conservative investments. Speculators are rather interested in making quick money than in earning steady rates of return over a longer period.

They usually have no interest in actually consuming the commodity, but want to profit from the purchase and resale (or vice versa if a speculator is betting on a bear market) of the commodity futures contract.

One could also include hoarding by consumers into the definition of speculation. Hoarding can actually serve the purpose of storing the commodity for later consumption if a longer bull market is expected. There are signs that hoarding and panic purchases by companies or even countries played a significant role in the price hike of crude oil. However, in this paper the term hoarding will not be considered in detail, as reliable data are very scarce.

The analysis of commodity price dynamics will be performed on five key commodities, namely crude oil, wheat, corn, copper and gold.⁹ Each of these commodities was subject to tremendous price increases after 2003 and especially between 2007 and mid 2008. The data was obtained from Thompson Datastream and is composed of daily (spot and futures) prices.

⁹ All of which are included in the IMF commodity price index.

3.1. Some Observations on Commodity Price Dynamics

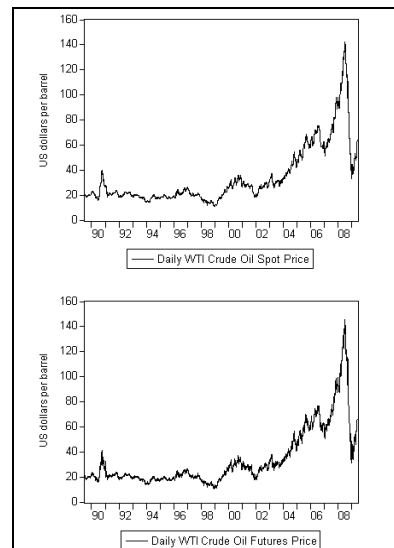
Figures 3 – 7 show the respective spot and futures prices of the five exemplary commodities.

Neither the spot nor the futures prices are stationary series but do exhibit strong volatilities. Mostly prices fluctuate around underlying market trends. These so-called bull and bear markets can last up to over a year. Earlier on it was stated that commodity prices react to fundamental changes. The responses of prices to real economic or political events can be observed in the price graphs.

Turning to the prices of WTI crude oil, e.g. the beginning of the Gulf war in 1990 activated a strong bull market.

Although the peak in the second half of 1990 seems rather insignificant compared to the enormous high in 2008, prices doubled already over that period of time.

Figure 3: Daily Crude Oil Price Movements



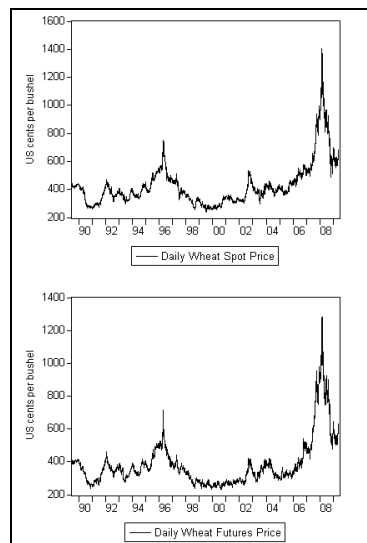
Data Source: Thompson Datastream

The liberalization of Kuwait then turned the bull- into a bear market, with prices falling back to the levels before the war.

Another bull market, initiated by strong economic growth, took off in 1999 and turned into a bear market during the last quarter of 2000.

Also wheat and corn prices were shaped by upward and downward trends. The most notable bull markets (before the 2007 price hike) took place in 1995/1996. At first glance, these events resemble the price hike ten years later only that in 2007 the upward trend lasted longer. Wheat production stagnated in 1995 and yields even declined. This supply shock led to a peak price of over 100 US cents per bushel in 1996.

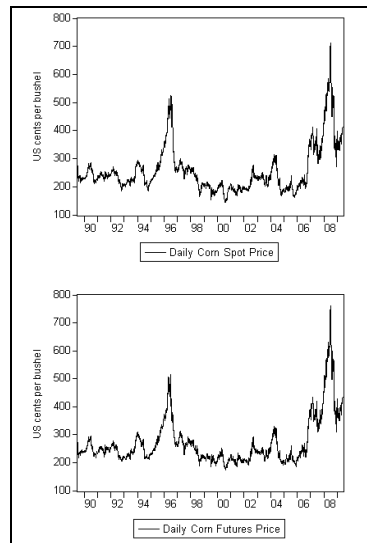
Figure 4: Daily Wheat Price Movements



Data Source: Thompson Datastream

Over the same period also corn production did not reach the expected level. However, in this case it was rather a demand shock that led to the strong price hike. After news spread that corn production was lagging behind, consumers started hoarding the commodity and thereby drove the price up.

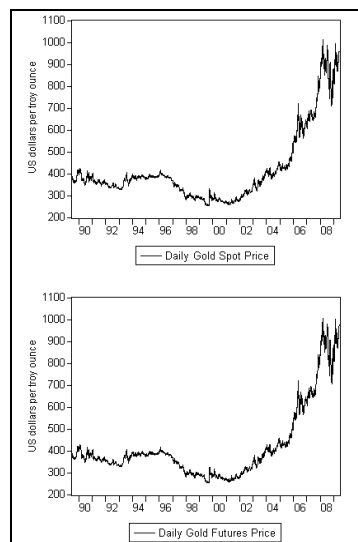
Figure 5: Daily Corn Price Movements



Data Source: Thompson Datastream

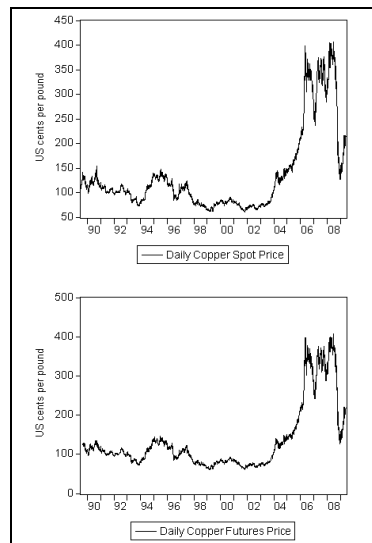
Gold and Copper prices appear nearly stationary over the 90's, however, they were also fluctuating around short run trends. No pronounced bull market was observed in gold price dynamics, which exhibited the smallest variances over the 90's of all commodities presented in this paper. Copper prices only increased rather strongly in 1994, when mine extraction in the United States, the world's second largest copper mine producer, stagnated due to heavy rainfalls in 1993 (<http://www.minerals.usgs.gov>).

Figure 6: Daily Gold Price Movements



Data Source: Thompson Datastream

Figure 7: Daily Copper Price Movements



Data Source: Thompson Datastream

Commodity prices have often been associated with a random walk without drift. Over the period 1990 – 2000 it seems that the dynamics could be consistent with this assumption, particularly often taken by the EMH. Prices appear to have wandered around as unpredictably as were the supply or demand shocks that caused the amplitudes. However, beginning with the year 2003 the picture changed. Prices followed a clearly identifiable upwards trend that culminated in peaks at least twice as high as the 1990's average. In mid 2008, this strong bull market turned into a strong downwards run.

In consideration of the price dynamics of the 21st century the random walk without drift hypothesis has to be rejected. At least from 2003 on prices followed distinctive trends.

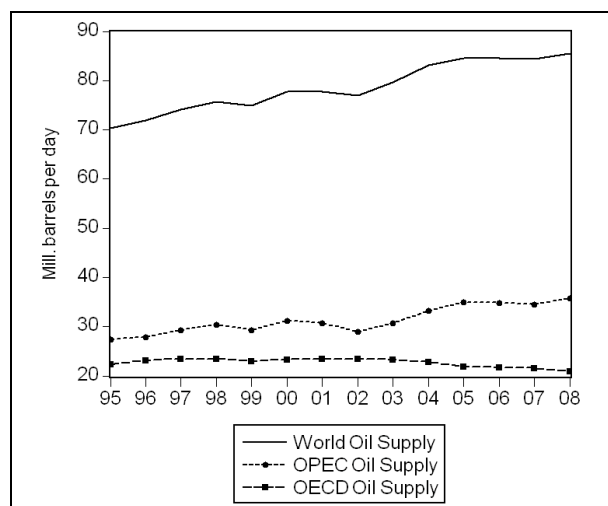
After taking a perfunctory look at the price dynamics, the next chapter will go into more detail regarding commodity fundamentals. For this purpose, supply and demand changes shall be compared to price movements over an equal time span.

3.2. Supply and Demand Conditions in Commodity Spot Markets

After taking a first glance at commodity spot and futures prices this section will include supply and demand conditions in the underlying commodity markets into the analysis. Due to the use of several graphs again, only the results for crude oil, wheat and corn will be shown. The logic deduced from looking at these three commodities, however, also applies to gold and copper. The introduction of data on supply of and demand for commodities into the analysis shall help to evaluate the validity of the hypothesis, that it was speculation that caused recent price increases. By contrast, fundamentalists suggest that exclusively (or at least to a great extent) changes in the supply of and demand for a commodity caused price dynamics.

Total worldwide oil production until 2003 increased from around 70,2 million barrels per day in 1995, to roughly 78 million barrels per day in 2002, which is equivalent to an average annual growth rate of 1,57 percent.

Figure 8: Crude Oil Supply after 1995

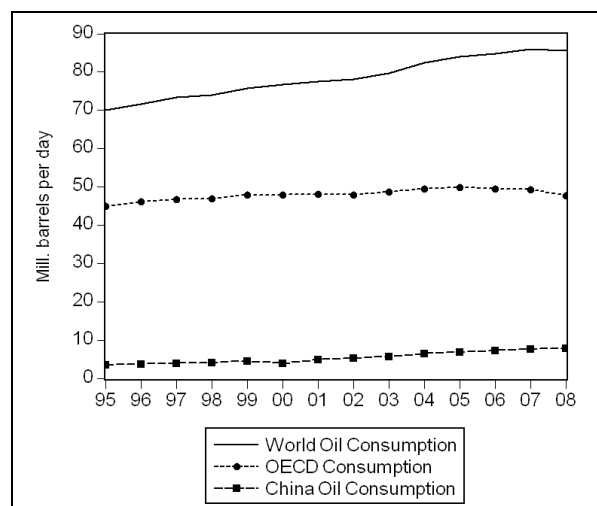


Data Source: Energy Information Agency (EIA)

Global oil consumption over the same period grew slightly stronger, by roughly 1,62 percent each year. As a consequence, commercial OECD oil inventories decreased between 1995 and 2002 (figure 10), however, crude oil spot and futures prices only rose very modestly, from roughly 18 dollars per

barrel to around 26 dollars per barrel in 2002. Against the background of demand slightly exceeding the production of crude oil, combined with decreases in commercial inventories, the modest price increase seems perfectly justified by fundamental changes.

Figure 9: Crude Oil Demand after 1995



Data Source: Energy Information Agency (EIA)

However, it was the period after 2003 the speculation hypothesis targets.

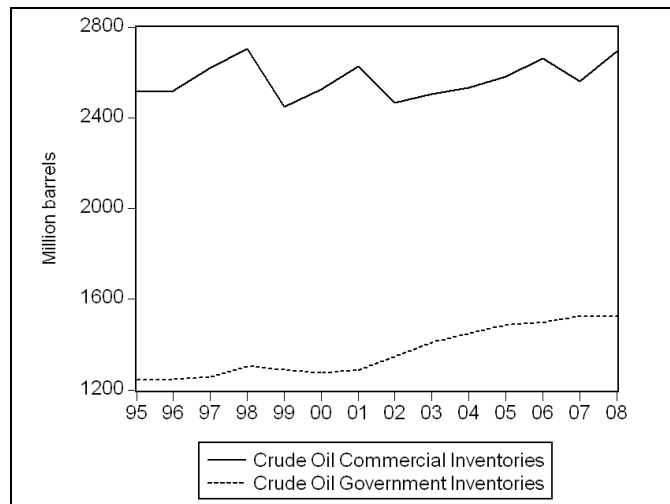
Between 2003 and 2007, global oil production picked up in speed and grew faster than global oil consumption. In 2004 and 2005 global oil supply even exceeded demand for oil; during 2006 the latter was marginally higher than production. As can be seen from figure 8, the increase in oil production between 2002 and 2005 mainly stemmed from additional OPEC supply.

As one would expect, commercial OECD inventories increased from 2003 on, due to the increase in production.

Comparing this period to the years between 1995 and 2002, one would expect spot and futures prices to have modestly decreased between 2003 and 2007, however, it was during that time when the oil price bull market started, with price increases from around 26 US dollars per barrel to roughly 65 US dollars per barrel in 2006.

It seems therefore rather implausible that it was solely market fundamentals that caused the strong price increases between 2003 and 2006.

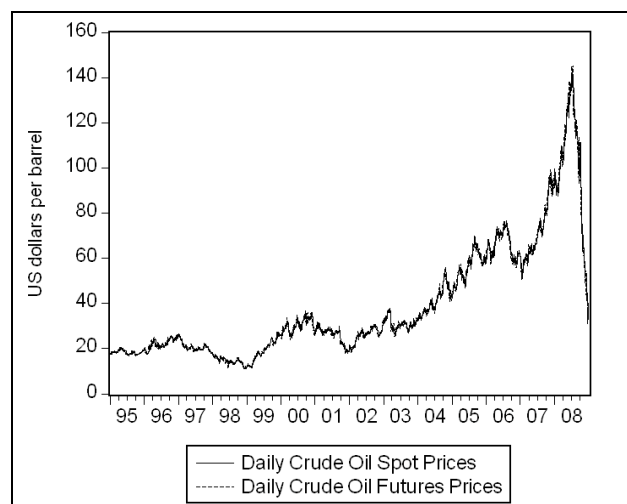
Figure 10: Commercial and Government Oil Inventories



Data Source: Energy Information Agency

The most spectacular crude oil price increases occurred between 2007 and mid 2008, when prices reached a peak of over 145 US dollars per barrel. During both years demand marginally exceeded the supply of crude oil, which is also the reason for the decline in commercial OECD inventories. As during the years before 2007, again it seems hard to believe that the crude oil bull market was caused by fundamentals.

Figure 11: Daily Crude Oil Spot and Futures Prices



Data Source: Thompson Datastream

The difference between supply and demand was not considerably higher than during the years from 1995 onwards. Also if the extent of the decrease in

inventories between 2007/2008 is compared to the increase between 2002 and 2007, it seems implausible that it could have caused such strong price increases.

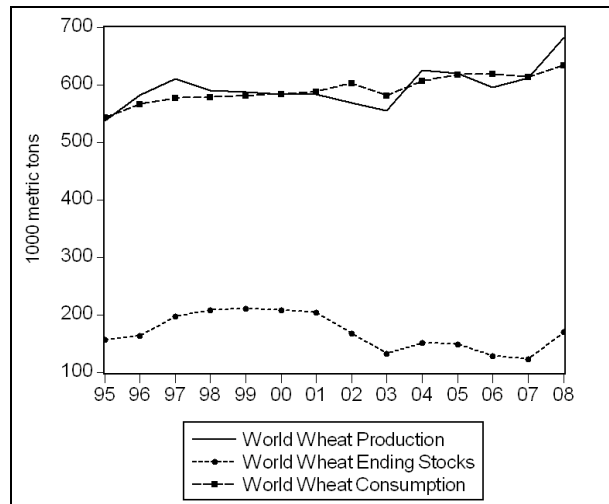
It is often argued that increasing demand from emerging economies, most notably China, has greatly influenced commodity prices (Schulmeister 2009). Figure 9 therefore also contains China's demand for crude oil. As can be seen, oil consumption of OECD countries stagnated between 1995 and 2008. The increasing global demand for crude oil therefore resulted almost exclusively from emerging markets. Chinese oil consumption, at least according to official data, has only increased very moderately over the past decade. The argument that Chinese demand for crude oil caused the impressive crude oil bull market between 2007 and 2008 is therefore also rather implausible. One question, however, that arises in the context of Chinese consumption is whether official data really captures the true extend of Chinese oil consumption.

Nevertheless, after analysing the development of the demand for and supply of crude oil, the speculation hypothesis seems to capture the causes of the price dynamics better than the efficiency hypothesis, as it is implausible that market fundamentals caused the strong bull markets between 2003 and mid 2008.

Let us now turn to the analysis of grain market conditions, namely those for corn and wheat. It can be anticipated that also for these two commodities, the fundamentalist hypothesis does not seem to be able to satisfactorily explain price increases.

Global production of wheat slightly exceeded consumption between 1995 and 2000, whereas from 2000 until 2004 the conditions were vice versa. Accordingly global wheat stocks increased until the year 2000, only to then decrease until 2004. The logic of supply and demand determining prices again would suggest that wheat prices should have increased between 2000 and 2004. However, they did not increase considerably, with the exception of a small bull market in 2002.

Figure 12: World Market Conditions for Wheat

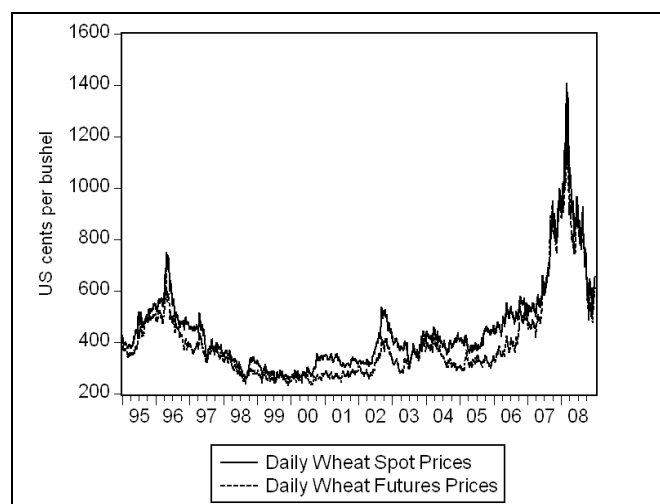


Data Source: United States Department of Agriculture (USDA)

It was from 2007 on, when wheat prices started to rocket. However, over that period wheat supply increased on average by 5,8 percent per year, while consumption annually increased only by 1,7 percent.

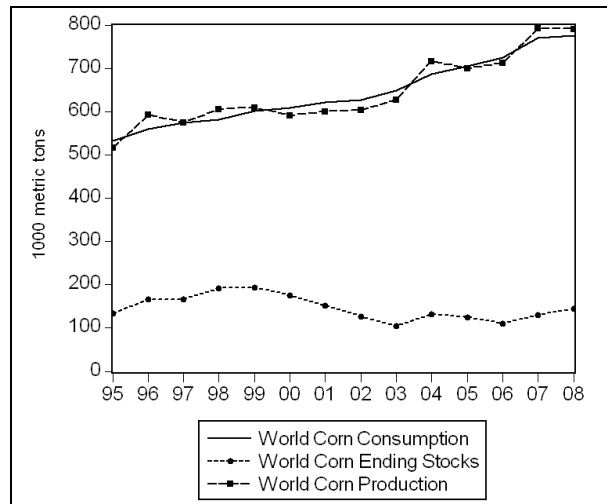
Again, if one compares the supply of and demand for wheat dynamics and their effects on prices over the years before 2007, it does not seem realistic that it was the fundamental changes that caused the strong bull market between 2007 and 2008.

Figure 13: Daily Wheat Spot and Futures Prices



Data Source: Thompson Datastream

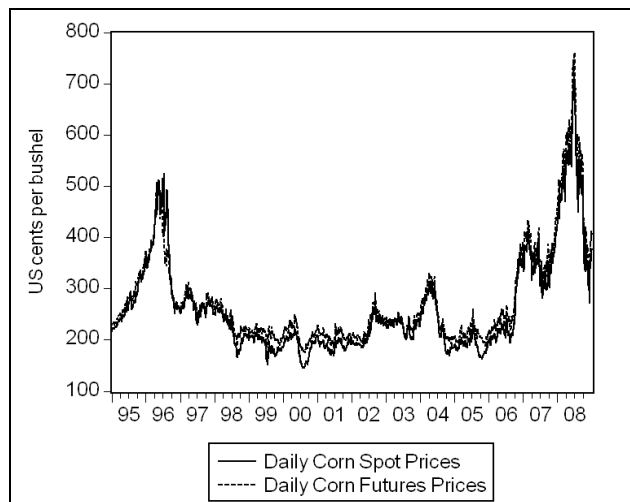
Figure 14: World Market Conditions for Corn



Data Source: United States Department of Agriculture (USDA)

Corn production and consumption dynamics were shaped very similar to wheat supply and demand dynamics. Between 2000 and 2004 consumption of corn exceeded the production, which caused corn stocks to decrease continuously until 2004. However, prices did not rise significantly during that period, but increased strongly between 2007 and 2008. Over that period corn production exceeded consumption and also stocks increased moderately.

Figure 15: Daily Corn Spot and Futures Prices



Data Source: Thompson Datastream

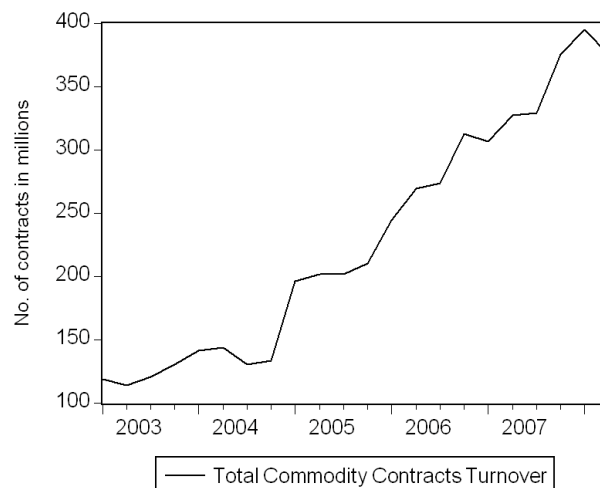
The analysis of the underlying market conditions leads to the conclusion that commodity prices overshoot their fundamental equilibrium prices considerably. Especially the bull markets between 2007 and mid 2008 were not justified by changes in the demand for or the supply of the commodities. This conclusion is backed up by the fact that the prices of crude oil, corn and wheat decreased virtually over night by over 50 percent in the second half of the year 2008, with fundamentals again not changing significantly. One reason for the strong price increases despite the absence of fundamental changes therefore could have been uninformed trading. Some markets participants may have responded to information other than on fundamental changes and therefore have traded on noise rather than on real information (UNCTAD 2009). Additionally a considerable part of investors may simply have followed the (trend exploiting) strategies of other market participants, which could be called herd behaviour. Both reasons indicate the failure of the Efficient Market Hypothesis on commodity markets. In an empirical analysis, however, it is not easy to distinguish between informed and uninformed traders, due to data restrictions.

3.3. An Analysis of Trading Activities in Commodity Futures Markets

In contrast to supply and demand factors, trading activities in commodity futures markets changed much more significantly over the period of large price increases.

The number of outstanding futures and options contracts on international commodity futures markets rose from roughly seven million contracts in 2003, to around 25 million contracts during the first quarter of 2008. The notional amount of over-the-counter commodity contracts increased from 2,9 billion US dollars in June 2005 to 7,6 billion US dollars in June 2007 (Bank of International Settlement, Quarterly Reviews). Also total turnover on international markets exhibited a sharp increase, as the following graph shows.

Figure 16: Turnover of Commodity Contracts



Data Source: Bank of International Settlement, Quarterly Review

This parallel development of financial activities on futures markets and the respective price increases could indicate the important role of speculation in commodity price dynamics.

To further investigate the role of speculation in recent commodity price dynamics, indicators provided by the Commodity Futures Trading Commission (CFTC) will be analysed. In their weekly- published Commitment of Traders report, the CFTC provides data on trading activities on commodity futures markets. The relevant market places for the commodities used in this paper are the Chicago Board of Trade (Corn and Wheat) and the New York Mercantile Exchange (Copper, Crude Oil and Gold).

Within their reports, the CFTC divides traders into two groups, commercial and non-commercial traders.

Traders obtaining commodity positions for hedging purposes are classified as commercial, while otherwise they will be captured as non-commercial. However, the distinction between the two categories is not clear in reality, as the increasing number of market participants and the evolution of more complex trading instruments complicate a definite determination. Furthermore, the distinction is based on a declaration traders have to fill out with the commission, leaving latitude for speculators to define (at least part of) their activities as commercial in order to bypass speculative position limits (UNCTAD 2009).

Additionally, since January 2006, the CFTC has further disaggregated data on traders by including a third category into their reports. The category Commodity Index Traders (CIT) contains financial players as investment or pension funds and swap dealers. However, data is only available for selective agricultural commodities, relevant for this paper only corn and wheat.

Data on the activities of Index Traders are of special interest as in discussions on commodity speculation they are often regarded as the elephant in the room, due to their large and long-only positions. Tables 1 and 2 not only provide evidence of the large proportion of open interest index traders accounted for on futures markets, but also on their almost exclusive engagement in long positions.¹⁰

The number of index traders is very small, less than 30 traders for each commodity (CFTC, Commitment of Traders Report). The average size of their long positions, however, is very large, as their positions account for a large proportion of total open interest.

Table 1: Composition of Open Interest Long between 2006 - 2008

	Percentage share in Open Interest long		
	2006	2007	2008
Wheat CBOT			
Pct. OI Non-commercial	35,73	39,92	41,31
Pct. OI Commercial	14,81	13,17	8,99
Pct. OI CIT	41,55	39,18	42,73
Non-reporting	7,9	7,73	6,97
Corn CBOT			
Pct. OI Non-commercial	41,01	42,57	43,71
Pct. OI Commercial	19,64	25,01	25,48
Pct. OI CIT	26,15	21	21,36
Non-reporting	13,2	11,4	9,45

Data Source: CFTC, Commitment of Traders Report

¹⁰ Open Interest denotes the total of all futures contracts in a market that have not been offset by transaction, delivery etc. One futures contract of corn or wheat includes 5000 bushels of the respective commodity.

Table 2: Composition of Open Interest Short between 2006 - 2008

Percentage share in Open Interest short			
	2006	2007	2008
Wheat CBOT			
Pct. OI Non-commercial	37,85	41,34	46,02
Pct. OI Commercial	48,09	42,96	35,93
Pct. OI CIT	0,975	2,2	5,95
Non-reporting	13	13,5	12,1
Corn CBOT			
Pct. OI Non-commercial	32,53	33,32	38,2
Pct. OI commercial	47,01	49,55	45,07
Pct. OI CIT	0,5	0,67	2,41
Non-reporting	19,96	16,46	14,32

Data Source: CFTC, Commitment of Traders Report

One has to keep in mind that prices in futures markets have been determined by buy (or sell) orders. Large long positions held by index traders therefore may well have driven up futures prices (at least temporarily). For example, the increasing US ethanol production has often been used as an argument to explain corn price increases. However, index traders accumulated enough corn contracts between 2003 and 2008 to fuel the entire US ethanol industry at full capacity for one year, which would put the United States in first place of worldwide ethanol production. Regarding wheat, index speculators obtained enough wheat contracts over the last years to satisfy the entire US household consumption for two years (Masters 2008a: 5).

As for crude oil, copper and gold no data on index speculation were available, therefore the ratio of non-commercial long- to total long positions was considered.

However, the analysis did not provide any clear evidence for an obvious correlation between the share of non-commercial positions in total positions and the respective futures prices.

Only after mid 2008, when futures prices decreased sharply, a weak correlation might have existed as the ratios for gold and copper also decreased rather significantly.

But as already mentioned before, one has to keep in mind the shortcomings of the (aggregated) CFTC data on market participants, especially since index traders were mostly classified as commercial traders (UNCTAD 2009).

3.4. Comparing the Composition of Commodity Price Runs During Bull Markets

Any primary bull market can be caused by two different dynamics (or a combination of those). Either short term upward runs last longer than their counter motions, or they are steeper. The same logic obviously applies, vice versa, to primary bear markets.

The Efficient Market Hypothesis predicts that prices react quickly to new information and move almost instantaneously into the direction at which fundamental changes point. According to this logic, the reason for a bull market should be that upward runs are steeper than downward runs, since prices adjust quickly to their new fundamental values. In a bull market, however, upward runs may also last longer than downward runs.

If speculation plays the decisive role in a bull market, then the dynamics should rather be the other way around. The concept of technical analysis, the most common tool used by commodity speculators, tries to capitalize on observable trends by betting either on their persistence or their reversal.

By buying additional commodity contracts, speculators who expect further price increases therefore prolong a bull market.

To gain further information on the characteristics of the strong price increases over the last years, the dynamics within primary bull markets were investigated.¹¹

For each commodity two well pronounced bull markets were chosen and the length as well as the slope of price runs within the long- term trend was

¹¹ A primary market is defined to last for a year or longer. Within the analysis, however, this concept was loosened, as some of the analysed bull markets lasted shorter than one year.

analysed.¹² Table 3 shows the average duration and average daily price change of upward runs in futures bull markets. Table 4 displays the results for downward runs within the same bull markets.¹³

Table 3: Upward Runs of Futures Prices during Bull Markets

		No. of upward runs	Average duration of upward runs in days	Average change in daily prices during upward runs
Crude Oil Futures	<i>1.7.2004 - 30.5.2006</i>	128	2,14	0,89 dollars per barrel
	<i>2.2.2007 - 3.7.2008</i>	98	2,08	1,42 dollars per barrel
Wheat Futures	<i>2.5.2006 - 16.10.2006</i>	34	1,88	6,71 US cents per bushel
	<i>4.4.2007 - 18.3.2008</i>	58	2,41	16,80 US cents per bushel
Corn Futures	<i>15.9.2006 - 22.2.2007</i>	32	2,22	5,69 US cents per barrel
	<i>2.8.2007 - 2.7.2008</i>	53	2,58	8,02 US cents per bushel
Gold Futures	<i>15.7.2005 - 11.5.2006</i>	53	2,42	4,94 US dollars per troy ounce
	<i>17.8.2007 - 18.3.2008</i>	34	2,71	7,79 US dollars per troy ounce
Copper Futures	<i>5.7.2005 - 11.5.2006</i>	55	2,49	3,18 US cents per pound
	<i>31.1.2007 - 4.5.2007</i>	17	2,47	5,41 US cents per pound

Data Source: Thompson Datastream

¹² The same kind of exercise was already carried out by Schulmeister (1987) and Schulmeister (2009).

¹³ Both based on original data.

Table 4: Downward Runs of Futures Prices during Bull Markets

		No. of downward runs	Average duration of downward runs in days	Average change in daily prices during downward runs
Crude Oil Futures	<i>1.7.2004 - 30.5.2006</i>	127	1,77	0,93 US dollars per barrel
	<i>2.2.2007 - 3.7.2008</i>	97	1,68	1,23 US dollars per barrel
Wheat Futures	<i>2.5.2006 - 16.10.2006</i>	33	1,69	5,63 US cents per bushel
	<i>4.4.2007 - 18.3.2008</i>	57	1,93	14,62 US cents per bushel
Corn Futures	<i>15.9.2006 - 22.2.2007</i>	31	1,42	4,71 US cents per bushel
	<i>2.8.2007 - 2.7.2008</i>	52	1,98	6,37 US cents per bushel
Gold Futures	<i>15.7.2005 - 11.5.2006</i>	52	1,67	3,79 US dollars per troy ounce
	<i>17.8.2007 - 18.3.2008</i>	33	1,85	5,94 US dollars per troy ounce
Copper Futures	<i>5.7.2005 - 11.5.2006</i>	54	1,59	2,18 US cents per pound
	<i>31.1.2007 - 4.5.2007</i>	16	1,62	4,1 US cents per pound

Data Source: Thompson Datastream

During the 2/2/2007 – 3/7/2008 crude oil futures bull market, upward runs were on average by 20% longer than downward runs (2,08 days compared to 1,68 days). The slope of upward price changes was just by roughly 13% steeper compared to downward runs. The average duration of upward runs during the 4/4/2007 – 18/3/2008 wheat futures bull market was also by 20% longer than their counter movements, while daily price changes during upward movements were steeper by just 13 percent.

Comparing the length of downward runs with upward runs also in the other bull markets, a clear pattern emerges.

In all out of the ten bull markets, upward runs lasted considerably longer than downward movements, on average by more than 25%. The most pronounced differences were observed in the copper bull markets, where upward runs lasted longer by over a third.

However, in nine out of ten bull markets also the slope of upward movements was steeper than the slope of their counter runs, on average by 17%. Only during the 2004 – 2006 crude oil bull market downward runs were steeper.

The fact that short- term upward runs always lasted longer than downward runs supports the logic of the speculation hypothesis. By betting on the persistence of upward trends, speculators protracted them at the same time. Especially the crude oil bull market between mid 2004 and mid 2006 fits the speculation logic, since upward runs not only lasted considerably longer than downward runs, but also exhibited the smaller slope.

However, these findings are put into perspective since in all other cases price level changes during upward trends were higher than during downward trends.

Another, although more ambiguous, pattern emerges if one compares the results of the different time horizons of the investigated bull markets. In three out of five cases during 2007 – 2008, the duration of upward runs was longer than during the same commodity's earlier bull market. In four out of five cases the short- term downward trends over the posterior period lasted longer compared to the earlier bull market.

E.g. compared to the 2006 wheat bull market, the average duration of upward runs during the 2007/2008 wheat bull market increased by further 20 percent, so did the length of downward runs by additional 13 percent. While an upward run within the 2006 – 2007 corn futures bull market lasted on average 2,22 days, the average duration increased to 2,58 days between 2007 and 2008.

One possible explanation for the increased durations of price runs during bull markets the year before the price crash in 2008 could be the bandwagon effect.

With the economic crisis on sight and spreading information on money making opportunities with commodity futures speculation, additional speculators, even amateurs, got into the game. By also using trend following trading techniques, the extra number of speculators that entered the market further extended upward runs within the bull markets. Also the dimension of average price increases during upward (downward) runs within 2007/2008 bull markets increased. Compared to the earlier bull market the average daily price change during the 2007 – 2008 wheat futures bull market more than doubled. As in the pattern before, the slope of price increases during upward runs is steeper than the slope of price changes during downward movements.

In this case, however, stronger daily price alterations could well have stemmed from additional speculative demand.

Both detected patterns of this partial analysis are in line with the speculation hypothesis. Persisting short- term price runs seem to have contributed considerably to primary bull markets.

The fact that daily price changes during upward movements were bigger, however, suggests that also fundamental changes influenced the dynamics.

One question that arises is whether the upward runs are sufficiently longer than downward runs during a bull market to conclude that speculation did cause bull market. Which number would mean “sufficiently longer”?

And is it possible that, especially during 2007/2008, increasing speculation, panic- acquisitions or hoarding caused the strong changes in price levels?

To draw a definite conclusion, further investigation of the price dynamics within primary bull markets would be required.

3.5 Krugman’s Propositions and their Shortcomings

In the preceding exercise I concluded that the persistence of upward runs during commodity bull markets indicated a price driving effect of trend following trading techniques, thus speculation.

Since commodity futures prices have been used as benchmarks for spot prices, speculative demand in the futures market determined also spot prices.

In a situation where speculation in the futures market shaped spot prices, Paul Krugman brought up two arguments.

First, price increases in the spot market should have caused a reduction in the demand for the physical commodity. For the market to still be in equilibrium, the excess spot supply has had to be either compensated by additional speculative demand, or producers had to cut down their supply. Additional speculative demand should then have shown up in rising inventories.

Second, the futures- and the spot market should have been in a *contango*, a market situation where the futures prices were higher than the spot prices (<http://krugman.blogs.nytimes.com>).

Table 5 summarizes the relationships between futures and spot prices during the 2007 – 2008 bull markets. During more than 50 percent of the days, futures prices were higher than spot prices. Within the crude oil bull market, the market was in roughly 64 percent of the days in a contango, during the gold bull market in around 68 percent of the days. The most striking result was obtained for corn, where during 2007 and 2008 the market was in a “pure” contango, with futures prices on average 33,3 US cents per bushel higher than spot prices.

The result for corn stands in clear contrast to the one obtained for wheat, which is not included in the table as the wheat market was mostly in backwardation.

Looking at the results of this examination, however, the question arises, whether the number of days in contango or the average price difference between futures- and spot prices really have any explanatory value. It is not clear, which price spread would be necessary in order to attract speculators? Data on storage costs would be required. Also, what if the accumulation of inventories was conducted underground? It could be possible that producers reduced their supply just by the amount necessary for the spot market to clear. If one assumes a small price elasticity of demand, then the excess spot supply could have been small enough that the reduction of supply is not easily detected in official data. OPEC supply of crude oil for example slightly decreased over the past years.

Another ambiguity is conveyed by the question which futures contracts were used as the benchmarks for spot prices. Within the analysis, the prices of the nearest contracts to expire were used. During such strong bull markets, however, it is not clear whether it was the contract closest to expire, which was used as a benchmark.

Table 5: Contango and Backwardation in Commodity Futures Markets

		No. Of days in contango	No. Of days in backwardation	Average price difference during contango
Crude Oil Futures	.2.2007 - 3.7.2008	236	134	2,55 US dollars per barrel
Corn Futures	.8.2007 - 2.7.2008	240	0	33,3 US cents per barrel
Gold Futures	.8.2007 - 18.3.2008	104	49	3,56 US dollars per troy ounce
Copper Futures	.1.1.2007 - 4.5.2007	38	30	4,22 US cents per pound

Data Source: Thompson Datastream

The first argument stated that if it had been speculation that had driven up prices, then this should have shown up in rising inventories.

However, the question is whether rising inventories really should have been an indispensable consequence of speculation.

It is realistic to assume that the short- term price elasticity of several commodities was very low, especially the one for crude oil and food (UNCTAD 2009). If no close substitutes were quickly available, consumers of those commodities had no other choice than to simply cope with price increases.

Therefore firms still kept up the same demand but shifted the rising production costs to consumers by increasing prices. US inflation rose from 2,08 percent in January 2007 to 5,6 percent in July 2008, according to the US Bureau of Labour Statistics. Spot demand did not decline accordingly and no accumulation of inventories happened. Data on commodity inventories are also not entirely reliable but rather incomplete. As inventories have often not been reported, a significant part is not included in official data. Additionally a large number of countries entailed trade restrictions on several commodities. Due to the resulting tight market conditions, consumers who wanted to accumulate inventories were not able to do so, however, the attempt could have done to push prices further up.

Whether the absence of observable increases in commodity inventories is an indicator that speculation did not cause the enormous price hikes is questionable, due to above- mentioned arguments.

3.6 Assumptions of Equilibrium Commodity Price Models

3.6.1. Normal Distribution and Independent Prices over Time

The probability theory underlying the economic analysis of commodity price dynamics very often describes commodity prices to be normally distributed.

The properties of the normal distribution are a consequence of the central limit theorem, which states that a sufficiently large number of random variables are approximately normally distributed, if they are independent and identically distributed (i.i.d.) with a finite variance and mean.

The assumption that prices are i.i.d. distributed can be found in a large number of papers dealing with commodity price dynamics, especially equilibrium (structural) models.

As the independence of (daily) prices also constitutes a crucial assumption for prices to follow a random walk, it is worth the time to take a closer look at it, especially against the background of recent year's dynamics.

As it usually constitutes one of the basic assumptions of equilibrium approaches, it is worth the time to take a closer look at it, especially against the background of recent years' dynamics.

If a number of random variables are independent and identically distributed, then the outcome of one variable does not depend on the outcome of any other variable, formally $P(X = x_i, Y = y_i) = P(X = x_i) \cdot P(Y = y_i)$.

In our case this means that each daily price is generated by independent events, and so today's price does not influence tomorrow's price. Prices are independent over time.

The logic behind the assumption of commodity prices being independent over time derives from the EMH, as formulated by Eugene Fama (1970).

It states that price changes are normally distributed random variables, as they occur due to the random emergence of new information on fundamental values of commodities.

Obviously this reasoning stands in clear contrast to the hypothesis formulated at the beginning of this chapter. It is hard to believe that commodity prices are

independent over time. According to my interpretation of the commodity price dynamics after 2003 using trend following trading techniques speculation exerted a significant influence on prices by elongating upward (downward) runs.

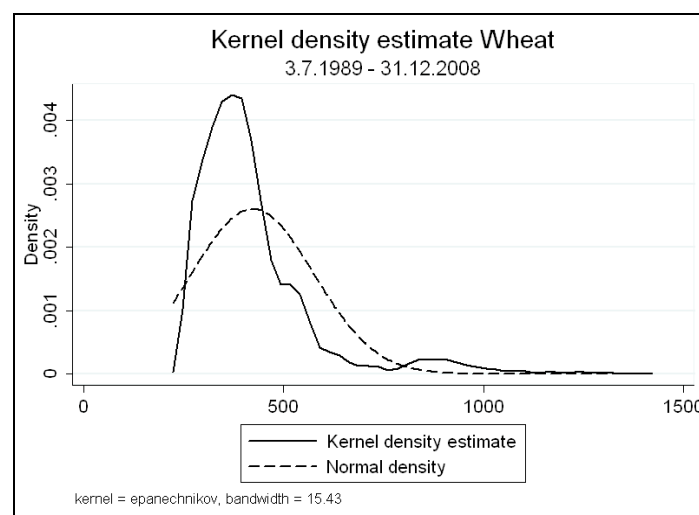
The EMH dismisses this argument stating that investors are fully rational and therefore prices will stay in line with their fundamental values.

However, it is the irrationality of market participants that causes the dependence of prices over time.

Investment techniques (such as technical analysis) used by commodity speculators try to exploit the persistence of price runs (the temporal dependence of prices). It even seems natural to believe that a strong upward run, fundamental changes *ceteris paribus*, will continue to persist up to a certain degree. By betting on the persistence of a short- term trend, speculators prolong it at the same time. The profitability of these trading rules, on which can be deduced by looking at the increasing volume of capital channelled into commodity futures, strengthens this self-reinforcing process.

In order to test these propositions, the author has analysed the distribution of daily spot prices of wheat, corn, crude oil, copper and gold.

Figure 17: Distribution of Daily Wheat Prices

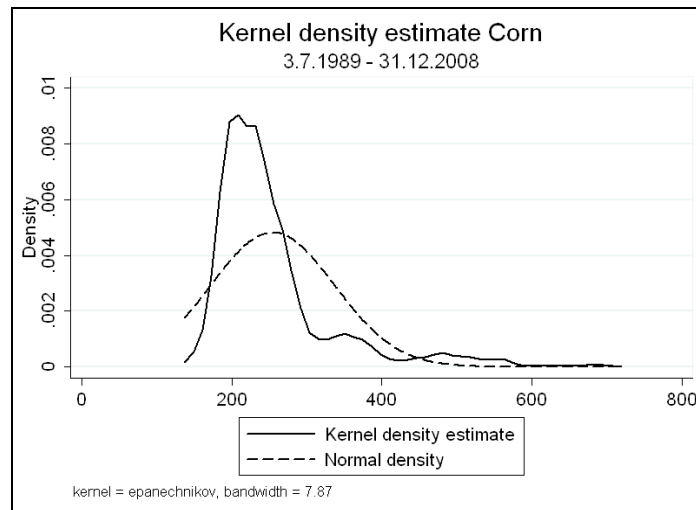


Data Source: Thompson Datastream

Figure 17 to 21 show the distribution of commodity spot prices over the whole data sample. All graphs include a Kernel Density estimation as well as a

normal overlay, to see what a normally distributed variable should look like. Kernel density graphs (which estimate the probability density function of each variable) have been chosen over a histogram due to their smoother appearance.

Figure 18: Distribution of Daily Corn Prices



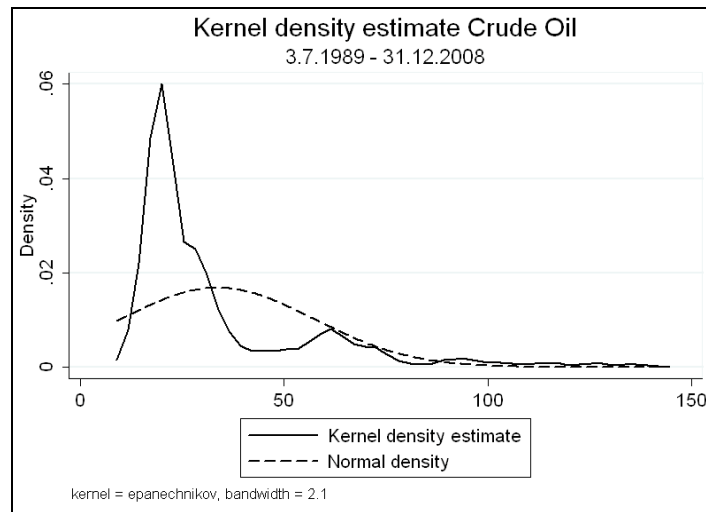
Data Source: Thompson Datastream

At first glance not a single variable appears normally distributed.

A normal distribution exhibits a theoretical value of zero for the skew and a value of three for the kurtosis. If commodity prices have deviated from a normal distribution it therefore can be noted from these values.

A kurtosis that exceeds the theoretical value of three can be interpreted as a sign for fat tails, meaning that the density at the edges exceeds the boundaries of a normal distribution. As can be seen from the kernel density estimates in the graphs, boundaries were exceeded for all five commodities, most notably for copper spot prices.

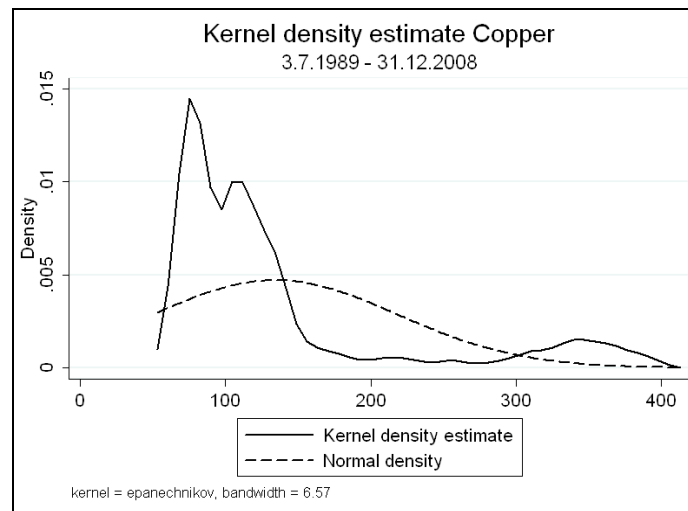
Figure 19: Distribution of Daily Crude Oil Prices



Data Source: Thompson Datastream

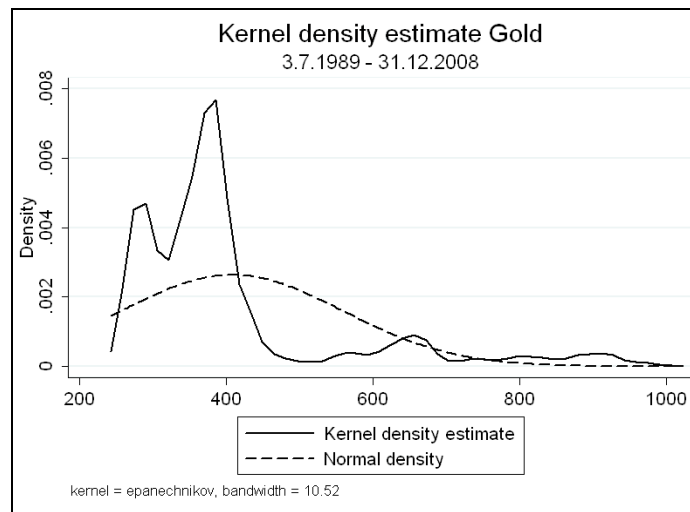
Prices exhibited heavy fat tail distributions to the right hand side. This means that for each commodity a considerable amount of daily prices exceeded the mean by far, which is not too surprising if one bears in mind the spectacular price increases over the last years.

Figure 20: Distribution of Daily Copper Prices



Data Source: Thompson Datastream

Figure 21: Distribution of Daily Gold Prices



Data Source: Thompson Datastream

Additionally to the heavy right fat tails, also the density in the centre of the distribution exceeded the boundaries of a normal distribution, whereas values slightly higher than the mean were less often observed.

Remarkably, the density functions at the fat right tails were larger than in regions with more modest positive price deviations from the mean, again very pronounced for copper. This indicates that over the sample period price increases exceeding the mean occurred to a large degree in regions with extremely high variances. If these price increases were really caused by fundamental changes, these would have had to be remarkably strong.

To back up these observations table 6 summarizes the values for the mean, standard deviation, skew, kurtosis and results for the Jarque Bera test for the five commodities. The latter was used to test whether prices were normally distributed. The Jarque Bera test statistic is defined as:

$$JB = \frac{n}{6} \cdot (s^2 + \frac{(k-3)^2}{4})$$

with s denoting the skew and k denoting the kurtosis of the distribution. Under the null hypothesis that the variable is normally distributed, the JB statistic is asymptotically Chi Squared distributed, with two degrees of freedom.

Table 6: Summary Statistics of Spot Prices between 1990 - 2009

	Mean	Std.Deviation	Skew	Kurtosis	JB test	Probability
Wheat	422,59	153,45	2,369	10,049	15297	0
Corn	254,34	82,85	2,191	8,598	10716	0
Crude Oil	33,65	23,68	2,036	7,157	7180	0
Copper	134,11	84,69	1,827	5,134	3798	0
Gold	407,9	151,27	1,948	6,293	5519	0

Data Source: Thompson Datastream

All commodities exhibited an excess kurtosis, proving the observation that price distributions have fat tails. If one takes the values of the mean and standard deviation and looks at the graphs again, it becomes very obvious that the density in the medium range above the mean was very low in all five cases. Price deviations upwards from the mean therefore occurred more often in very high price regions. E.g. the density of price deviations from the mean of daily copper spot prices was higher for the region between 300 and 400 US cents per pound, than the density for values between 200 and 300 US cents per pound, with a copper spot price mean of 134,11 US cents per pound.

Finally, the null hypothesis of the Jarque Bera- Test that prices were normally distributed can clearly be rejected in all cases.

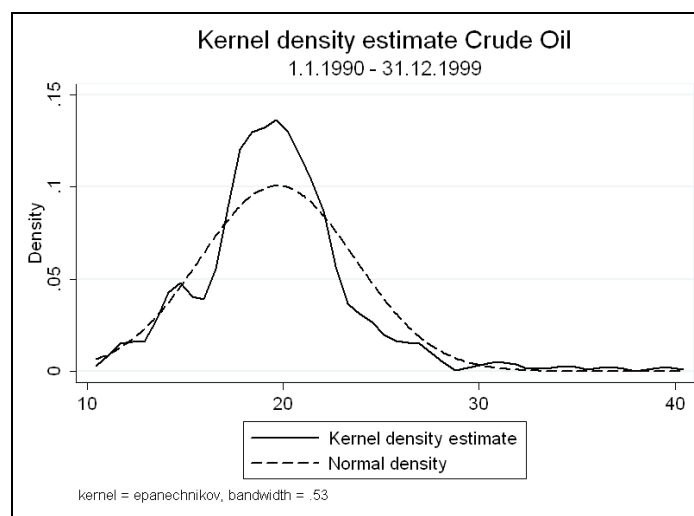
Over the sample period 1989 to the end of 2008, spot prices for wheat, corn, crude oil, copper and gold were not normally distributed. The findings of this chapter clearly rule out that commodity prices actually followed a random walk without drift (often assumed by the EMH) as prices have not been independent over time. Additionally the price correlations over time raise doubt about the well functioning of arbitrage, as proposed by the EMH.

In a next step, the sample will be divided into two periods, namely the 1990's and the target period of the hypothesis, 2003 – 2008.

Splitting up the entire sample shall serve the purpose to analyse whether prices followed different distributions, one with a small variance over the 1990's and one with a large variance after 2003. The assumption behind this procedure is that commodity prices might be approximated by two different distributions, one for "ordinary" times and one for times characterized by

financial turbulences (Streißler 2009). As I stated in my hypothesis, investors were looking for new investment opportunities at the beginning of the 21st century. Capital was channelled into commodity futures markets. After the outbreak of the financial crisis had become apparent in mid 2007, dynamics in commodity markets tightened even more, ending with the price crash over the second half of 2008. Financial developments after 2003 therefore have greatly influenced the behaviour of commodity prices.

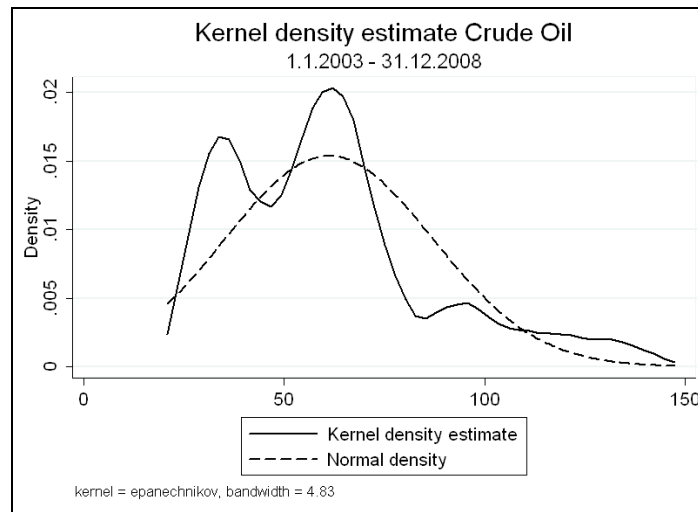
Figure 22: Distribution of Daily Crude Oil Prices before 2003



Data Source: Thompson Datastream

However, I still do not expect prices over the 90's to be approximated by a normal distribution.

Figure 23: Distribution of Daily Crude Oil Prices after 2003



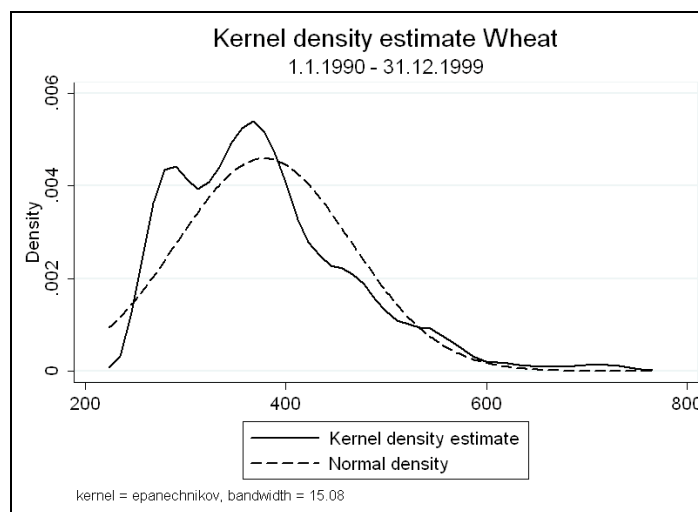
Data Source: Thompson Datastream

Again the graphs show that prices were not normally distributed, neither during the first, nor during the second period.

However, over the 1990's the kernel density estimation did not differ as obviously from the normal overlay as over the posterior period.

Crude oil prices over the 90's could have followed a leptokurtic distribution, as the excess kurtosis in the centre (the crown above the peak of the Gaussian bell) is most pronounced, while the fat tail is less.

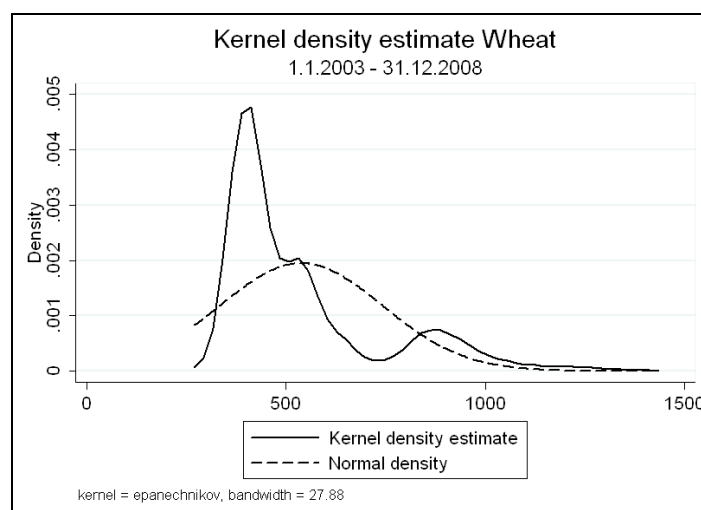
Figure 24: Distribution of Daily Wheat Prices before 2003



Data Source: Thompson Datastream

The latter, which were observed clearly in the whole sample, are also considerably less pronounced for wheat prices between the years 1990 and 2000. After 2003 they are again more visible. Density in the region with prices slightly above the mean was notably higher during the 90's, while the density of the middle range is quite small again after 2003.

Figure 25: Distribution of Daily Wheat Prices after 2003



Data Source: Thompson Datastream

The null hypothesis of the Jarque Bera test again can be rejected again. During both periods prices were not normally distributed. For four out of five commodities, the kurtosis was even higher during the 1990's.

Table 7: Summary Statistics of Spot Prices between 1990 - 2000

	Mean	Std.Deviation	Skew	Kurtosis	JB test	Probability
Wheat	378,4	86,85	1,04	4,41	697	0
Corn	251,4	59,69	2,12	8,59	5365	0
Crude Oil	19,7	3,96	1,18	7,05	2396	0
Copper	100,8	20,42	0,02	2,1	88,21	0
Gold	351	39,48	-0,71	2,45	251	0

Data Source: Thompson Datastream

The most notable difference, however, was the significantly increased standard deviations between 2003 and 2008. Compared to the 90's, standard deviations increased at least by 200%. During the latter period commodity

prices were a lot more volatile, with considerably higher deviations of daily prices from the mean.

Table 8: Summary Statistics of Spot Prices between 2003 - 2009

	Mean	Std.Deviation	Skew	Kurtosis	JB test	Probability
Wheat	538	204,79	1,51	4,61	771	0
Corn	289	114,93	1,35	4,28	587	0
Crude Oil	61	25,69	1	3,67	292	0
Copper	220	107,58	0,17	1,48	157	0
Gold	565	184,16	0,6	2,13	143	0

Data Source: Thompson Datastream

3.6.2. Inter-Correlations and Index Speculation

In addition to price dependence over time, prices of different commodities were inter-correlated between 2003 and 2009.

To a certain extent, assuming the mutual independence of different commodity prices would be more intuitive than the independence of prices over time. One would hardly think that daily prices of crude oil futures are influenced by the dynamics of corn prices.

However, by investing in commodity indices, speculation also led to significant inter-correlations between the prices of different commodities. Rather than analysing individual market conditions, many institutional investors (hedge funds, pension funds etc.) distributed their capital among key commodities. With a large amount of additional speculative capital channelled into commodity indices between 2003 and 2008, the prices of several commodities increased jointly.

To see whether this last proposition that commodity prices are mutually dependent is valid, correlations between the different commodities were constructed. Again, according to the line of arguments, the whole sample was divided into two sub samples, the 1990's and the period 2003 until the end of 2008. The results of the correlations are presented in table 9 and 10.

Table 9: Correlations between Spot Prices over 1990 - 2000

	Wheat	Corn	Crude Oil	Copper	Gold
Wheat	1				
Corn	0,8	1			
Crude Oil	0,008	0,06	1		
Copper	0,44	0,26	0,37	1	
Gold	0,51	0,46	0,29	0,68	1

Data Source: Thompson Datastream

Table 9, covering the period from 1990 to the end of the past century exhibits the correlation results one would expect for such diverse commodities. The only notably high correlations were between wheat and corn and between gold and copper, although to a much lesser extent.

Both wheat and corn share some of the most important producers, such as the United States or Canada. If one or more of these countries are affected by disadvantageous weather conditions, such as a severe drought, both commodities yields will be affected. Price movements into similar directions are therefore not too surprising.

Other correlations, for example between wheat and crude oil or corn and copper were clearly insignificant, with values of 0,008 and 0,26 respectively.

Table 10: Correlations between Spot Prices over 2003 - 2009

	Wheat	Corn	Crude Oil	Copper	Gold
Wheat	1				
Corn	0,84	1			
Crude Oil	0,83	0,76	1		
Copper	0,75	0,63	0,84	1	
Gold	0,9	0,82	0,88	0,85	1

Data Source: Thompson Datastream

After 2003, however, correlations changed significantly and several pairs of commodities showed unexpected results.

The correlation between crude oil and wheat increased from 0,008 over the first period to a value of 0,83 after 2003.

Crude oil- as well as gold prices correlated with every other price during the latter period. This result is indeed very much a surprise, since one would not have expected a correlation of 0,90 between gold and wheat prices.

The answer to the mutual dependence of daily commodity prices after 2003 is provided by the hypothesis formulated in this paper. Investors distributed fixed amounts of capital across a number of commodities, by investing in commodity indices, such as the Goldman Sachs or the Dow Jones-AIG index. By doing so, additional (speculative) demand increased significantly for all of the commodities included in an index. Price movements into similar directions, most notably of course upward movements, were the result.

Increasing inter-correlations between different commodities could also have been (partly) the result of herd behaviour and uniformed trading, especially after the beginning collapse of the real estate market (UNCTAD 2009).

4. Conclusion

The main purpose of this study was the analysis of the empirical behaviour of five key commodity prices in order to contribute to the discussion about the role of speculation in commodity price dynamics between 2003 and 2009.

A comprehensive knowledge and understanding of commodity price dynamics is a necessary condition for economic and political stability. Crude oil still constitutes a major input factor of global industrial production and price hikes therefore directly affect global economic growth. The vast majority of people in developing countries are net food buyers and spend a large proportion of their income on food (Minot 2008, Ivanic and Martin 2008). The sharp price increases of agricultural commodities between 2007 and mid 2008 therefore especially hit the poorest worldwide. This fact was reflected in the considerable increase of the number of malnourished people worldwide over those 18 months. FAO estimated that compared to 2003, an additional 150 million has had to suffer from chronic hunger in 2009 (FAO 2009).

The empirical findings of this study stand in clear contrast to the predominant paradigm of contemporary economics of resources, the belief in the efficiency of commodity markets.

Remember that in efficient commodity markets, changes in the supply of and the demand for a commodity cause price dynamics. Section 3.2 analysed the fundamental conditions in the underlying spot markets for corn, crude oil and wheat. Until the beginning of the 21st century it seemed plausible that the price dynamics of corn, crude oil and wheat were caused by shifts in fundamental factors. Prices increased when demand exceeded supply and vice versa. However, the dynamics after 2003 did not appear to be consistent with fundamental changes. Between 2003 and 2007 the spot price of crude oil more than doubled even though supply of the commodity grew faster than demand for the commodity. If the crude oil price over the subsequent 18 months is compared to anterior fundamental changes and the corresponding price dynamics, it also seems implausible that the immense price hikes were caused by market fundamentals. The same conclusion was drawn after

analysing spot market conditions for corn and wheat. Based on the comparison of market fundamentals and price movements, it seemed that the proposition of efficient markets could not hold up against the empirical findings.

The analysis of trading activities in commodity futures markets did not deliver any such definite results. However, this was mainly due to the non-transparency of data on trader categories in futures markets. Only after 2006 the CFTC provided more detailed data on commodity futures trading activities, a space of time too short for obtaining substantive results.

Section 3.4 of the study broke down the primary bull market between 2003 and mid 2008 into several periods of smaller length. The goal of this approach was the comparison of the duration and slope of upward and downward runs within any chosen bull market. The logic behind the EMH would have predicted that daily price increases during bull markets exhibited a steeper slope than daily price decreases. If one perceived speculation, i.e. trend following trading techniques to have caused the bull markets, upward runs should have lasted longer than downward runs during bull markets.

The procedure yielded mixed results again. However, it rather emphasised the influence of speculative activity on price dynamics. Within each considered bull market for all five commodities upward runs indeed lasted longer than downward runs, however, in most cases also exhibited the greater slope.

The fact that during bull markets between 2007 and mid 2008, the period characterized by the sharpest price hikes, upward runs lasted longer compared to upward runs during bull markets before 2007 added additional support to the speculation hypothesis.

The strongest evidence for the destabilizing effects of speculation on commodity prices resulted from the examination of price distributions and the detailed correlation analysis.

Over the whole sample period, 1990 – 2009, prices of all five commodities were not, as assumed by equilibrium models, normally distributed. Instead, excess kurtosis and heavy fat tails were observed. The same results were

obtained when the whole data sample was reduced to the period 2003 – 2009. The observation of extremely high variances points to the magnitude of price changes that were observed in commodity markets over the past years. Even more important, it puts considerable pressure on the proposition of efficient commodity markets. The high density of prices that exceeded the sample mean by far could indicate a price-driving effect of speculation. Due to inductive behaviour, traders in commodity futures markets protracted price hikes without any fundamental reasons to do so. Past price increases induced speculators to bet on the hikes to continue. This is exactly what trend following trading techniques, vastly used in commodity futures markets did. The process was self-reinforcing since rising prices and the profitability of trading supported each other.

Supporters of the EMH would immediately bring up the stabilizing effects of arbitrage to counter the argument of self-reinforcing price runs. However, as it was described in section 3.5 of the study, arbitrageurs are in an agency relationship with uninformed investors whose capital they need in order to perform their trades. Since investors lack any profound knowledge of the market, they allocate their capital based on past returns. So if the mispricing against which arbitrageurs trade worsens over time, investors will only observe arbitrageurs losing money and therefore will withdraw their funds (Shleifer 2000). Arbitrage in commodity futures market might therefore have been most constrained, when prices deviated the strongest from their fundamental equilibrium values. And even if arbitrageurs had not been subject to capital constraints, they still might have been forced to concern themselves with the mass psychology of the market, rather than with the “true value” of a commodity (Keynes 1936). The finding of high variances also highlights the crucial importance of assessing shorter time horizons in the evaluation of commodity markets. Structural models only acknowledge temporary price deviations (not caused by speculation) and assume a mean reverting effect over the long run. However, over the period 2003 to 2009 no such mean reverting effect was observed. Until the second quarter of 2008, commodity prices increased without converging to any long run equilibrium value. And even after the crashes in the second half of 2008, prices were considerably higher than before 2003, without fundamentals seeming to justify this level.

Speculators and commercial traders in commodity futures markets are focused on short time horizons. Comprehensive approaches to theoretically modelled commodity markets should acknowledge this fact. Furthermore, a period of more than five years, during which no mean reversion was observed can hardly be considered as a short time horizon.

The fact that prices were not normally distributed after 1990 also contradicts the random walk without drift hypothesis. Remember, if prices had followed a random walk without drift, speculation based on past price observations could not have had yielded constant above equilibrium returns. However, the dependence of prices over time did leave room for the continued profitability of trend following trading and therefore for the destabilizing effect of speculation.

In the last section of the empirical part of this study, considerably high inter-correlations between substantially different commodities were encountered. Nearly identical price movements of diverse commodities after 2003 suggest that index speculation played a large role in price hikes. Investors in commodity indices allocated fixed amounts of capital across several key commodities, regardless of the underlying fundamental market conditions. As a result, large buy orders put pressure on all of these prices, even if fundamental factors did not change significantly.

The evidence found in this study credibly supports the hypothesis that speculation amplified price dynamics and caused prices to overshoot their fundamental equilibrium values during the period 2003 – 2009. The finding of speculatively driven commodity prices has several important theoretical and empirical implications. First, it underlines the inability of equilibrium models to describe commodity price dynamics between 2003 and 2009. Commodity markets did not function in accordance with the efficient market view. It seems that irrational behaviour and limited arbitrage have been a general condition in commodity markets, at least over the recent years. The dependence of prices over time and inter-correlations need to be incorporated into theoretical models. So has to be the absence of mean reversion over a considerable long time period. The fact that commodity prices exhibited high variances over the past years challenges the convergence of prices to any long run equilibrium

over this period of time. To depart from sticking to the existence of long run equilibrium and to market efficiency is also an important task of critical economic science, as during periods of mispricing considerable time passes. Even if prices converge to their long run equilibrium at some point in time, until then millions of people might die of hunger and the inability to afford food. The growing importance of speculation in commodity futures markets also increases the difficulties commercial traders face. Hedging becomes more complex due to the presence of speculators, since price signals stemming from futures contracts cannot be relied on. To the extent that speculators caused the high variance of prices, hedging might even become unaffordable for commercial traders from developing countries, since they may not be able to afford margin calls (UNCTAD 2009). During the analysed period 2003 – 2009, margin levels for several commodities have increased at the Chicago Board of Trade.

The results of this study suggest that the functioning of commodity markets has not been in line with the efficiency view. However, further research on the topic is still required in order to support the findings of this study.

The main challenge to the analysis of commodity price dynamics remains the lack of comprehensive data. It has been hard for critics of the efficient market theorem to establish a clear link between speculation and commodity price hikes. Little detailed information was available on trading activities in commodity futures markets. Only recently has the CFTC began to collect disaggregated data. Also data on stocks, which constitute a major factor in the analysis of resources, is far from complete. Due to the lack of data, regressions and causality tests performed during the creation of this study were left out in the final version of this paper.

Lately critics of the efficiency hypothesis have very often arrogated the regulation of and political intervention in commodity markets. However, it is crucial for the regulator to be equipped with comprehensive knowledge and understanding of the respective markets. The ability of commodity market regulation strongly depends on further collection of data on trading activities in futures markets.

5. References

- Allen, Franklin and Gale, Douglas (1994): "Limited Market Participation and Volatility of Asset Prices", *The American Economic Review*, Vol. 84, No. 4, pp. 933-955.
- Alexander, Gordon J. and Sharpe, William (1990): "Investments", 4th Edition, Englewood Cliffs, NJ, Prentice Hall.
- Bailey, Roy and Chambers, Marcus (1996): "A Theory of Commodity Price Fluctuations", *The Journal of Political Economy*, Vol. 104, No. 5, pp. 924-954.
- Barberis, Nicholas, Shleifer, Andrei and Vishny Robert (1998): "A model of Investor Sentiment", *Journal of Financial Economics*, Vol. 49, pp. 307-343.
- Casassus, Jaime, Collin-Dufresne, Pierre and Routledge, Bryan R. (2005): "Equilibrium Commodity Prices with Irreversible Investment and Non-Linear Technologies", NBER Working Paper No. 11864.
Available from: <http://www.nber.org> (8/8/2009)
- Deaton, Angus and Laroque, Guy (1992): "On the Behaviour of Commodity Prices", *Review of Economic Studies* 59, pp. 1-23.
- Deaton, Angus and Laroque, Guy (1996): "Competitive Storage and Commodity Price Dynamics", *The Journal of Political Economy*, Vol. 104, No. 5, pp. 896-923.
- Fama, Eugene (1970): "Efficient Capital Markets: A Review of Theory and Empirical Work", *The Journal of Finance*, Vol. 25, No. 2, pp. 383-417.

Fama, Eugene (1976): "Foundations of Finance", Basic Books Inc., Publishers, New York.

Fama Eugene (1991): "Efficient Capital Markets II", The Journal of Finance, Vol. 46, No. 5, pp. 1575-1617.

Fama, Eugene (1997): "Market Efficiency, long-term returns, and behavioural finance", Journal of Financial Economics, Vol. 49, pp. 283-306.

Fattouh, Bassam (2005): "The Causes of Crude Oil Price Volatility", Middle East Economic Survey, Vol. XLVIII, No. 13. Available from: <http://www.mees.com/postedarticles/oped/v48n13-50d01.htm> (2/4/2009)

Food and Agriculture Organization of the United Nations (FAO) (2009): "Hunger in the Face of Crisis", Economic and Social Perspectives, Policy Brief 6. Available from: <http://www.fao.org> (9/25/2009)

Frankel, Jeffrey (2006): "The Effect of Monetary Policy on Real Commodity Prices", University of Chicago Press, Chicago.

Grossman, Sanford J. and Stiglitz, Joseph (1980): "On the Impossibility of Informationally Efficient Markets", The American Economic Review, Vol. 70, No. 3, pp. 393-408.

Habermeier, Karl and Kirilenko, Andrei (2001): "Securities Transaction Taxes and Financial Markets", Working Paper WP/01/51, International Monetary Fund (IMF). Available from: <http://www.imf.org> (2/8/2009)

Hotelling, Harold (1931): "The Economics of Exhaustible Resources", The Journal of Political Economy, Vol. 39, No. 2, pp. 137-175.

Jensen, Michael C. (1978): "Some Anomalous Evidence Regarding Market Efficiency", *Journal of Financial Economics*, Vol. 6, No. 2-3, pp. 95-101.

Kahneman, Daniel and Riepe, Mark (1998): "Aspects of Investor Psychology. Beliefs, Preferences, and Biases Investment Advisors Should Know About", *Journal of Portfolio Management*, Vol. 24, No. 4, pp. 52-66.

Keynes, John Maynard (1967): "The General Theory of Employment, Interest and Money", Macmillan, London.

Krugman, Paul (2008): "Speculation and Signatures".
Available from: <http://krugman.blogs.nytimes.com/2008/06/24/>

Malkiel, Burton G. (2003): "The Efficient Market Hypothesis and Its Critics", *The Journal of Economic Perspectives*, Vol. 17, No. 1, pp. 59-82.

Mandelbrot, Benoit (1966): "Forecast of Future Prices, Unbiased Markets, and Martingale Models", *The Journal of Business*, Vol. 39, No. 1, Part 2, pp. 242-255.

Maros, Ivanic and Will, Martin (2008): "Implications of Higher Global Food Prices for Poverty in Low-Income Countries", Policy Research Working Paper No. 4594, Development Research Group, World Bank.

Masters, Michael (2008a): "Testimony before the Committee on Homeland Security and Governmental Affairs", United States Senate, June 2008.
Available from:
http://hsgac.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=4b570baa-713f-45a3-9c42-794c93ff5a41 (6/8/2009)

Masters, Michael (2008b): "Testimony before the Committee on Homeland Security and Governmental Affairs", United States Senate, May 2008. Available from: http://hsgac.senate.gov/public/_files/052008Masters.pdf (6/8/2009)

Minot, Nicolas (2008): "The Food Crisis and its Implications for Agricultural Development", Testimony presented to the Subcommittee on Speciality Crops, Rural Development, and Foreign Agriculture. Available from: <http://agriculture.house.gov/testimony/110/h80716/Minot.pdf> (6/8/2009)

Mundell, Robert A. (2000): "A Reconsideration of the Twentieth Century", The American Economic Review, Vol. 90, No. 3, 327-340.

Picek, Oliver, Schratzenstaller, Margit and Schulmeister, Stephan (2008): "A General Financial Transaction Tax. Motives, Revenues, Feasibility and Effects", Research Study by the Austrian Institute of Economic Research (WIFO). Available from: <http://www.wifo.ac.at/jsp/index.jsp?&fid=18> (2/4/2009)

Robles, Miguel, Torero, Maximo and Von Braun, Joachim (2009): "When Speculation Matters", International Food Policy Research Institute (IFPRI), Policy Brief 57.

Samuelson, Paul A. (1965): "Proof that Properly Anticipated Prices Fluctuate Randomly", Industrial Management Review, 1965, Vol. 6, No. 2, pp. 41-49.

Scheinkman, Josè A. and Xiong, Wei (2003): "Overconfidence and Speculative Bubbles", The Journal of Political Economy, Vol. 111, No. 6, pp. 1183-1219.

- Schwartz, Eduardo and Smith, James E. (2000): "Short-Term Variations and Long-Term Dynamics in Commodity Prices", *Management Science*, Vol. 46, No. 7, pp. 893-911.
- Schulmeister, Stephan (1987): "An Essay on Exchange Rate Dynamics", Discussion Paper, Wissenschaftszentrum Berlin für Sozialforschung, IIM/LMP 87-8, ISSN No. 0722-673X.
- Schulmeister, Stephan (2009): "Trading Practices and Price Dynamics in Commodity Markets and the Stabilizing Effects of a Transaction Tax", Austrian Institute of Economic Research (WIFO), Study commissioned by the Austrian Federal Ministry of Finance and the Austrian Federal Ministry of Economics and Labour.
- Sharpe, William F. (1964): "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk", *The Journal of Finance*, Vol. 19, No. 3, pp. 425-442.
- Sharpe, William F. (1990): "Capital Asset Prices with and without Negative Holdings", Nobel Lecture, 1990.
- Shleifer, Andrei and Vishny, Robert (1997): "The Limits of Arbitrage", *The Journal of Finance*, Vol. 52, No. 1, pp. 35-55.
- Shleifer, Andrei (2000): "Inefficient Markets. An Introduction to Behavioural Finance", Oxford University Press Inc., New York.
- Solow, Robert (1974): "The Economics of Resources or the Resources of Economics", *American Economic Review*, Vol. 64, No. 2, pp. 1-14.
- Soros, George (2008): "Testimony before the U.S. Senat Commerce Committee Oversight", Hearing on FTC Advanced Rulemaking on Oil Market Manipulation. Available from: <http://commerce.senate.gov/public> (6/8/2009)

Streißler, Erich (2009): “The Financial Market Crisis”, Lecture at the Academy of Sciences, Vienna.

United Nations Conference on Trade and Development (UNCTAD) (2009): “The Global Economic Crisis: Systemic Failures and Multilateral Remedies”, Report by the UNCTAD Secretariat Task Force on Systemic Issues and Economic Cooperation, New York and Geneva.

von Braun, Joachim (2008): “Food and Financial Crisis. Implications for Agriculture and the Poor”, Food Policy Report, International Food Policy Research Institute (IFPRI), Washington D.C.

Appendix A

A.1. English Summary

This diploma thesis analyses the empirical behaviour of commodity prices in the 21st century. A comprehensive reconsideration of commodity price dynamics is of great contemporary importance not only to evaluate the present state of the world economy but also for political stability, especially in developing countries.

The purpose of this study is to elaborate whether commodity price dynamics can be explained without the influence of speculation in commodity futures markets. Within the first part of the study, two theoretical perceptions of financial markets are opposed, i.e. the hypothesis of efficient markets versus the hypothesis of inefficient markets. This procedure shall highlight possible shortcomings of real commodity futures markets.

In the second part of the study, the author formulates the hypothesis that destabilizing speculation has considerably influenced commodity prices in the 21st century. In order to prove this position, the behaviour of copper, corn, crude oil, gold and wheat prices are analysed in a general to specific approach.

The results of the empirical analysis of key commodities prices support the author's hypothesis that speculation influenced commodity prices. An analysis of supply and demand conditions and parallel price movements shows that market fundamentals did not account for the extent of price increases after 2003. Furthermore, prices were not normally distributed after 1990, which rules out the proposition that price changes followed a random walk, a major argument of the efficiency hypothesis. Strong evidence in support of the author's hypothesis results also from the dependence of prices over time and the considerably high inter-correlations of different commodities.

The results of this study credibly suggest that the functioning of commodity markets after 2003 has not been in line with the efficiency hypothesis.

A.2 German Summary

Die vorliegende Diplomarbeit analysiert das empirische Verhalten von Rohstoffpreisen im 21. Jahrhundert. Eine umfassende Neubewertung dieser Preisdynamiken ist von größter aktueller Bedeutung, da Rohstoffe sowohl wichtige Einsatzfaktoren industrieller Produktion darstellen, als auch die politische Stabilität insbesondere in Entwicklungsländern maßgeblich beeinflussen.

Die zentrale Frage dieser Studie ist, ob die Dynamiken von Rohstoffpreisen der letzten Jahre ohne den Einfluss von Spekulation in Futures Märkten erklärbar sind. Innerhalb des ersten Teiles dieser Arbeit werden zwei unterschiedliche Auffassungen von Finanzmärkten einander gegenübergestellt, d.h. die Markteffizienzhypothese versus die Hypothese ineffizienter Finanzmärkte. Diese Vorgehensweise soll etwaige Defizite realer Rohstoff Futures Märkte hervorheben. Im zweiten Teil dieser Studie formuliert der Autor die Hypothese, dass Rohstoffpreise während des 21. Jahrhunderts wesentlich von Spekulation beeinflusst bzw. geformt wurden. Um dies zu belegen wird das Preisverhalten von Kupfer, Mais, Rohöl, Gold und Weizen betrachtet, wobei die Analyse vom Allgemeinen ins Spezifische erfolgt.

Die Resultate der empirischen Analyse von Rohstoffpreisen unterstützen die Hypothese des Autors. Preise wurden maßgeblich von Spekulation beeinflusst. Die Betrachtung von Angebots- und Nachfragebedingungen in Spotmärkten sowie der dazugehörigen Preise kam zu dem Ergebnis, dass eine ausschließliche Begründung der Preisanstiege nach 2003 durch fundamentale Faktoren als nicht zulässig erscheint. Die beobachteten Preisverteilungen führen zu einer Ablehnung der Random Walk Hypothese. Weitere Belege für die Spekulations- Hypothese resultieren aus der zeitlichen Abhängigkeit von Preisen, sowie signifikant hohen Inter-Korrelationen. Die vorliegende Studie zeigt deutlich, dass die Wirkungsweise von Rohstoffmärkten keinesfalls im Einklang mit der Markteffizienzhypothese steht.

A.3. Curriculum Vitae

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10/2006 – 2/2007 Erasmus Mobility Programme
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