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Fertilizer markets and their interplay with commodity and food prices

Hervé Ott

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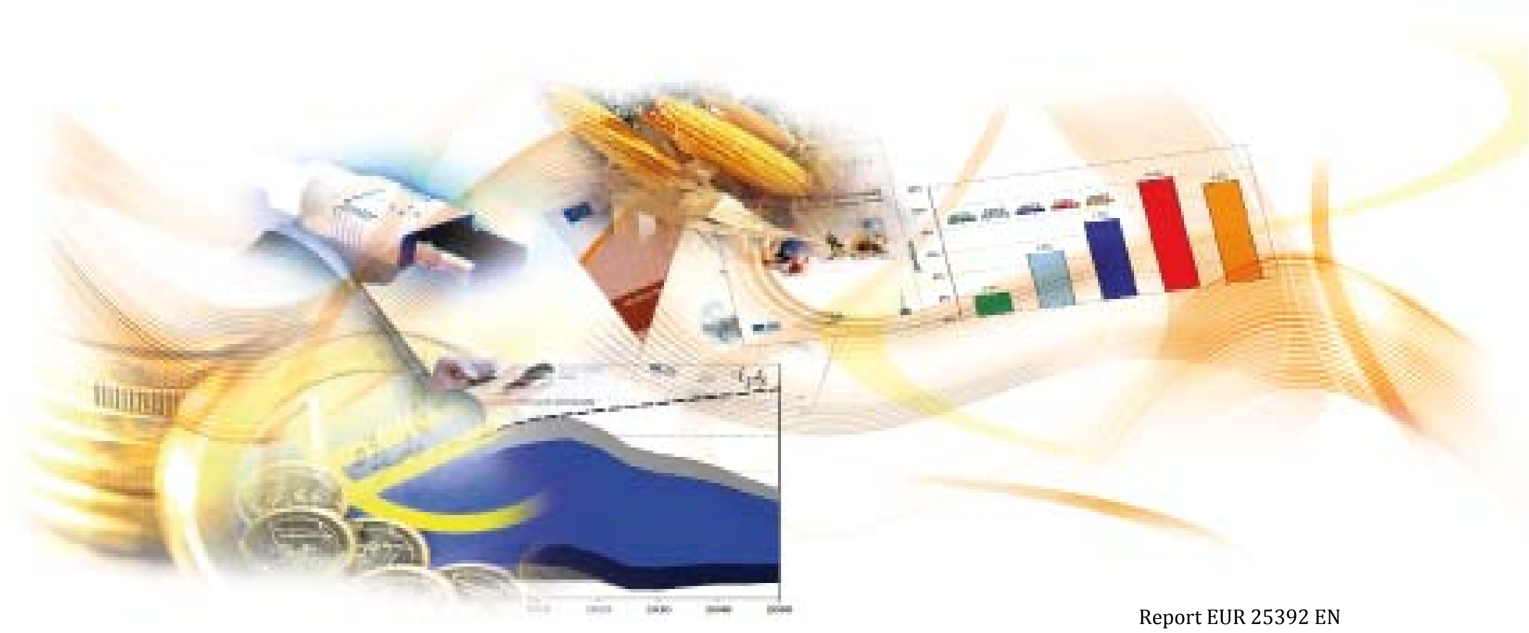

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1 Introduction

Fertilizers are among the major production factors to increase agricultural output. They accounted for approximately 60% of the registered yield increase in the last 50 years (Steward et al., 2005). Consequently, if the agricultural sector is to produce sufficient feed and food for the future requirements of an additional 2 billion people by 2050, efficient access to fertilizers is a relevant issue, particularly in the least developed areas. In Africa, closing the gap between actual and potential agricultural yields, which could mitigate food insecurity, depends heavily on improved access to and use of fertilizers (Saravia-Matus et al., 2012; Malingreau et al., 2012).

Food commodity prices reached unprecedented levels in 2007-2008 and, at the same time, the sudden rise of their price level and volatility added to insecurity and fears in national and international markets. According to the FAO (2009), the reduced supply response of smallholders (largely in low income areas) was partly explained by the simultaneous increase in the cost of inputs. Compared to the last 20 year period, today's prices for agricultural commodities like wheat and maize are still high and continue to experience high volatility. The factors in play which may explain the food price swings have been reviewed in Baffes and Haniotis (2010): low agricultural investment in the past, weak dollar, fiscal expansion, lax monetary policy, reduced global stocks and index fund investment in commodities. Regarding the activity of the index fund, De Schutter (2010) and Roblel et al. (2009) argue that since the US Commodity Futures Modernization Act in 2000, 'speculative capital' entered the commodity market on a massive scale. The entry of index funds caused the number of futures and options "traded globally on commodity exchanges to increase by more than 5 times between 2002 and 2008" (De Schutter, 2010), which in turn destabilized the physical food market affecting food security at local, national and world levels.

This study is structured to address three main objectives related to the fertilizer market and its interplay with food and energy markets. The first objective is to investigate whether speculative activity may have affected fertilizer prices. The second objective is to analyse how the food commodity prices, the fertilizer prices, and the energy prices interact. The third objective is to analyse the volatility of fertilizer prices. Regularly, politicians and market analysts blame speculation and the derivatives market for destabilizing the physical markets (Masters, 2008; Robles et al., 2009); whereas experts in fertilizer markets point to the fundamental structural factors in play (Huang, 2009). This study will shed light on this controversy by reviewing academic and policy documents on the subject and analysing relevant fertilizer, fuel and food commodity data. The objectives mentioned above will be pursued in three steps: firstly by reporting selected stylized facts about the fertilizer market, secondly by examining the situation of the fertilizer derivatives market and quantifying the potential speculation (bubble) behaviour, and thirdly the interplay with food and energy prices. In the conclusion, the main findings are summarized.

2 Literature review and hypothesis

There is a growing literature analysing recent food price developments, commodity price formation and their interaction with market fundamentals. Studies have analysed, among other things, the long run relationship between fuel and food prices (e.g. Campiche et al., 2007; Yu et al., 2006; Hameed and Arshad, 2008; Imai et al., 2008; Ciaian and Kancs, 2011), and also the price interdependencies among different types of energy markets (Serletis and Herbert, 1999; Asche et al., 2001; Paul et al., 2001; Asche et al., 2003; Siliverstovs et al., 2005; Cuddington and Wang, 2006). Finally Du, Yu and Hayes (2011) argue that speculation in the energy sector led to higher energy price volatility which in turn spreads to the wheat and corn market after 2006.

Recently, only a few studies have focused on fertilizers: Huang (2007) for example investigates the relationship between the long run ammonia price elasticity and natural gas price using a cointegration analysis. Torero (2011) examines the market structure and shows that the fertilizer industry is a global one with a high level of concentration. For instance Trong-Tuan (2010) finds evidence that the domestic Vietnamese price of phosphate reflects the world price. Payne (1997) focused on the price formation of fertilizer prices and their spatial pattern by studying the case of the urea fertilizer industry in Western

Canada. Earlier literature on fertilizers analysed the demand (Burrell, 1980) and supply (Anderson, 1984).

The purpose of this paper is to analyse international fertilizer prices, the factors driving their recent fluctuation and the role of speculation, and its interplay with the energy and commodity markets. The current literature does not cover this topic which is surprising given the fact that fertilizers represent a key input in agricultural production and may play an important role in explaining, partly or fully, the recent food price increase. At the same time, fertilizers are strongly linked to energy markets as the main input for their production is oil and gas. There is also backward feedback from food markets to energy markets as the agricultural sector employs energy inputs in its production process. This triangular interdependency between the energy, fertilizer and food markets is vital for understanding commodity price developments in general and in particular the recent food price developments. However the interdependency with commodity prices is not analysed in the current literature. As all these studies only partially address fertilizers' price formation and the interdependency between it and commodity and food prices, the aim of this paper is to examine the following three questions:

1. The role of speculation in the formation of fertilizers' price formation. The Homm and Breitung (2012) approach is used to identify whether there is potential speculative behaviour on the fertilizers' physical (spot) market. Secondly, the question whether the derivatives (future) market is a source of speculations is investigated.
2. The interaction among fertilizer, food and energy prices. A VAR (Vector Autoregressive) model is used to analyse the interplay between the market prices of fertilizers, energy and commodities.
3. Fertilizer price volatility and its relation to food and energy price volatilities. Price volatility indices are calculated to analyse fertilizer price volatility and compare and/or contrast developments to those of the volatility of food and energy prices.

These three issues have dominated the discussion among policy makers and academics in the context of the recent commodity price developments (Baffes and Haniotis, 2010). Policy makers tend to consider speculation as a key driver for the recent increase in commodity prices and their volatility (De Schutter, 2010). On the other hand, the academic literature is inconclusive and more research is needed to quantify the exact contribution of speculations and market fundamentals to the formation of commodity prices. The aim of this paper is to shed some light on this debate by focusing in more detail on the fertilizer market.

3 Data

All data have been extracted by means of the DataM tool (Hélaine et al., 2012). Fertilizer prices, namely world fertilizer price index, urea, potassium, phosphate, DAP and Brent crude oil, have a monthly frequency and stem from the World Bank. The time span dates from 1960 to 2012. The fertilizer index of the World Bank is a weighting of nitrogen, phosphate and potassium prices. The other World Bank indices used are the energy index, composed of the price of oil, gas and electricity, and the grain index, composed of the price of wheat, corn, soybean and rice. Both indices have a monthly frequency dating from 1967 to 2012. The source of food commodity prices, such as those of wheat, corn, soybean and rice, is also the World Bank and they have the same time span and frequency as the other indices. The source of the world production and consumption of potash, phosphate and nitrogen is the FAO (FAO Stat); their frequency is annual from 1993 to 2010.

4 Stylized facts

4.1 Fertilizer prices

The evolution of the fertilizer index, and the prices of the nutrients: nitrogen (N), phosphorus (P), potassium (K) and DAP (DiAmmonium Phosphate) are depicted in Figures 1 to 5. Fertilizer prices have increased steadily since 2002 with an historic peak in 2008. DAP posted the largest increases – around 100% increase. The peak in 2008 looks like the 'mathematical signature' of a bubble as defined in

Sornete et al. (2009) or Watanabe et al. (2007): faster than exponential price growth followed by an abrupt fall. In the next section, the quantitative analysis will be undertaken on this question of a bubble.

For the three fertilizer components (including the fertilizer index itself) the price peaks occur almost simultaneously. This strong co-movement in all fertilizer components proves that the only explanation is common factors. The supply factor, like the energy price (input cost), which enters the production process of all fertilizer components (especially urea), seems to have triggered an initial sharp price increase (see crude oil price in Figure 6). This might explain the co-movement. Except the crude oil price (and to a lesser extent the exchange rate), the world supply chain (nitrogen, phosphate and potassium) are independent of each other (see section 4.2). The main exporters are located in different countries: the supply of nitrogen is mainly from Russia, the supply of phosphate from the USA, China, Morocco and Russia, and finally the potash from Canada, Russia, and Belarus (see Table 1). This leaves the demand side elements a role of potentially major importance. The demand for the different fertilizer components move together because they are complements in consumption, i.e. they are used in a given proportion to produce the fertilizer as the final output. Indeed, the three basic plant nutrients, N, P and K are crucial to the growth of crops. Their proportions may change depending on the soil fertility and/or the crop itself in order to foster optimal development, but all three are necessary. Thus, chemical fertilizers as end-products (like DAP) use all three elements together: N, P and K with no possibility of substitution, and so the strong demand (see Figure 7-12) and price co-movement between them is the natural consequence.

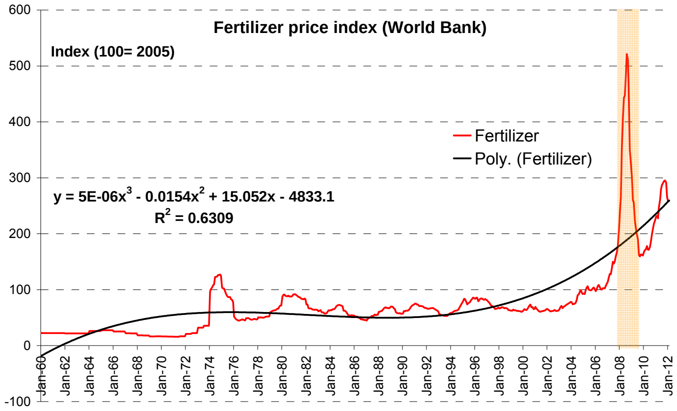

Figure 1: World fertilizer price index

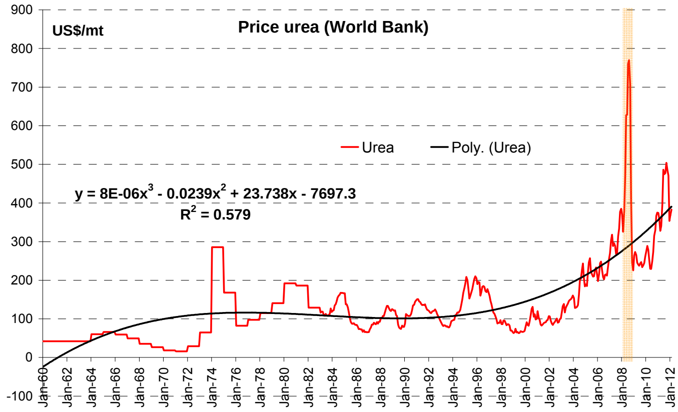

Figure 2: Price urea (nitrogen), US Gulf

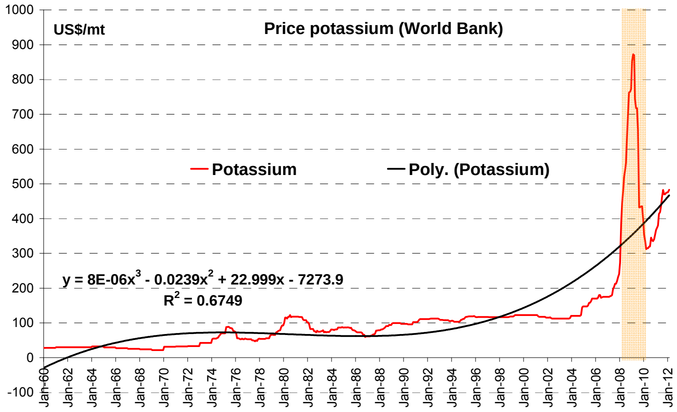

Figure 3: Price potassium, US Gulf

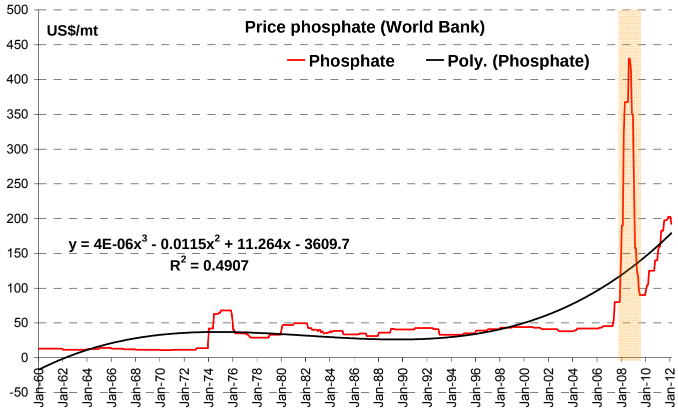

Figure 4: Price phosphate, US Gulf

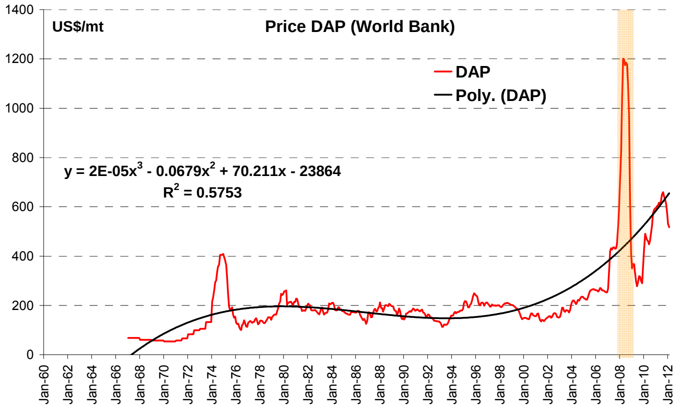

Figure 5: Price DAP, US Gulf

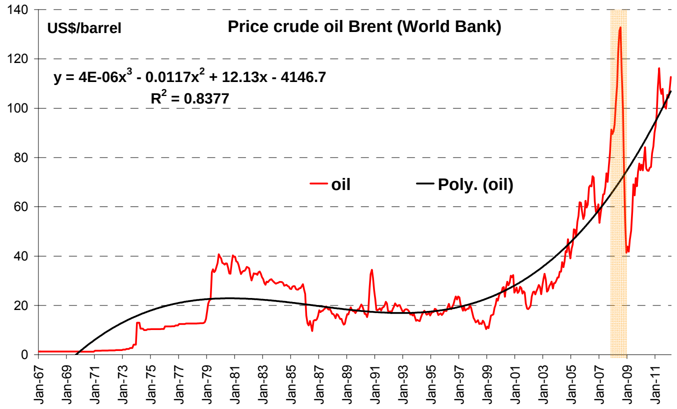

Figure 6: Price Brent crude oil, NYBOT

4.2 Potential factors explaining the fertilizer price

Meeting the escalating global food needs due to a growing population willing to eat more caloric food can mainly be achieved by land area extension and/or crop yield improvement. Given the scarcity of land, yield increase is the key source of additional food supply necessary to satisfy future food needs. One of the main drivers stimulating yield improvements are fertilizers. This link between yield and fertilizers is likely to be the main cause of the upward trend in fertilizer use observed in recent periods and closely follows food demand expansion. Taking into consideration these facts on food demand developments and their interaction with fertilizers, there are four major factors that need to be taken into account in order to understand the fertilizer prices (Figures 1 - 5): the increased globalized structure of the world fertilizer market, the increased food commodity demand (long-term trend and short-term demand peak), fertilizer production costs, and concentration in the fertilizer market (market structure).

Globalization of the world fertilizer market

The fertilizer market is not exactly spatially integrated, and may differ depending on the location (Payne, 1997). However, fertilizer prices determined in the US Gulf, especially nitrogen and phosphate, are considered a reference for world prices. US factors affecting world fertilizer prices have weakened over time. Thus, the fertilizer clearing price which stems from the interaction between demand and supply is now to an increasing degree subject to global economic factors, including commodity prices, raw material costs and worldwide natural resources, and energy and transportation costs, the US dollar exchange rate, global economic development and population growth.

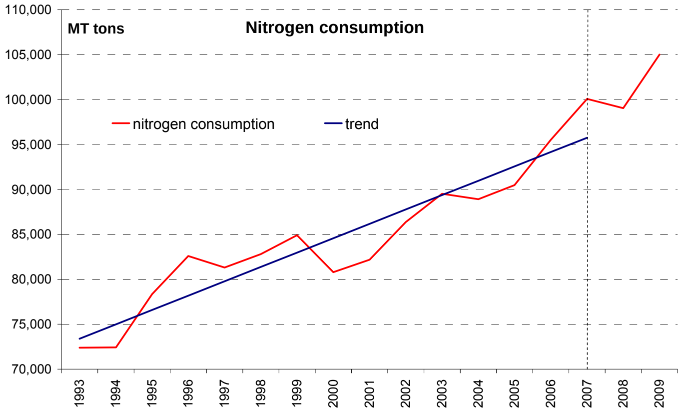

Figure 7: World consumption nitrogen (FAO)

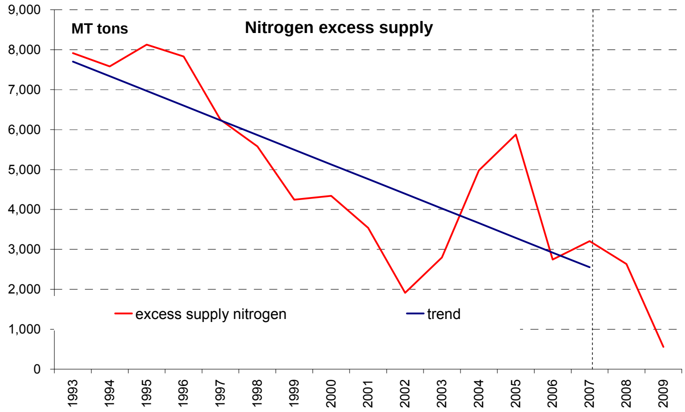

Figure 8: World excess supply: nitrogen (FAO)

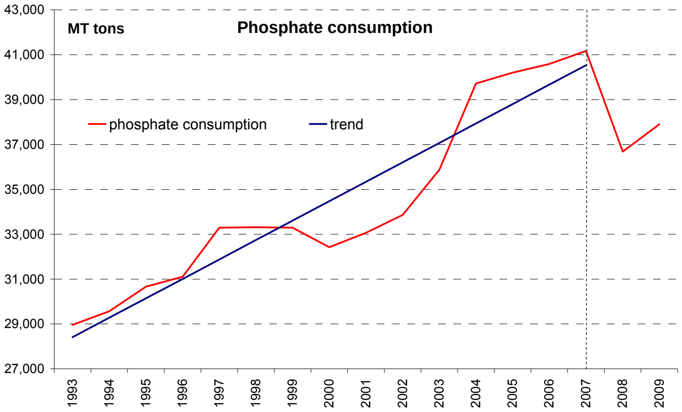

Figure 9: World consumption phosphate (FAO)

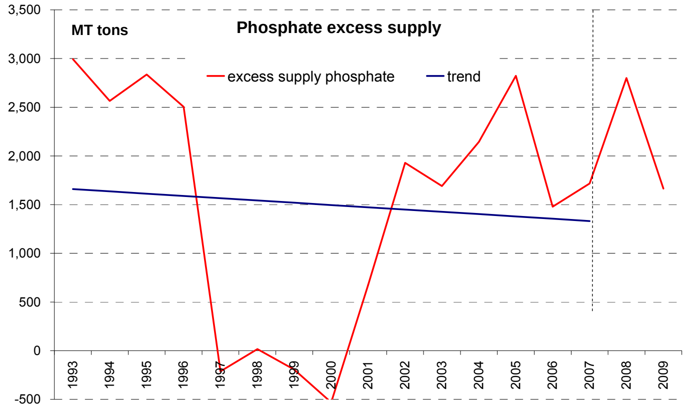

Figure 10: World excess supply: phosphate (FAO)

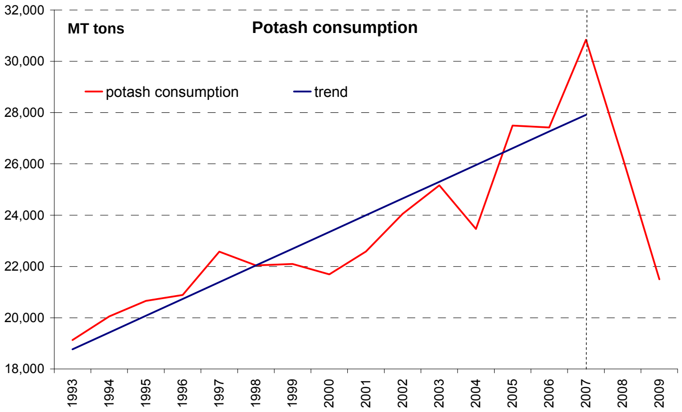

Figure 11: World consumption potash (FAO)

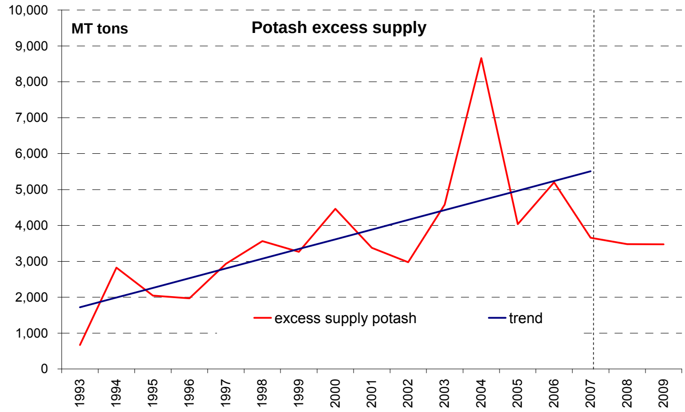

Figure 12: World excess supply: potash (FAO)

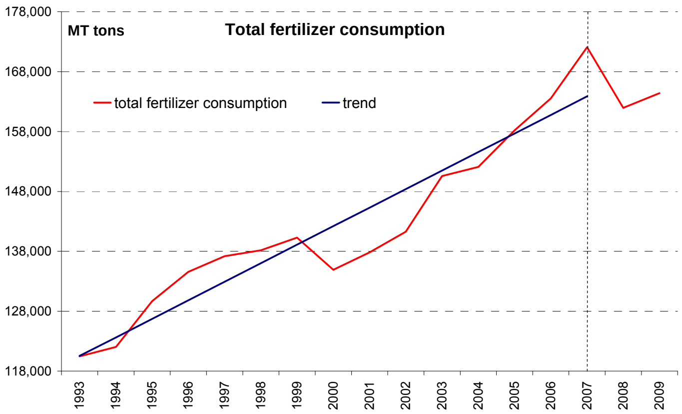

Figure 13: World consumption total fertilizer (FAO)

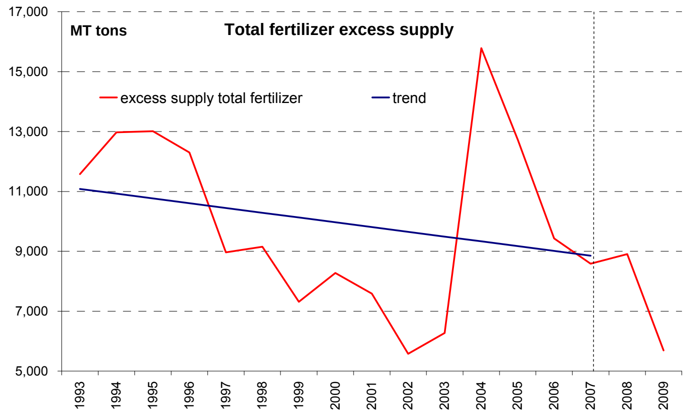

Figure 14: World excess supply total fertilizer (FAO)

The global consumption of fertilizer nutrients since 1993 is depicted in Figures 7, 9, 11 and 13. The graphs also indicate the trend until 2007 when the peak occurred. From 1993 to 2007 fertilizer consumption (nitrogen, phosphate, and potash) increased at an annual growth rate of 2.4%, 2.6% and 3.6% respectively. China and India imported increasing quantities of fertilizers over time to meet the rising food demand. The influence of these two countries on global fertilizer prices is growing. For the same period of time, nitrogen, phosphate and potash production rose at a rate of 1.8%, 2.2% and 4.1% per year respectively. These percentages indicate the imbalance between supply and consumption, especially for nitrogen and to a lesser extent phosphate. Figures 8, 10 and 12 depict the difference between the world supply and demand (called 'excessive supply') for each nutrient and also for the aggregate (Figure 14). The gap between supply and demand widened for nitrogen in particular but also phosphate as indicated by the downward sloping trend. The strong growing demand could only be matched by making use of and thus reducing the stock of fertilizer nutrients. Meanwhile, the stocks of potash have increased according to the data for the last 15 years. This is the reason why the peak for potash prices occurred later (beginning of 2008). It seems obvious that phosphate and especially nitrogen pushed up phosphate prices due to their complementary nature within the fertilizer sector. It appears that the potash sector was not responsible of the overall price peak in the fertilizer sector.

High commodity prices

What are the reasons for this strong demand for fertilizers? The demand for fertilizers depends directly on the situation of the commodity market. As can be seen in Figure 15, fertilizer and food commodity prices follow the same pattern and the two markets are inter-related. More recently, western government policies by implementing biofuel mandates added an important factor in the demand for food commodities, especially for corn (ethanol) and oilseed (bio-diesel) (see e.g. Diffenbaugh and al., 2012). For instance the expansion of ethanol production in the US has led to an increase in the planting of corn at the expense of soybeans and wheat. Corn production is more demanding in terms of nitrogen than soybeans and wheat. Furthermore, the biofuel programmes have increased the interdependence between food commodity prices and energy prices (see Du et al., 2011). The energy prices are the primary cost of the nitrogen production. This suggests that it is likely that the commonality between fertilizers and commodities might increase over time as long as bio-fuel production expands.

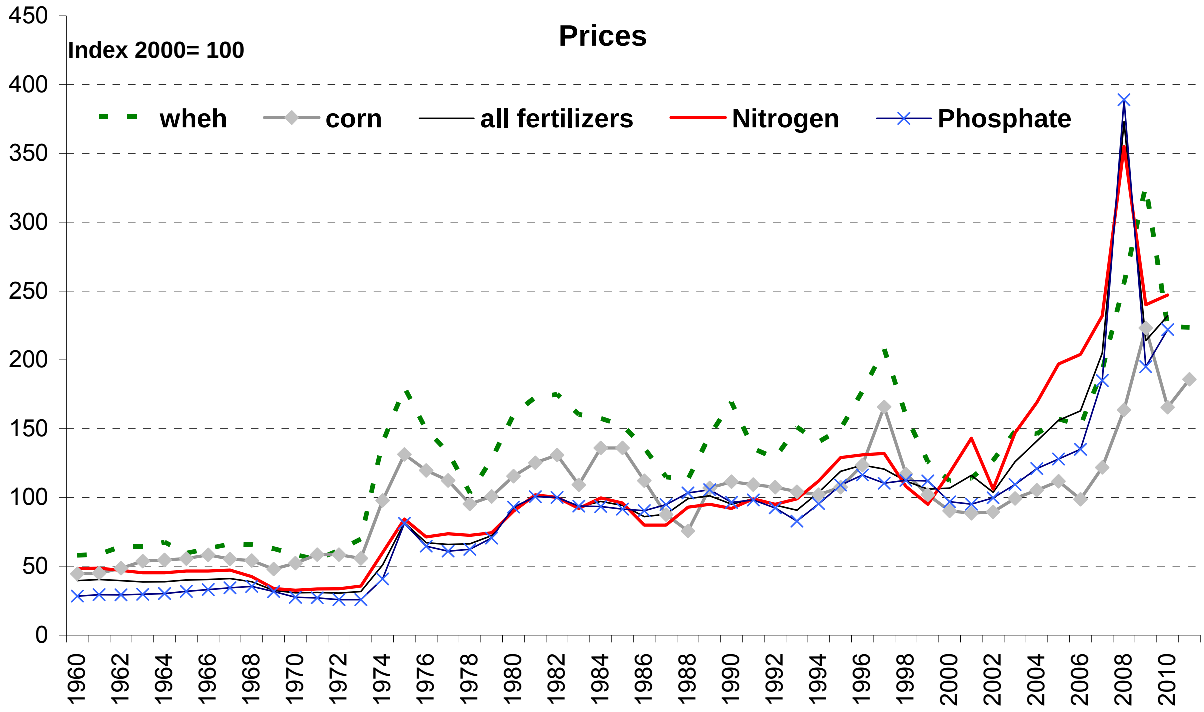

Figure 15: Grain prices (wheat and corn) and fertilizers (N and P)

Furthermore, since 2007 the global supply of commodities has experienced a series of adverse weather shocks: drought and floods in Australia, drought in Ukraine, fires in Russia, extended dry spell in the north-western area of the EU in the spring, cool wet weather in the US Corn Belt, floods in Thailand, El Niño in the Pacific etc. These fundamental supply shocks coupled with the strong demand lowered the stock of commodities and eventually provoked historical price peaks in commodity prices in 2007-2008 (see Figure 15). Although commodity prices have decreased since they are still above average. High commodity prices lead to larger marginal revenues of agricultural production which drive up fertilizer prices. In response to high commodity prices farmers expanded their land use by around 5 million hectares at world level. High commodity prices also encourage farmers to increase their fertilizer application rate in order to increase the quantity of the output. The total fertilizer demand (nitrogen) was around 172 (100) Mtons in 2007 compared to 140 (83) Mtons in average between 1993 and 2007. This historically high demand in 2007 led to the lowest level of inventory of fertilizers in the last 15 years, as depicted in Figure 14 (Figure 8).

Production costs

On the production side of the fertilizer market, the input costs put upward pressure on fertilizer prices. Chemical fertilizer production is an energy intensive process and requires large amounts of energy. Ammonia used to produce urea and nitrate is particularly energy dependent. Nitrogen as a raw material (78% volume in the atmosphere) is available almost without limit but its transformation into ammonia (Haber-Bosch process) is highly demanding in terms of energy, particularly natural gas. Natural gas accounts for 72-85% of ammonia production costs according to Huang (2007). In addition, the costs of shipping ammonia (as a hazardous material transported in pressurized containers) are relatively high, e.g. transport costs represent 50% of the cost of ammonia shipped from Russia to the US Gulf (Huang, 2007). Although phosphorus and potassium production is less demanding in energy, the extraction of phosphorus from phosphate rock and potassium from potash represents an important cost item in addition to the transportation costs. Energy prices (gas and oil) have been experiencing an upward trend since the beginning of the 2000s (between 1999 and 2008 natural gas prices increased by more than 550% and oil by 970%) with a peak in 2008, which in turn has made the fertilizer cost higher (see Figure 6).

A highly concentrated fertilizer market

The structure of the fertilizer market may also explain a part of the story related to its price formation and vulnerability to fluctuations. Trade in fertilizers has been growing in the USA and Europe for the last 20 years. The international fertilizer prices set in the US Gulf depend more and more on international factors. China is now the largest importer of potash followed by the USA. Also the supply chain is integrated on a world scale. The fertilizer market is now global. Some local events provoke peaks in internal fertilizer prices. For instance, in 2007, the value of the Moroccan phosphate rock contract increased by almost 350%, while the international price of sulphur grew by almost 200%, and the ammonia price doubled (US Gulf). Thus, the costs of raw material to produce DAP (DAP is produced by means of phosphate rock, sulphur and ammonia) in Europe doubled in just a couple of months. This example illustrates how the fertilizer industry is linked at world level. Supply chains gained in efficiency but became more vulnerable to international shocks. This world integration of the fertilizer industry leads to a 'just in time' supply practice in order to lower inventory costs (which are very high for fertilizers). Low stocks of raw fertilizers in Europe or the USA makes the fertilizer industry very vulnerable to unexpected shocks since they translate immediately into price peaks.

High rates of internationalization also increased the competition within the fertilizer sector. The rationalization of the fertilizer industry was essentially made through mergers of production factories. Today, much of the industry is very concentrated with only a few large suppliers (firms, associations). For instance in the USA, only 7 firms produce phosphoric acid and only three companies control 80% of the production of phosphoric acid (Huang (2009). In Canada and Russia the export of potash also depends on one single association. Thus, the global phosphate and potash fertilizer marketing is highly concentrated. This market structure is prone to non-competitive price setting. Concentration is also seen regarding the location of the raw materials for fertilizers. Potassium reserves are owned by a few countries and companies; two thirds of world production takes place in Canada, Russia, and Belarus; and only 8 companies control 80% of the production. Ammonia is produced mostly in Russia, Ukraine and Trinidad and Tobago (Malingreau et al., 2012). The USA and China dominate the supply of phosphate. The top six countries controlling more than two thirds of the world's production capacity of all major fertilizer products are summarized in Table 1.

Table 1: Percentage of world share of fertilizer production (FAO, year 2007 in Mtons)

Nitrogen	%	Phosphate	%	Potassium	%
China	34.2	China	32.4	Canada	31.3
India	10.1	USA	25.6	Russia	21.1
USA	8.2	Russia	6.5	Belarus	14.8
Russia	7.0	India	6.3	Germany	8.4
Indonesia	2.9	Morocco	2.7	China	5.8
Ukraine	2.6	France	1.0	USA	3.2
Top 6	73.0	Top 6	77.0	Top 6	84.6

This highly integrated fertilizer supply largely depends on the internal flow functioning well. The trade policies of the major players impact directly on the world price of fertilizers. China imposed a special tariff rate (export tax) of 100% on fertilizers to lower the volume of exports. Consequently, the international price of DAP increased by about 185% according to Huang (2009) because China is the second largest exporter of phosphate and the largest exporter of urea. Some indirect measures also distort world trade allocation: for instance in India the government subsidises the use of fertilizer, which fosters imports as most of the fertilizers are imported. To conclude, Chinese and Indian government activated trade policy measures (decrease exports and increase imports) to provide their farmers with enough fertilizer, thus provoking even higher world prices.

5 The role of speculations in fertilizer price formation

This section attempts to investigate the importance of speculations in determining fertilizer price developments. First the occurrence of speculations on the fertilizer market is estimated and second the potential source in the derivatives market is investigated. Speculative behaviour is seen by many market analysts, as well as by policy makers, as a key driver of recent price developments on commodity markets (De Schuster, 2010). According to Stiglitz (1990), a speculator can be defined as an agent who buys an asset or commodity expecting to sell it at a higher price without being concerned about market fundamentals. The behaviour of speculators might be caused by trading techniques like technical extrapolation, herding behaviour or moral hazard (in the event of a public bail-out the agent does not bear the entire risk and so adopts an excessive risk investment). In contrast, the 'investor' is considered a 'fundamentalist'. The price of an asset or commodity which does not reflect fundamentals (its intrinsic value based on fundamental factors) over several years is considered a period of a 'price bubble' or 'speculative bubble'. The price misalignment is caused by speculators who do not invest relative to the 'fundamental factors' but believe that the selling price will be higher and still beyond its fundamentals (Stiglitz 1990). The literature on asset price bubbles is vast, and there are many different approaches to modelling bubbles. The first type of model is the so-called rational bubbles proposed by Blanchard and Watson (1982). The second type of model is the agent-based type where the interaction between trend following "chartist" and "fundamentalist" explain the price dynamic (Day and Huang (1990). Finally, a physics inspired model leading to super-exponential growth has been developed by Derman (2002). Empirically, the challenge of all these models is to detect the 'intrinsic' (fundamental) value of a commodity. A model must be very well specified otherwise the estimates may be misleading. Sophisticated econometric tools and sufficiently detailed data are necessary to disentangle what belongs to a bubble movement from the underlying fundamental factors.

Given these difficulties, econometric tests have been developed to detect bubbles. Some econometricians like Homm and Breitung (2012) argue that it is more realistic to directly observe the raw price (without a factor model) and to observe the bubble ex-post. Homm and Breitung (2012) and Phillips, Wu and Yu (2011) assimilate the emergence of a bubble with the date of a regime switch from a random walk to an explosive process. A random walk is characterized by having an autoregressive coefficient of one ($Y_{t+1} = Y_t + X_t$, with x_t niid(0,1)), whereas the explosive process has an autoregressive coefficient larger than one ($Y_{t+1} = bY_t + X_t$, with b>1 and X_t niid(0,1)). Thus, the signature of the bubble is an explosive price rise followed by an abrupt price collapse. Here again, this is an interesting approximation because an abrupt price fall for instance should only be considered as the bursting of a bubble if no new information concerning supply or demand appears.

Table 2: Unit root tests adapted by Homm and Breitung (2012)

Test	Statistics		Critical values[a]			Bubble period	
			90%	95%	99%	Begin	End
Fertilizer index							
Watanaba&Takaysu						08/2007	11/2009
Phillips&Wu&Yu	rec_d	11.0***	2.26	2.59	3.24	Yes	-
Chow type	sup DFC	0.63NS	1.57	1.9327	2.62	04/2002	
Brusetti&Taylor	sup BT	2.29*	1.9317	2.47	3.88	05/2006*	11/2009
Urea							
Watanaba&Takaysu						11/2007	12/2008
Phillips&Wu&Yu	rec_d	3.6145***	2.2610	2.5958	3.2400	Yes	-
Chow type	sup DFC	-0.6297NS	1.5762	1.9327	2.6285	06/1999	
Brusetti&Taylor	sup BT	-0.9750NS	1.9317	2.4748	3.8878	10/1998	12/2008
Potassium							
Watanaba&Takaysu						01/2008	05/2010
Phillips&Wu&Yu	rec_d	15.2385	2.2610	2.5958	3.2400	Yes	-
Chow type	sup DFC	0.9310	1.5762	1.9327	2.6285	10/1986	
Brusetti&Taylor	sup BT	3.3775	1.9317	2.4748	3.8878	07/2003	05/2010
Phosphate							
Watanaba&Takaysu						09/2007	09/2009
Phillips&Wu&Yu	rec_d	8.9475	2.2610	2.5958	3.2400	Yes	-
Chow type	sup DFC	-0.6310	1.5762	1.9327	2.6285	06/1977	
Brusetti&Taylor	sup BT	1.9592	1.9317	2.4748	3.8878	12/2006	11/2009
DAP							
Watanaba&Takaysu						10/2007	03/2009
Phillips&Wu&Yu	rec_d	7.9691	2.2610	2.5958	3.2400	Yes	-
Chow type	sup DFC	-0.3354	1.5762	1.9327	2.6285	03/1986	
Brusetti&Taylor	sup BT	1.7952	1.9317	2.4748	3.8878	08/2000	03/2009

(a) Critical values with trend

5.1 Identification of speculations (bubbles)

The approach of Homm and Breitung (2012) to identify whether there is a bubble on the physical (spot) fertilizers market is adopted. Their approach consists of testing for the existence of an explosive process in fertilizer prices (i.e. whether the autoregressive coefficient is larger than one). Three unit root tests adapted by Homm and Breitung (2012) are performed on the monthly prices of the fertilizer index, urea, phosphate, potassium, and DAP. The null hypothesis of all tests is that the price series is I(1) against an I(1) process which experiences a regime switch to an explosive process. The three tests are derived from Phillips, Wu and Yu (2011): a recursive Dickey Fuller test, a Brusetti and Taylor (2004) and a Chow type test with structural break. The results of the tests are reported in Table 2. Phillips, Wu and Yu's test detects a bubble in all fertilizer prices. The Brusetti and Taylor test detects potassium and phosphate (at 90%). This reveals the potential existence of bubbles in fertilizer markets.

Since the Phillips, Wu and Yu do not inform on the beginning and end of the bubble, the Watanabe and Takayasu and Takayasu (2007) method was performed in order to detect the exact timing. Figures 1 to 5 depict the nominal prices of the fertilizer, their quadratic trend, and the period of the bubble (dashed area) according to the bubble timing of the Watanabe, Takayasu and Takayasu (2007) method. The graphs show that fertilizer prices experienced a price bubble (explosive) followed by an abrupt fall. Urea, phosphate and DAP experienced the beginning of the bubble in late 2007 and potassium in January 2008. Potassium was the last to be affected certainly because it is less energy dependent. Energy prices have triggered a rise in the price of nitrogen, which in turn dragged up the price of the other components due to their complementary nature as explained in section 4. Common expectations for every fertilizer component (due to their complementarities) might have followed for the whole fertilizer market. This explains the simultaneity of price bubbles among the fertilizer components.

According to the tests, the fertilizer market might have experienced a bubble. However, the evidence is not conclusive as not all tests (depending on the fertilizer) were significant. The next section examines whether the derivative (future) markets can explain the potential bubble (if any). First the relationship between derivatives and the physical (spot) fertilizers' market is described. Then the effects of speculations are measured. The derivative market is the focus point as it was identified in some literature as the main source of speculations (De Schutter, 2010 and Robles et al. 2009). The potential cause of a bubble coming from other sources such as the physical market itself, as well as from other markets such as energy and food, is not investigated in this study.

5.2 Relationship between derivative and physical fertilizers market

The fertilizer market (like the commodity market) has a derivatives market. Currently the only type of derivative product available to hedge against price swings of fertilizers are off-exchange market derivatives (OTC: Over The Counter). Two major brokers provide fertilizer SWAPS: Direct Hedge based in Copenhagen and FIS (Freight Investor Service) located in London. These brokers offer SWAPS for four major fertilizer underliers: nitrogen (urea & UAN), DAP and Ammonia. The broker facilitates a tailored agreement between buyers and sellers. All fertilizer SWAPS are cash-settled (no physical delivery). At maturity, the difference in price between the fertilizer index of the given underlier and the future price agreed upon previously will be cashed in by the buyer or the seller, called cash-settled vanilla SWAP. Currently, Direct Hedge and FIS fertilizer SWAPS establish cash-settled fertilizer SWAPS of roughly 6 million metric tons (Mtons) per year (for all types of underliers).

The major broker in the fertilizer insurance market is Direct Hedge which, since 2000, offers fertilizer SWAPS. At the beginning of 2000, the volume traded was around 200 000 metric tons of fertilizers. The fertilizer indices used by Direct Hedge are: urea granular bulk US Gulf, UAN US nola, DAP Bulk tampa US gulf, and DAP Bulk nola fob. As the volume traded has increased the exposure to settlement risk credit risk has grown in parallel. The requirement for a credit-secure derivatives trading environment has developed in the fertilizer market. As a result, since July 2011, Direct Hedge introduced four types of standardized SWAPS (100 metric tons) into the CME clearport to ensure the clearing and settlement. These four SWAPS are: urea granular bulk, UAN fob nola, DAP fob Tampa, and DAP fob nola.

The second most important broker also active in offering fertilizer SWAPS is FIS which has only been active since 2005. The FIS Fertilizer SWAP is settled against the respective Fertilizer Index. The Fertilizer Index is a single reference price calculated from three weekly price ranges provided by FertilizerWEEK, FERTECON and FMB using a simple averaging technique. The volume traded by FIS is lower but has also grown very rapidly in recent years. For the same reason, FIS introduced SWAPS to the LCH (London Clearing House).

5.3 Interaction between future and physical market

Derivatives are contracts whose price depends on the factors which drive the price of the commodity (physical). A priori, the future price depends on the expectations of the market participants regarding the market prospects in the future (level of stock prices, supply and demand). The derivative market helps the price discovery of the spot price. The difference between the expected spot at the maturity of the derivative contract and the forward price should only be the cost of carry (price of time: interest rate, the storage cost of warehousing, insurance, depreciation) minus the convenience yield (benefit from physical holding). However, future prices can affect the spot price via the physical stocks. For instance if the future prices are much higher than the spot prices (backwardation), stores will increase their inventories which drives up the spot price, and vice versa. The consequence of this mechanism is a lowering of the spot price swings. This is the first reason why derivative markets decrease volatility regardless the players on the derivative markets are speculators or hedgers. Moreover, as shown by Turnovsky (1983) and Torricelli (1993), the existence of a derivative market increases the level of inventory in the long-term. Indeed, suppose a commercial hedger (for its physical stock) needs a counterpart to hedge it, and there is no hedger accepting the risk (counter position), the commercial hedger eventually would not store, or store less or even quit the business because he is risk-averse. In the opposite case, a liquid derivative market will ensure the commercial hedger to find a counterpart, which can be a hedger or a speculator as they do the same job. A liquid derivative market leads to larger stocks, which in turn lowers the volatility, as it can act as a buffer to mitigate supply (or demand) shocks. Speculators help to increase the liquidity of the market. Figure 15 shows the volatility of fertilizers since 1974. There is no sign of volatility increasing since the introduction of fertilizer swaps. However, the volatility of urea exhibits a positive trend since the 2000s but this tendency parallels the increase in energy commodity volatility.

Moreover, the tendency of volatility to increase in the fertilizer market recently cannot be attributed to the introduction of the derivative markets in the energy sector since they were created several decades ago. Most of them were established at the beginning of the 1970s: Heating oil NYMEX futures, 1978; Gas oil IPE futures, 1981; NYMEX WTI in 1983, Brent crude IPE, 1988; natural gas IPE futures, 1997 etc..

5.4 Measuring speculative activity in the derivative market

Contrary to the stock market (secondary) the derivative market is by nature a hedging market (risk management tool). Consequently, speculation is more difficult to evaluate because there is a need to differentiate between speculation and non-speculation. It is obvious that the price of the contract will change if the expectations of the price change of the underlier, and so speculation is also possible. Working (1960) proposes that commercials (traders who are in the agro-business) be considered as 'hedgers' since they have to hedge their real activity, whereas non-commercials are considered as 'speculators' with no hedging needs. However, since there is rarely a balance between short hedgers and long hedgers, speculators have a vital role to allow the agro-business to hedge. The question is whether there is 'excessive' speculation (including index investment) relative to commercial hedging needs in the agricultural markets. If there is more speculation than is required for commercial hedging needs, then the derivative market becomes one of speculators trading with other speculators. Consequently, to measure speculative behaviour, Working (1960) defines the T index as follows:

T= 1 + SS/ (HL + HS) if HS > HL
or T = 1 + SL (HL + HS) if HL > HS,

where open interest held by speculators (non-commercials) and hedgers (commercials) is denoted as follows: SS = Speculation Short; HL = Heading Long; SL = Speculation Long; HS = Hedging Short.

The intuition behind this index is straightforward to understand. The denominator is the total amount of futures open interest due to hedging activity. If the amount of short hedging is greater than the amount of long hedging, then speculative longs are needed to balance the market; and technically, speculative shorts are not required by hedgers. Any surplus of speculative short positions would thereby need to be balanced by additional speculative long positions. The speculative short positions would then be superfluous, or 'excessive'. Thus, the speculative T index measures the excess of speculative positions beyond what is technically needed to balance commercial needs, and this excess is measured relative to commercial open interest. The T index can tell us whether trading speculative derivatives are excessive relative to commercial hedging needs.

Unfortunately, fertilizer SWAPS have only recently been cleared on the CBOT and LCH. Moreover, neither the US CFTC nor the EC inform of the origin of the market players regarding fertilizer SWAPS. The information should be held by Direct Hedging and FIS Fertilizer. If they do not provide this information, the 'excessive' speculation on the derivative market cannot be quantified. According to practitioners in the fertilizer SWAP industry, most of the traders on derivatives are also active on the physical market. Furthermore, the world production of nitrogen, phosphate and potash equals 154 200, 43 300 and 43 213 (1000 Mtons) respectively according to the FAO. The volume traded on the derivative market is around 6 000 (1000 Mtons) which is equivalent to a gearing of about 0.024%. According to these figures, the volume traded on the derivative market is marginal compared to the one traded on the physical market. If it is supposed that the size of the derivative market (trading volume) indicates a market power over the determination of the sport price, then it is hardly credible that open interests on the derivative market can be blamed for the bubbles on the fertilizer market.

6 Price interaction between fertilizers, food and energy

In this section we attempt to examine the interplay among fertilizer prices, energy prices and commodity prices. More specifically we examine to what extent food and energy prices play a role in fertilizer price formation. All their markets are interlinked and thus their prices affect each other. Firstly, fertilizers are linked to energy markets because the main input for their production is oil and gas.

Secondly, fertilizers enter as an input into agricultural production and affect the productivity of the agricultural sector. More importantly, the use of fertilizer increases as the price of commodity prices increases. Finally, there is feedback from the food market to the energy market through its demand for energy in agricultural production (e.g. fuel). The exact causal relationship between the three markets is an empirical question as it depends on many factors such as the size of the respective market, market structure, etc. To empirically identify the direction of causality between fertilizer, food and energy prices the Vector Autoregressive (VAR) model and the accompanying Granger causality test (Granger, 1969) is employed.

6.1 VAR analysis

Because prices are interdependent, applying a standard regression approach would violate the exogeneity assumption of regressors. A general method to analyse interdependences between endogenous variables is the VAR model whereby the causality between the current and past values of the variables is examined. The general specification of the VAR, measuring the interplay between fertilizer, energy and food markets, is represented as follows:

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + A_3 y_{t-3} + e_t \ ,$$

where y is the vector of variables (prices), A_1 , A_2 and A_3 are the matrix and c the vector of the parameters, and their dimension depends on the number of variables, and e are the residuals.

The specification of the VAR which is proposed hereinafter is a compromise between the number of variables and the number of lags. The addition of lags and variables leads to a larger number of coefficients to be estimated, which reduces the power of the estimates. The classical time series unit root tests were performed: ADF (Augmented Dickey-Fuller, 1981), the PP (Phillips-Perron, 1988) and the ERS (Elliott-Rothenberg-Stock, 1996). The first difference of logarithm was used for each time series in order to ensure stationarity. The maximum of lags chosen were set to 3, and the lag structure is based on the SBCI (Schwartz Bayesian Information Criteria).

The sample used has a monthly frequency, with a time span from 1967 to 2012, which gives 536 observations per variable. Three specifications of the model are set. In the first specification (1), price indices are used for the vector of variables y: *energy index*, *grain index fertilizer index* of the World Bank. Using an index has the advantage of reducing the number of variable series and so the number of coefficients to be estimated. In the other two specifications, specific energy and fertilizer prices were used, *oil price*, *dap*, *urea*, *potassium*, *phosphate*, instead of global indices. Also instead of using the *grain index*, the prices of *wheat, corn* and *soybean* were used. The problem is that with three lags, the number of coefficients to be estimated increases exponentially if all these specific prices are included in the VAR and the estimation becomes intractable. For this reason a compromise solution is chosen where only selected prices are included. Thus, in specification (2) *energy*, *fertilizer*, *dap* and *grain* were included into the vector of variables y. In specification (3), *oil*, *dap* and *grain price* were included in the vector of variables y.

The VAR was completed with the Granger causality test (Granger, 1969). The Granger causality test examines the causality between variables of interest. Under the null hypothesis, the variable (A) does not Granger-cause variable(s) (B). Thus, under the alternative hypothesis, the variable (B) Granger-causes (B), which means that variable(s) (B) can be better predicted using the past values of both variable (A) and variable(s) (B) than it can be using variable (B) alone.

VAR results

The results of the Granger causality test are reported in Table 3. The causality tests clearly reveal that *energy prices (costs)* caused an increase in the price of *fertilizers* and *commodity prices*. However, the increase in *commodity prices* preceded the increase in *fertilizers*. Thus, the increase in *commodity prices* provoked an increase in *fertilizer prices*, and not the opposite.

Table 3: Granger causality between the fertilizer, commodity and energy prices

VAR	variables (prices): (A)	(B)	Chi χ^2	dof*	p-val.	H_0	Con-clusion
(1)	energy	fertilizer, grain	19.12	6	0.00	Reject at 1%	(A) => (B)
(2)	energy	fertilizer, dap, grain	14.81	6	0.02	Reject at 5%	(A) => (B)
(1)	grain	fertilizer	6.29	3	0.09	Reject at 10%	(A) => (B)
(2)	fertilizer	energy	0.60	2	0.74	No rejection	(A) ≠> (B)
(2)	fertilizer	grain	25.41	2	0.00	Reject at 1%	(A) => (B)
(2)	dap	grain	27.44	2	0.00	Reject at 1%	(A) => (B)
(2)	energy	grain	12.95	2	0.00	Reject at 1%	(A) => (B)
(3)	grain	oil	1.33	2	0.52	No rejection	(A) ≠> (B)

(*) degree of freedom

7 Fertilizers price volatility

This section expands on the previous analysis by examining fertilizers' price volatility. Its aim is to explore how fertilizers' price volatility evolved over time compared to the volatility observed in the food and energy markets. A prevalent perception is that volatility in commodity markets has increased in recent years, in particular when related to food and energy prices as proved in the chapters of Piot-Lepetit and M'Barek (2011). Furthermore, Baffes and Haniotis (2010) show that all commodities were affected by the volatility increase in 2007-08 (compared to the 1972-73 crisis) proving that the link between energy and non-energy commodities (food particularly) is nowadays stronger. Hereinafter, the similarities and differences of the volatility of fertilizer prices with respect to food and energy prices are analysed. To measure price volatility two indices were calculated. First, the volatility is measured as the standard deviation of the monthly return over one year with no overlap (no rolling window), the measure is annualized (multiplied by the square root of 12). However, to understand more precisely the co-movement of volatility between the energy sector and the different fertilizer components, the volatility was recalculated as depicted in Figure 17. Measuring volatility with no overlaps from one year to the next has the advantage that every volatility observation is independent. The drawback however is that it is difficult to assess the timing (which volatility precedes) among the different volatilities. As a result, a rolling-window of one month was applied (Figure 17).

The evolution over time of the volatility of energy, fertilizers and food from 1960 to 20012 is depicted in Figure 16 (World Bank indices). It shows that food volatility is, on average, much lower than others volatilities (fertilizer, energy). Although food also experienced a volatility increase during the petrol crisis of 1973-74 and the commodity crisis of 2007-08, the volatility of fertilizer follows the volatility of energy (and oil) much more closely. Indeed, during the two historical commodity crises (1973-74 and 2007-08) the volatility jumps in energy and fertilizers are alike. However, the volatility increase in energy in 1986 and 1990 did not spread to the fertilizer market. The volatility increase in the energy sector was due to a strong price fall. This indicates that fertilizer and energy volatility move together when the volatility increase happens in an environment of rising energy prices. Interestingly, prior to the first oil price shock, the volatility of energy was much lower whereas afterwards the volatility of energy is systematically larger than fertilizer and especially food volatility.

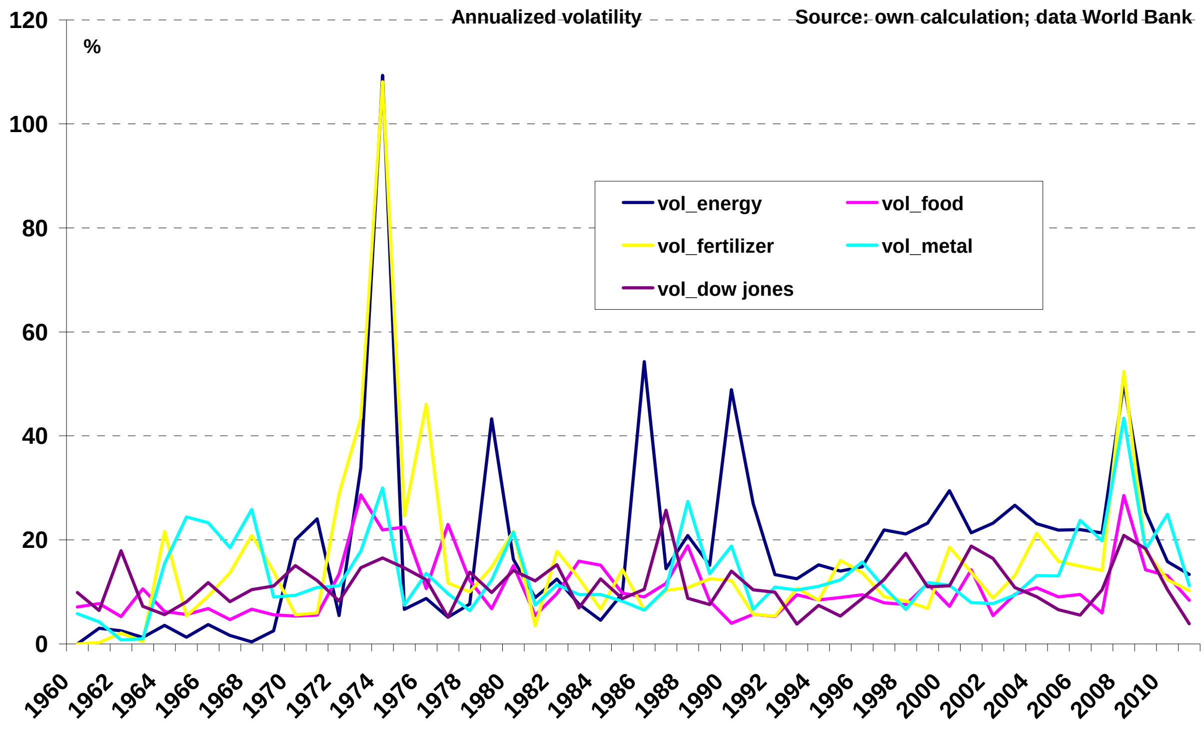

Figure 16: Annualized volatility of energy, fertilizer and food (no rolling window)

In this paragraph, the different components of fertilizers are analysed. The volatilities of urea and energy (or oil) have the strongest correlation over time among all fertilizer nutrients. This phenomenon is explained by the fact that most of the input of urea is energy (see section 4.2). Potassium, but also phosphate, has a much lower volatility and their volatility is much more independent of the energy price volatility. DAP and fertilizer index volatility are very similar, which is normal as both contain nitrogen, phosphate and potassium. The volatility of urea is much higher on average than that of the other fertilizer components; it seems obvious that its high dependence on the energy sector is the most plausible explanation, especially when the volatility of energy is increasing proportionally to rising energy prices. Finally, the volatilities experienced in the fertilizer and energy sectors during the first oil price shock in 1973/74 were higher (and shorter) than during the commodity crisis of 2007/08 where there are no peaks but the increase is longer lasting. Since the mid-2000s, the volatility has been increasing in the fertilizer and energy markets and for now shows no signs of decreasing.

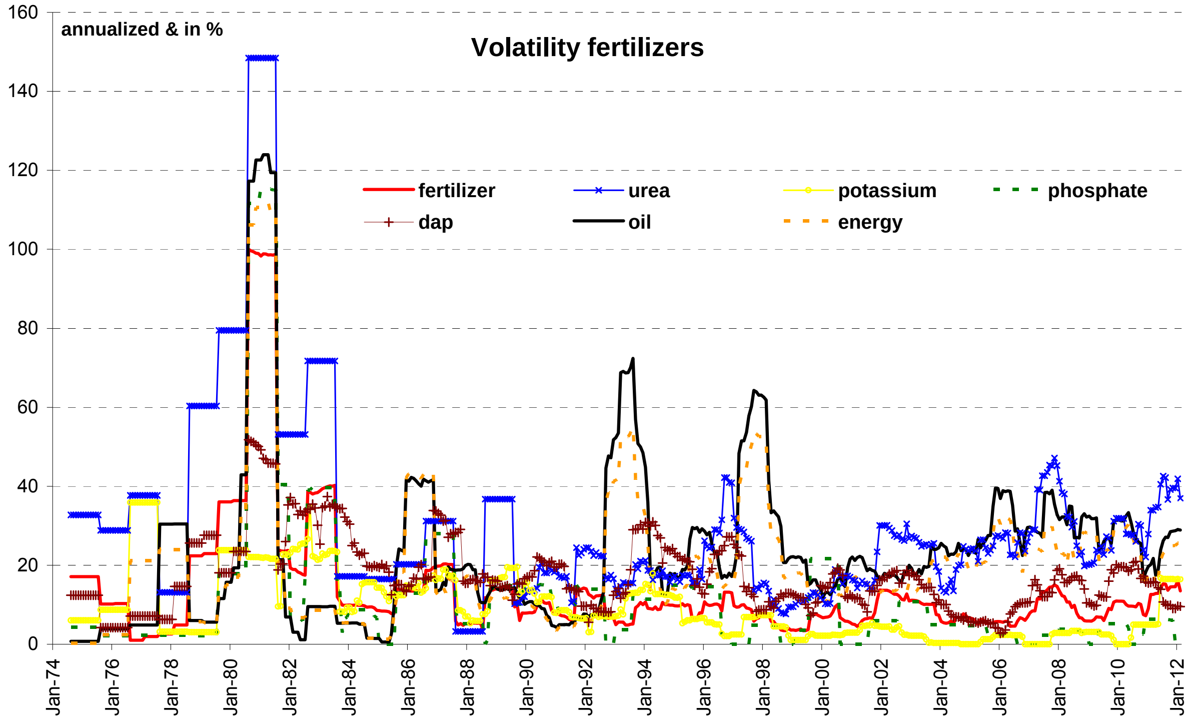

Figure 17: Annualized volatility of fertilizer and oil and food (rolling window)

8 Conclusion

This study analyses the drivers behind the recent price evolution of fertilizers and their interplay with energy and food commodity market prices. This study focuses on three issues that shape the current debate on commodity price developments:

(i) the role of speculations (bubbles) for fertilizers price formation and (ii) the interaction among fertilizers, food and energy prices and (iii) fertilizers price volatility.

First, evidence of speculative behaviour on fertilizer markets is found. However, speculation on derivative markets can hardly be considered as the cause. Indeed, the volume of the fertilizers' derivative market is marginal (6 Mtons in total) compared to the physical market (170 000 Mtons of fertilizers consumed). This argument holds if one believes that the amount of volume traded indicates a kind of market power of the derivative market over the spot market. In that case, the recent rapid expansion of this new derivative market might instead be due to the growing volatility of international fertilizer prices, especially urea, and it is probable that most of the fertilizer derivative products may be used as hedging tools and not as speculative ones. The co-movement of prices in the derivative and physical markets just show that they are driven by the same fundamental factors. Some authors might have been misled when believing that the prices on the derivative market lead the physical market; high correlation does not mean causality. On the contrary, the peak in fertilizer prices first occurred on the physical market due to the uncertainty of the grain and fertilizer markets (high volatility). However a potential cause of bubbles coming from other sources such as the physical market itself or other factors have not been analysed yet. Furthermore, further research should be conducted to see if speculation outside the fertilizer sector (i.e. in food and energy markets) may have partly induced the price increases and volatility of fertilizers.

Second, the prices of food commodities have influenced the fertilizer market and not vice versa. Our results show that there is substantial co-movement between fertilizers' and food prices, but that the food prices are among the causes of the fertilizer price movements. In addition, higher food prices induced a higher demand for fertilizers, again boosting prices to higher levels.

Third, the energy sector triggered the increase in fertilizer prices through the input cost channel. Energy represents a key input in the production of fertilizers. Rising oil and natural gas prices provoked a spark for the nitrogen nutrients whose production depends heavily on energy inputs for production and transport. The same occurred to phosphate and potash, where energy input is less important in their respective production cost structures.

Fourth, given the oligopolistic fertilizer supply chain and the inelasticity of the supply of fertilizers (there is a 5 to 10 year delay before new production plants can be put into the supply chain), this created an upward adjustment of the expectations in the fertilizer market causing an upward spiral effect of the price. This eventually might have provoked a price peak in 2007 due to the uncertainty surrounding the low levels of global fertilizer stocks (nitrogen and phosphate). Over the previous 15 years, the excess nitrogen supply has nearly vanished while phosphate and potash have remained at marginal levels, meaning that no buffer could protect the market when an adverse shock occurred in 2007.

Finally, the volatility of energy, food and fertilizer prices move closely together in an environment of rising energy prices. In the opposite scenario, food and fertilizer volatility do not move together with the volatility of energy prices in an environment of decreasing energy prices. Consistent with other studies, the volatility of fertilizer, energy and food prices is lower during the commodity price peak of 2007/08 than during the 1973/74 oil price shock.

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Abstract

This study analyses the drivers behind the recent price evolution of fertilizers and their interplay with energy and food commodity market prices. First, evidence of speculative behaviour on fertilizer markets is found. However, speculation on derivative markets can hardly be considered as the cause. The recent rapid expansion of this new derivative market might be due to the growing volatility of international fertilizer prices, especially urea, and it is probable that most of the fertilizer derivative products may be used as hedging tools and not as speculative ones. Indeed, the peak in fertilizer prices first occurred on the physical market due to the uncertainty of the grain and fertilizer markets (high volatility). Second, the prices of food commodities have influenced the fertilizer market and not vice versa. The results show that there is substantial co-movement between fertilizers' and food prices, but that the food prices are among the causes of the fertilizer price movements. Higher food prices induced a higher demand for fertilizers, again boosting prices to higher levels. Third, the energy sector triggered the increase in fertilizer prices through the input cost channel. Energy represents a key input in the production of fertilizers. Rising oil and natural gas prices provoked a spark for the nitrogen nutrients whose production depends heavily on energy inputs for production and transport. The same occurred to phosphate and potash, where energy input is less important in their respective production cost structures. Fourth, given the oligopolistic fertilizer supply chain and the inelasticity of the supply of fertilizers (there is a 5 to 10 year delay before new production plants can be put into the supply chain), this created an upward adjustment of the expectations in the fertilizer market causing an upward spiral effect of the price. This eventually might have provoked a price peak in 2007 due to the uncertainty surrounding the low levels of global fertilizer stocks (nitrogen and phosphate). Over the previous 15 years, the excess nitrogen supply has nearly vanished while phosphate and potash have remained at marginal levels, meaning that no buffer could protect the market when an adverse shock occurred in 2007. Fifth, the volatility of energy, food and fertilizer prices move closely together in an environment of rising energy prices. In the opposite scenario, food and fertilizer volatility do not move together with the volatility of energy prices in an environment of decreasing energy prices. Consistent with other studies, the volatility of fertilizer, energy and food prices was lower during the commodity price peak of 2007/08 than during the 1973/74 oil price shock.

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