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Dynamics behind agricultural food commodity prices: a forecast

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Abstract

This paper develops a model that is able to forecast the prices of futures of the agricultural food commodities wheat, corn, soybeans and rice. Using the Diebold Mariano (1995) test of equal predictive ability, it is found that the forecast model provides better forecasts than the random walk, making it perform better than the most important benchmark to beat. The model contains variables that can be placed in four groups: cost of production, change of demand, speculation and change in exchange rate. While analysing the forecast model it is also seen that the price of fertilizer, production of biofuel, speculation intensity and the trade weighted US dollar exchange rate affect one or more of the agricultural food commodity prices negatively. The crude oil price and worldwide GDP growth, on the other hand, impact one or more of the agricultural food commodity prices positively.

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Section 1. Introduction

In July 2014, the Organisation for Economic Cooperation and Development (henceforward the OECD) published in cooperation with the Food and Agriculture Organization of the United Nations (henceforward the FAO) the OECD-FAO Agricultural Outlook 2014-2023. At the presentation of the report the Secretary-General of the OECD Angel Gurría stated that "*Agriculture markets are returning to more settled conditions after a period of unusually high prices.*". His colleague FAO Director-General José Graziano da Silva added: "*We foresee that prices related to cereals will decrease for at least the next two years. [...] The good performance of the agricultural sector particularly in developing countries will contribute to the eradication of hunger and poverty.*" (OECD website, 2014a). These messages clearly distinct from the statements that were given at the presentation of the previous report in 2013. Here Angel Gurrá said: "*The outlook for global agriculture is relatively bright with strong demand, expanding trade and high prices*." (OECD website, 2014b). Over the past years, food prices have shown high volatility and rapidly changing situations. The pace of these changes are represented best when putting recent headlines of FAO press releases after each other: "*FAO Food Price Index hits a six-month low in July*" (published 7 August 2014; FAO website, 2014) comes right after "*FAO Food Price Index sees sharpest rise in months*" (published 6 March 2014; FAO website, 2014). These headlines were published only months after the following: "*FAO expects more balanced food markets, less price volatility*" (published 6 November 2013; FAO website, 2014). This shows that even the FAO, an authority when it comes to international food developments, can be surprised by the volatility over time.

Fluctuations in prices, supply and demand are common for all economy as a whole. However, the consequences of these fluctuations differ significantly between markets. The products that are captured in the previously mentioned FAO Food Price Index[1] are considered to be among the commodities that are human's base nutrients. Fluctuations in prices, supply and demand for these products therefore will affect the whole worldwide population. Especially the poor population in developing countries that spend half of their household income on food will feel the consequences of food price fluctuations that can create food scarcity and hunger (Mitchell, 2008). Various nongovernmental organisations and other organisations have made it their goal to ensure worldwide food security (FAO, website 2014). Unfortunately, it remains unclear what exactly affects agricultural commodity prices (Nazlioglu, Erdem & Soytas, 2013).

[1] The FAO Food Price Index is calculated using the weighted prices of two poultry products, three bovine meat products, three pig meat products, one ovine meat product, butter, milk, cheese, 10 wheat quotations, maize, 16 rice quotations, 10 vegetable oils and sugar (FAO website, 2014).

As already discussed above, even the organisations that are considered authorities in this manner are not always able to foresee upcoming changes. Therefore, this paper will strive to develop a proper model to be able to forecast agricultural food commodity prices.

Agricultural food commodities are internationally traded on a large scale using commodity futures. These futures are contracts that state the obligation to buy or sell a certain amount of a commodity at a specific time (FAO, 2010). Using these futures enables a trader to participate on a future transaction and be certain of a transaction price that is not affected by market developments anymore. Commodity futures are traded openly and the markets can be entered by any trader. Therefore, it is thought that through arbitrage the price of the futures includes all market information that is publicly available. This paper develops a model that tries to forecast agricultural food commodity prices using parts of this market information that fall in the categories cost of production, change of demand, speculation and exchange rate.

The outline of the paper is as follows: Section 2 discusses what determines agricultural food commodity prices following from the literature. Section 3 outlines the method that is used and the description of the data. Then Section 4 interprets and discusses the empirical results, followed by Section 5 where conclusions are made based on the findings of this paper.

Section 2. What determines agricultural food commodity prices?

Although commodity is a widely used term in the academic literature, there is no clear cut definition for these products (Cantree, 2007). Despite lacking a definition, the characteristics of the products that are commonly described as commodities are objects of value, things that can be exchanged and things that can be bought and sold via money (Cantree, 2007). These characteristics imply that a broad range of products can be defined as commodities. In order for commodities to be internationally traded it has to have either a futures contract assigned that is traded on an exchange market, or an exchange-traded fund tracking it. An important function of these markets is that it allows agents to trade the commodities based on market information, creating a market price (Gilbert, 2010). Commodities are frequently grouped according to product characteristics and production method. An example of this grouping is the International Monetary Fund (henceforward IMF) division distinguishing commodities in food, beverages, agricultural raw materials, metals and energy (IMF website, 2014). Commodity futures exchanges facilitate trading of one or more of specific groups of commodities. There is a large number of commodity futures exchanges worldwide and it depends on the commodity of interest which exchange is the most notable. Based on the number of contracts overall without differentiating in specific commodities the most important exchanges are the New York Merchantile Exchange (mainly energy and metals), the Chicago Board of Trade (mainly agricultural products) in the United States and the Dalian Commodity Exchange (mainly agricultural products) in China (Santana-Boado & Gross, 2006). The characteristics of these markets will be further elaborated in Section 1.3.

As commodities can be very different from each other, movements and volatility of prices can vary considerably across individual commodities (Gilbert, 2010). Nevertheless, overall and over the years commodities have exhibited a pattern of fluctuations with high volatility. This pattern has changed over the last decade. In this period commodity prices have shown a prolonged upsurge before the financial crisis and a downturn during and in the aftermath of the financial crisis (Cevik & Saadi Sedik, 2011). During this period especially food commodity prices showed remarkable increases just like the general rise of commodity prices (Du, Yu & Haynes, 2011; Gilbert, 2010; Mitchell, 2008). This trend can be seen in Figure 1, where the IMF Food Price index[2] and the IMF All Commodity Price index[3] show an upward trend over the last ten years. What is also striking is that food prices show less volatility than the general price of all commodities. This exceptional behaviour of food commodity prices makes it worthwhile to further investigate the mechanisms that add to the realisation of these prices. Whether the trend of increasing commodity prices is permanent is debatable. As Calvo-Gonzalez, Shankar & Trezzi (2010) point out, evidence suggests that structural breaks with upward or downward commodity price volatility alternate each other so that there is no strict trend over time.

[2] The IMF Food Price index includes prices of internationally traded cereals, vegetable oils, meat, seafood, sugar, bananas and oranges.
[3] The IMF All Commodity Price index includes prices of fuel and non-fuel commodities.

Figure 1. Comparing the Food Price Index trend to the general commodity price trend[4]

Source: IMF, Primary Commodity Price data (IMF website, 2014)

Although there appears to be no defined long run upward or downward trend in commodity prices, the consequences of the short term spikes can be profound. Sharp and sudden movements in commodity prices cause an important shift in the terms of trade, real incomes and fiscal positions of countries that depend on commodities (Nazlioglu et al., 2012). Also, price movements in agricultural commodities have enormous consequences for the poor population in developing countries that spend roughly half of their household income on food (Mitchell, 2008). Therefore, the volatility of commodity prices has a broad range of policy implications to respond to welfare effects of variable commodity prices. For policy makers to be able to respond in time to commodity price shocks and changes its consequences, is necessary to have information on the mechanisms that influence commodity prices and to have forward looking information on the expected prices. The first, the mechanisms that add to the realisation of agricultural commodity prices, has been reviewed extensively in the academic literature (examples: Baffes, 2007; Gilbert, 2010; Harri & Hudson, 2009a; Harri, Nelley & Hudson, 2009b; Ji & Fan, 2011; Liu, 2014). The latter, forward looking information on the

[4] Food Price Index includes price indices of cereal, vegetable oils, meat, seafood, sugar, bananas and oranges. Beverage Price Index includes price indices of coffee, tea and cacao. Industrial Inputs Price Index includes price indices of agricultural raw materials and metals. Fuel Price Index includes price indices of crude oil, natural gas and coal. All Commodity Price Index includes Food Price Index, Beverage Price Index, Industrial Inputs Price Index and the Fuel Price Index.

expected prices, is merely being investigated through the explanation and forecast of the volatility of commodity prices (examples: Calvo-Gonzalez et al., 2010; Du et al., 2011; Huang, Huang, Matei & Wang, 2012; Nazlioglu et al. 2012; Reboredo, 2012). Nevertheless, the academic literature lacks a proper forecast method of the agricultural food commodity prices itself. Therefore this paper seeks to develop this forecast method that will provide risk management strategies for policy makers concerned with food commodity prices.

The forecast method used in this paper will be based on variables that can be placed in four groups: cost of production, changes in demand, speculation and changes in exchange rates. The next section will further elaborate on these four groups and the variables that they contain.

2.1 Cost of production

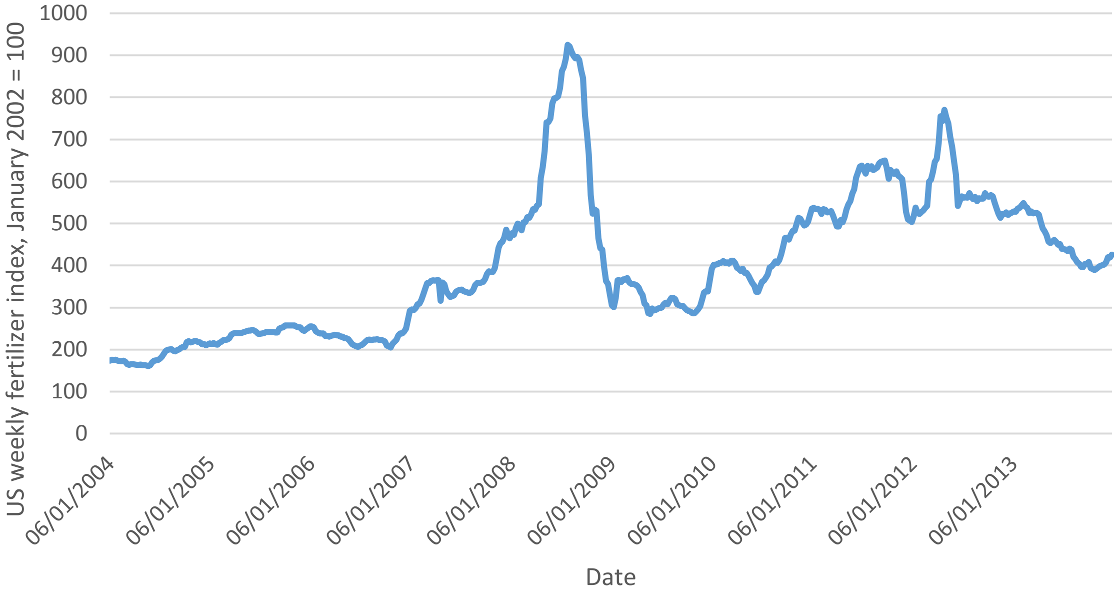
As with all products, the cost of production reflects in the price of the product. Therefore, large swings in production costs can cause large swings in commodity prices in order for the supplier to be able to make profits. As the commodities that are considered in this paper are traded on international futures markets, arbitrage is thought to enable changes in production cost to be reflected in the futures price immediately. The cost of production is therefore an important determinant when forecasting commodity prices with an expected positive effect on agricultural food prices. The proxies for the cost of production that are used in this paper are the fertilizer price and the oil price. In 2013, in the United States these costs accounted for on average 45 percent of the operational cost of production for agricultural food commodities[5]. Together they accounted for on average two thirds of the increase in operational cost of production between 2012 and 2013 (USDA (United States Department of Agriculture), 2014). They can therefore be seen as the most important drivers behind the cost of production for agricultural commodities (Mitchell, 2008).

Fertilizer enables suppliers of agricultural food products to yield a higher production per square metre. It is therefore inevitable in the production process and its price will be reflected in the agricultural food commodity prices as part of the production costs. Von Braun and Torero (2009) also name the increased use fertilizer as one of the drivers behind the recent spikes in commodity prices. Mitchell (2008) adds to that by identifying fertilizer as one of the main causes of the volatility of agricultural commodity prices. However, there might be a difference in the effect of fertilizer prices in regional markets and international markets. In

[5] Calculated based on the production cost breakdown of corn, soybeans, wheat and rice (USDA, 2014).

regional markets agricultural food commodity supply is relatively inelastic over time. Therefore, differences in the costs of production are likely to be passed through to the consumer. In international markets supply is less inelastic and supply can switch to crops that yield the highest profits (FAO, 2008). As can be seen in Figure 2, fertilizer has experienced rapid and high price increases between 2007 and 2009 and 2010 and 2012.

Figure 2. Development of the US weekly fertilizer index[6]



Source: Green Markets

These periods are also marked with increased agricultural production (FAO, 2012). It can therefore also be that the price of fertilizer reflects worldwide production, where an increasing (declining) fertilizer price indicates increasing (declining) production. In this way the price of fertilizer might have a negative effect on the price of internationally traded futures of agricultural food commodities, as the balance between supply and demand changes.

The crude oil price can have an effect on agricultural food prices as fuel is an important input for the production of agricultural food commodities as they are produced by an energy intensive production process. During 2013 fuel and electricity entailed for on average 15% of the operational production costs of wheat, corn, soybean and rice produced in the United States

[6] The US Weekly Fertilizer index is computed using US Gulf Coast Urea, US Cornbelt Potash and NOLA Barge DAP weighted based on the annual global demand of each nutrient.

(USDA, 2014). Therefore, changes in the crude oil price will positively affect the production costs that will be passed on to the agricultural food commodity prices.

The relation between agricultural commodity prices and the oil price has been investigated thoroughly. Baffes (2007) finds that the pass-through of crude oil price changes to agricultural price indices is 0.17 by examining 35 internationally traded primary commodities for the 1960-2005 period. Ji & Fan (2011) also conclude that after examining the price spill over and the variance spill over between the crude oil price and commodity prices that the crude oil market is at a core position in the commodity markets. Nevertheless, they find that this relation has changed and weakened during the financial crisis. Contrary to this result, finds Liu (2014) that the cross-correlation between crude oil and agricultural commodity returns even strengthened during the financial crisis. These findings are supported by Nazlioglu et al. (2012) who also finds significant volatility transmission from oil returns towards agricultural commodity returns. Another recent papers on the relation between oil prices and commodity prices is Harri & Hudson (2009a), who uses a cointegration method and finds that oil prices are correlated with the prices of corn, cotton and soybeans. Du et al. (2011) on the other hand, finds moderate evidence of volatility pass through from the crude oil price to the price of corn and wheat. However, for the November 1998 to October 2006 period they find that the markets behave very differently. It can be concluded that this topic has been reviewed widely but without consensus results. Therefore, in this paper the oil price is included not as a sole determinant for agricultural food commodity prices, but as part of a more diversified set of variables.

2.2 Change of demand

Changes in demand for a commodity combined with stable production can lead to price fluctuations. Therefore, changes in demand are an important factor to look at when assessing agricultural food commodity price changes. As the commodities that are considered in this paper are traded on futures markets, changes in demand can be immediately translated into the commodity price. Mitchell (2008) suggests that shifts in demand are the largest influence on the recent commodity price rise. Also, as these markets operate internationally, changes in demand should be looked at not at an individual level, but at a broader macroeconomic view (Gilbert, 2010). The proxies for changes in demand that are used in this paper are money supply, world gross domestic product (henceforward GDP) growth and biofuel production.

Countries influence money availability with their money supply. Monetary expansion increases the money available in de economy and increases the interest rate, monetary contraction does the complete opposite. The production of agricultural food commodities, on the other hand, can’t be changed dramatically overnight. When the money available in the economy increases (decreases) and the number of agricultural food commodities stays equal traders have more (less) money available to offer. This will lead to increasing (decreasing) agricultural food commodity prices. Therefore, monetary expansion (contraction) would lead to an increase (decrease) in agricultural food commodity prices (Liu, 2014). Gilbert (2010) finds that these policies are one of the main determinants of changes in the overall level of agricultural commodity prices (Gilbert, 2010). The recent spikes in commodity prices could therefore possibly be linked to the monetary expansion policies during the financial crisis.

Worldwide GDP growth entails the worldwide growth in production and therefore worldwide growth of overall demand. Assuming that production of agricultural commodities stays equal, world GDP growth will result in a rise of agricultural commodity prices. Especially the increased growth and demand coming from emerging countries has had and profound influence on the agricultural commodity price fluctuations (Cevik & Saadi Sedik, 2011). This makes world GDP growth one of the main determinants in the group of proxies for changes in demand (Gilbert, 2010).

A new dynamic in the agricultural commodity markets is the usage of commodities for biofuels like ethanol and biodiesel. Soybeans, wheat and corn are used for the production of these fuel products and therefore it is expected that for these agricultural food commodities the energy and agricultural markets show a tight market integration (Nazlioglu et al., 2012). This whole new application has led to a trade-off between food and fuel and is argued to be an important factor in the recent commodity price increase (Rosegrant, Zhu, Msangi & Sulser, 2008). As the acres for agricultural commodity production are limited the demand for biofuels will lead to an increase in agricultural food commodity prices overall that is not only product specific (Liu, 2014). Gilbert (2010) finds that the demand for biofuels was responsible for approximately 25 to 30 percent of the rise in food prices between 2006 and 2008. Mitchell (2008) even states that biofuels and related consequences account for approximately 70 percent of the increase in international food prices. As markets become more and more interrelated due to these new techniques, it seems logical that agricultural commodities import price variability from the biofuels sector (Harri & Hudson, 2009a; Ji & Fan, 2011). This new market integration is thought to be a highly important change in the agricultural commodity market that can change its dynamics forever (Nazlioglu et al., 2012). Agricultural commodity prices import price variability from the biofuels sector (Harri & Hudson, 2009a) and therefore these dynamics are included in the model used in this paper.

2.3 Speculation

Trading large amounts of agricultural food commodities on international futures exchanges comes with a side effect: the price of the commodity is also affected by traders that make transactions with these contracts for investment reasons only. More than in other markets general commodity markets consists of traders that can be divided into financial traders and commercial traders. Commercial traders use the commodities for consumption or production and are therefore seeking to hedge their position in the futures market. In this way, they can anticipate on future transactions and have a transaction price that is not affected by market developments anymore. Financial traders in commodity markets traditionally make profits by arbitrage and offsetting positions of commercial traders. Thereby, financial traders provide liquidity in the general commodity markets (Domanski & Heath, 2007). The presence of these investors and speculators are thought to have had an enhancing influence during the recent commodity price increases (Du et al., 2011; Gilbert, 2010; Mitchell, 2008). To capture these effects in the model to forecast agricultural commodity prices the amount of speculation and market liquidity are used.

Financial traders view commodity markets as a profitable way to diversify their investment portfolio and hedge risks. Therefore, commodities can also be seen as financial assets (Nazlioglu et al., 2012). This so called financialisation of commodities has intensified over the last decade (Nazlioglu et al., 2012). As a result of this commodities and their prices are also subject to dynamics of financial markets. Du et al. (2011) find that speculation intensity of non-commercial has explanatory value of the volatility of the oil price. However, it is debatable whether speculation influences agricultural food commodity prices positively or negatively. Financial traders that enter the market create new demand and might therefore increase the price of agricultural food commodities. But, the distinction between commercial traders and financial traders can make their effect on agricultural food commodity prices ambiguous. Commercial traders are seeking to hedge their future positions to price risk and are therefore willing to pay a risk premium. Financial investors enter the market when they expect to collect this risk premium (Johnson, 1960). The more financial investors are in the market, the more options the commercial trader has to hedge its position. This creates a downward pressure on the risk premium and the agricultural food commodity prices.

Liquidity of the market represents the trader's ability to buy or sell quantities of an asset quickly and at low cost (Chordia, Sarkar & Subrahranyam, 2005). In this way a trader can easily respond to new public information that affect the return on its investments. Liquidity can change over time and the market price of an asset therefore includes liquidity risk. Changes in liquidity can change corn and wheat price variability is positively influenced by market liquidity (Du et al., 2011). Also Reboredo (2012) stipulates that markets perform optimal when they are as liquid as possible. The more liquid the market, the less risk commodity futures carry with them. This makes it more usable for hedging and other investment purposes. Higher demand resulting from this is thought to have a positive effect on agricultural food commodity prices. Therefore, it is necessary to include market liquidity in the forecast of this paper. Combined with the financialisation of commodities over the last decade this could provide important information on future movements.

2.4 Exchange rate

The relation between exchange rates and commodity prices has also been investigated thoroughly in the economic academic literature. As most internationally traded commodities are priced in dollars they will be affected by changes in the dollar exchange rate (Gilbert, 2010; Ji & Fan, 2011). Depreciation (appreciation) of the dollar exchange rate to the currencies of the international trading partners of the United States will make commodity futures relatively cheaper (more expensive). This creates changes in demand that can affect agricultural food commodity prices positively. Evidence for this relation is found by Harri & Hudson (2009a), who find a cointegration relationship between exchange rates and the corn price between April 2006 and March 2009. Also, Gilbert (2010) finds that the dollar depreciation was an important determinant in the commodity price increase between 2006 and 2008. He estimates that 15.1% of the commodity price change can be related to dollar exchange rate differences. Mitchell (2008) assigns an even higher portion of the commodity price change to dollar exchange rate movements, namely approximately 20 percent. The relation between dollar exchange rates and commodity prices can change over time. Ji & Fan (2011) examines the volatility spill over between the exchange rate and 19 widely traded commodities and finds that the relation has weakened since the financial crisis in 2008, changing from significant for all commodities to insignificant volatility spill overs. The dollar exchange rate to its international trading partners appears to contain predictive information on commodity prices and is included in the model of this paper.

2.5 Forecasting

The forecasting method that will be used in this paper is an out-of sample forecast with realised fundamentals. The advantage of this method is that it is not seeking for an ex ante examination of the estimated results, but focuses on evaluating the predictive ability of the model (Ferraro, Rogoff & Rossi, 2012). Also, a large part of the parameters used in this paper are sensitive to politics and unpredictable external shocks. Therefore, the parameters are hard to forecast. When the forecasts of these parameters itself are not an easy task to perform, using these forecasts to forecast agricultural commodity prices is inaccurate. It could lead to rejecting the predictive ability of the model of this paper due to inexact forecasts of the parameters, instead of the model itself. Using realised values of the parameters can eliminate this problem (Ferraro et al., 2012). The forecasting method will be explained more thoroughly in Section 3.

Section 3. Data and method

The main focus of this paper is to develop and assess a model that has the ability to forecast agricultural food commodity prices. This section will describe the data that is used to determine the model and the method that is used to assess the predictive ability of the model.

3.1 Method

As described in the previous section, the model used in this paper identifies eight independent variables to influence the dependent variable of the agricultural food commodity price. This results in the following model:

$$\Delta C_t = \alpha + \beta\Delta F_t + \gamma\Delta O_t + \zeta\Delta M_t + \eta\Delta Y_t + \theta\Delta B_t + \xi\Delta SI_t + \chi\Delta ML_t + \psi\Delta X_t + u_t,\ t = 1, \ldots, T,$$

where ΔC_t is the first difference of the logarithm of the price of the futures contract of the respective agricultural food commodity,

ΔF_t is the growth rate of the price of fertilizer,

ΔO_t is the growth rate of the crude oil price,

ΔM_t is the growth rate of worldwide money supply,

ΔY_t is the growth rate of worldwide GDP,

ΔB_t is the growth rate of biofuel production,

ΔSI_t is the growth rate of the speculation intensity,

ΔML_t is the growth rate of the market liquidity,

ΔX_t is the growth rate of the trade weighted US dollar exchange rate,

u_t is an unforcastable error term,

and T is the total sample size.

It is expected that all of the dependent variables have a positive effect on agricultural food commodity prices. The aim of this paper is not so much to only explain the past movements of agricultural food commodity prices, but to assess whether it might be possible to predict these prices. Therefore, the right-hand-side of the equation will be tested for its predictive ability.

Forecasting literature distinguishes two types of prediction methods: ex ante forecasts and ex post forecasts. The difference between the two methods concerns the information on the explanatory variables that is used for the prediction. The ex ante approach forecasts a future event using the information that was available before the event occurred. An example of this would be predicting tomorrow's share price of a listed company based on market information that is available today. In this way the forecast method should provide information on the change of the market information from today to tomorrow and on the effect of tomorrow's market information on tomorrow's share price of a listed company. This method is used at occasions where it is necessary to be able to anticipate upfront on future events. The ex post approach forecasts a future event using the information that was available right at the moment the event happened. This can only be done in retrospect. An example of this is predicting yesterday's share price of a listed company based on market information that was available yesterday. In this way the forecast method should have to provide only information on the effect of yesterday's market information on yesterday's share price of a listed company. The method should not have to provide any information on the market information itself, compared to the ex ante approach (Ferraro et al., 2012). An advantage is that one can prevent to reject the predictive ability of the model not due to the absence of a relation between the dependent variable and the explanatory variables, but due to poor prediction of the explanatory variables. This method is used for assessing models and determining its performance by comparing the forecasts with the actual outcomes and it is widely used for the prediction of exchange rates (Cheung, Chinn & Pascual, 2005; Meese & Rogoff, 1983). Therefore, the ex post method is used to assess the model of this paper.

The forecasts will be made using a one-step-ahead pseudo out-of-sample forecast method using the realized values of the explanatory variables to create ex post forecasting. The parameters are estimated using a rolling sample of observations. This means that the estimates are made over a given data sample before creating a one-step-ahead forecast. Then the end of the sample is rolled forward with one observation, while the start of the sample is anchored at the first observation. Based on that sample new estimates are made, again creating another one-step-ahead forecast. This procedure is iterated until the end of the observations. The advantage of this method is that allows for relations to change overtime, as it is reasonable to suspect that these are time varying for agricultural food commodity prices (Cheung et al., 2005).

The forecast model of this paper will estimate the following model for the forecasts of the agricultural food commodity prices $\Delta C^f{}_{t+1}$:

$$\Delta C^f{}_{t+1} = \hat{\alpha}_t + \hat{\beta}_t \Delta F_{t+1} + \hat{\gamma}_t \Delta O_{t+1} + \hat{\zeta}_t \Delta M_{t+1} + \hat{\eta}_t \Delta Y_{t+1} + \hat{\theta}_t \Delta B_{t+1} + \hat{\xi}_t \Delta SI_{t+1} + \hat{\chi}_t \Delta ML_{t+1} + \hat{\psi}_t \Delta X_{t+1},\ t = R, R+1, \ldots, T-1$$

where T is the total sample size and R is the estimation window size.

To determine the predictive ability of the model its forecast have to be compared to another model. To date, the random walk[7] without drift that is considered by Meese & Rogoff (1983) is still the most important model to beat when it comes to forecasting (Ferraro et al., 2012). The squared forecast errors (SFEs) of both models can be compared by the Diebold and Mariano (1995) test. This test calculates the difference between the SFEs of the forecast model and the SFEs of the random walk using the following equation

$$SFE_{m,t} - SFE_{rw,t} = \alpha + u_t,\ t = 1, \ldots, T,$$

where $SFE_{m,t}$ is the squared forecast error of the model at time t, $SFE_{rw,t}$ is the squared forecast error of the random walk at time t, α is the constant drift that might me significantly present in the difference between the two SFEs, u_t the unforecastable error term and T the total sample size. The SFEs are calculated by the squared difference between the actual value of the change in the agricultural food commodity price and the forecasted value provided by the model:

$$SFE_{m,t} = (\Delta C_t - \Delta C^f{}_{m,t})^2$$

[7] The predictive ability of the forecast model will only be compared with the random walk without drift, as the random walk with drift is not significant for all four agricultural food commodities that are used in this paper.

When performing the Diebold Mariano test, a value for α that is significantly larger (smaller) than zero indicates that the model of this paper performs worse (better) than the random walk.

3.2 Data description

The sample that is used for assessing the model contains data of every Tuesday running from 6 January 2004 to 31 December 2013. As the most important agricultural food commodity exchange markets are located in the United States (Santana-Boado & Gross, 2006), are the agricultural food commodities that are considered in this paper traded on the Chicago Board of Trade. Therefore, the focus of the variables is on production of commodities in the United States. But, because international traders can easily access this commodity exchange market the proxies for commodity demand will focus on providing worldwide information. Additional information per variable is available in Appendix A**.**

Agricultural food commodity prices (C): Weekly settlement price calculated volume-based between 13:14 hours and 13:15 hours of the futures contracts of corn, soybeans, wheat and rough rice traded on the Chicago Board of Trade. Source: Datastream.

Fertilizer price (F): Weekly index of the US Weekly Fertilizer index, computed using US Gulf Coast Urea, US Cornbelt Potash and NOLA Barge DAP weighted based on the annual global demand of each nutrient. Source: Green Markets.

Crude oil price (O): Weekly spot price of West Texas Intermediate crude oil, the benchmark in oil pricing for oil futures contracts traded in the United States. Source: Datastream.

Money supply (M): Monthly nominal M2 of the United States, the Euro zone, the United Kingdom, Japan, Canada and China. Monthly data is first converted to United States dollars using the monthly average exchange rate (source: Datastream). Source: IMF, International Financial Statistics.

GDP (Y): Quarterly real Gross Domestic Product of the United States in constant 2009 prices, the Euro zone in constant 2005 prices, the United Kingdom in constant 2010 prices, Japan in constant 2005 prices and Canada in constant 2007 prices. Quarterly data is first converted to United States dollars using the monthly average exchange rate (source: Datastream). Source: IMF, International Financial Statistics, National Statistics United Kingdom and Statistics Canada.

Biofuel production (B): Monthly supply of fuel ethanol in the United States in thousands of gallons. Source: US Department of Agriculture, Economic Research Service

Speculation intensity (SI): Weekly speculation index of the ratio of excess short or long positions held by non-commercial traders to the total hedging positions held by commercial traders. The data is specific to the considered agricultural food commodity. Source: US Commodity Futures Trading Commission. As non-commercial traders offset demand for hedging by commercial traders for financial reasons, the amount of excess positions held by non-commercial traders is speculation. When NL (NS) would represent long (short) positions held by non-commercial traders and CL (CS) the long (short) positions of commercial traders, the following equation must hold: NL + CL = NS + CS. The speculation index then calculates the positions of non-commercial traders exceeds the necessary minimum to offset hedging positions of commercial traders. This means that the speculation index is calculated as follows:

$$SI = \begin{cases} 1 + \dfrac{NL}{CL + CS}, & CL > CS \\ 1 + \dfrac{NS}{CL + CS}, & CS > CL \end{cases}$$

Market liquidity (ML): Weekly scalping index calculated by the ratio of futures market volume to futures open interest. The data is specific to the considered agricultural food commodity. Source: Datastream (futures market volume), US Commodity Futures Trading Commission (futures open interest). Scalping is done by traders that open and close contracts very quickly in order to make small profits. The number of contracts that have not been settled at the end of the day are the futures open interest.

Exchange rate (X): Weekly trade weighted United States dollar index. The index is calculated by the weighted average of the exchange rate of the United States dollar against the currencies of major trading partners of the United States[8] and not seasonally adjusted. Source: Federal Reserve Economic Data.

Agricultural food commodity prices can fluctuate significantly over a short period of time. Therefore, it is desirable to be able to forecast these prices over an as short period as possible in order to capture these fluctuations. However, data availability puts us in a dilemma. Information on the agricultural food commodity prices, fertilizer price, oil price, speculation intensity, market liquidity and exchange rates are all available on a weekly basis.

[8] The major trading partners of the United States included in the index are the Euro zone, Canada, Japan, Mexico, China, the United Kingdom, Taiwan, Korea, Singapore, Hong Kong, Malaysia, Brazil, Switzerland, Thailand, Philippines, Australia, Indonesia, India, Israel, Saudi Arabia, Russia, Sweden, Argentina, Venezuela, Chile and Colombia (Board of Governors of the Federal Reserve System).

Unfortunately, money supply and biofuel production are reported monthly, while GDP is only reported quarterly. This puts us to the choice either to use monthly data and neglect weekly fluctuations, or to interpolate the variables to weekly data and make the strong assumption that they would have constant growth rates during the month. To consider which option is best to forecast agricultural food commodity prices, weekly and monthly frequencies are compared based on their SFEs.

SFEs are the squared differences between the forecast of the model and the actual values of the agricultural food commodity prices. They indicate how accurate the model is able to forecast these prices. To see whether the forecast is significantly different from the actual value one can determine whether there is a constant drift in de SFEs by the following model:

$$(\Delta C_t - \Delta C^f{}_t)^2 = \alpha + u_t, t = 1, \dots, T,$$

where ΔC_t is growth rate of the price of the futures contract of the respective agricultural food commodity, $\Delta C^f{}_t$ is the growth rate of the price of the futures contract of the respective agricultural food commodity forecasted by the model, α the constant drift in the squared difference between the two, u_t the unforcastable error term and T the total sample size. When α is significantly different from zero, then the forecast is significantly different from the actual value. Furthermore, the value of α makes it possible to compare the SFEs of different models. Therefore, it is used here to compare the accuracy of the forecasts of monthly and weekly frequencies.

The model to forecast agricultural food commodity prices uses time varying coefficients obtained using a window size that is anchored at the beginning of the sample. As the number of observations differs between the monthly frequency and the weekly frequency, it is necessary to control for the differences in the length of the sample. Therefore, the forecasts to compare the SFEs for the two data frequencies are obtained using a window size that is not anchored at the beginning of the sample, but a constant window size of 60, 40, 30 and 24[9].

Table 1 shows α, the constant drift in SFEs, per agricultural food commodity for the monthly and weekly data frequency and for different window sizes.

[9] These window sizes refer to 1/2, 1/3, 1/4 and 1/5 of the total number of 120 observations of the monthly sample.

Table 1. SFE constant drift comparison weekly and monthly data frequency

Commodity	**Wheat**		**Corn**		**Soybean**		**Rice**	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Window size	*Drift*	*Drift*	*Drift*	*Drift*	*Drift*	*Drift*	*Drift*	*Drift*
60	0.0025	0.0112	0.0024	0.0068	0.0015	0.0049	0.0012	0.0053
40	0.0027	0.0131	0.0028	0.0122	0.0020	0.0085	0.0017	0.0066
30	0.0032	0.0136	0.0031	0.0172	0.0021	0.0112	0.0019	0.0063
24	0.0021	0.0135	0.005	0.0221	0.0031	0.0114	0.0148	0.0075

Note: all constant drifts are significant at the 99% significance level.

All constant drifts in the SFEs are significant, meaning that for both data frequencies the forecasts of the growth of agricultural food commodity prices made by the model are significantly different from the actual realised values of the growth rates. However, this doesn't say anything about the performance of the model relative to the random walk in forecasting agricultural food commodity prices. This will be elaborated on more thoroughly in Section 4.

What can be seen in Table 1 is that when comparing weekly and monthly data frequency while eliminating sample size differences weekly data has structurally lower constant drifts in SFEs than monthly data for every window size, except for forecasting rice with a window size of 24 observations. This means that the accuracy of the model performs better when forecasting weekly agricultural food commodity prices using weekly data, than forecasting monthly prices using monthly data. The choice of data frequency was a dilemma of choosing to either use monthly data and neglect weekly fluctuations, or to interpolate some variables to weekly data and make the strong assumption that they would have constant growth rates during the month. Because weekly data has structurally lower SFEs, the choice will be to use weekly data for the forecasts.

Section 4. Does the model have predictive ability?

As discussed above, the forecasts made by the model of this paper result in SFEs with a significant constant drift. This means that the forecasts are significantly different from the actual values of agricultural food commodity prices that they are forecasting. However, this provides no information on the performance of the model relative to other models. This section will discuss the predictive ability of the model relative to the model to beat: the random walk. As the four different agricultural food commodities wheat, corn, soybean and rice have different characteristics the effect of the explanatory variables can vary between the different agricultural food commodities. In this section, the model will be first estimated per agricultural food commodity using non-time-varying coefficients. In this way, it can be seen which variables affect the agricultural food commodity prices significantly over the entire period. When there are variables that have a clear insignificant effect, the model is estimated again leaving out the insignificant variables. Afterwards it is tested whether the forecasts made with the new estimation are significantly better than the forecasts made with the estimation with inclusion of all variables. The predictive ability of the best performing model will then be compared with the random walk.

The results for the estimation with non-time-varying coefficients for the prices of the agricultural food commodities are summarised in Table 2. The table contains the estimated coefficients and corresponding *p*-values between brackets. Specifications (1), (3), (5) and (7) entail the results of the estimation with inclusion of all variables of the model for wheat, corn, soybean and rice respectively. Specifications (2), (4), (6) and (8) entail the results of the estimation without the clear insignificant variables per agricultural food commodity for wheat, corn, soybean and rice respectively. First, the results are discussed per explanatory variable. Second, it is reviewed whether the model provides better forecasts when it leaves out clear insignificant variables per agricultural food commodity. Last, the specifications that provide the best results per agricultural food commodity will be compared with the random walk for its predictive ability.

Table 2. Non-time-varying coefficient estimations of the forecast model

Dependent variable: Δ Price of the futures contract								
	Wheat		**Corn**		**Soybean**		**Rice**	
Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable								
Δ Fertilizer price	-0.1193	-0.1006	-0.1374	-0.1320	-0.0075		-0.0150	
	(0.093)	(0.138)	(0.050)	(0.058)	(0.899)		(0.796)	
Δ Oil price	0.1489	0.1549	0.1228	0.1279	0.1485	0.1506	0.0204	
	(0.001)	(0.000)	(0.005)	(0.003)	(0.000)	(0.000)	(0.561)	
Δ Money supply	-0.1553		-0.8025		-0.6390		0.3194	
	(0.842)		(0.297)		(0.328)		(0.610)	
Δ GDP	2.6730		4.2335	3.6364	1.3911		3.3783	3.5067
	(0.203)		(0.041)	(0.067)	(0.427)		(0.045)	(0.024)
Δ Biofuel production	-0.2836	-0.2674	-0.1013		-0.0647		-0.0542	
	(0.089)	(0.102)	(0.536)		(0.641)		(0.685)	
Δ Speculation intensity	-0.3120	-0.3142	-0.4151	-0.4044	-0.2807	-0.2708	-0.1575	-0.1572
	(0.020)	(0.019)	(0.000)	(0.000)	(0.002)	(0.002)	(0.002)	(0.002)
Δ Market liquidity	-0.0014		-0.0007		-0.0021		0.0018	0.0017
	(0.719)		(0.849)		(0.576)		(0.047)	(0.047)
Δ Exchange rate	-1.7856	-1.8398	-1.3629	-1.3436	-1.1462	-1.1153	-1.0684	-1.1392
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.1587	0.1596	0.1491	0.1488	0.1459	0.1433	0.1005	0.0991

Notes: Regressions use a constant and *p*-values are displayed in parentheses.

4.1 The individual influence of the explanatory variables

The influence of the fertilizer price on agricultural food commodity prices presents a striking result. As it has a negative impact on the price of futures in wheat and corn it is not considered to be a cost of production that is passed through in the price. Also, it only has a significant effect on the prices of wheat and corn, not of soybeans and rice. As discussed earlier, the negative impact may indicate that the fertilizer price is rather a sign of production where an increasing (decreasing) price may indicate increasing (decreasing) production. The extra supply will then lead to decreasing prices, where 1 percent price increase of fertilizer leads to a 0.12 percent lower price of wheat and a 0.14 percent lower price of corn.

The crude oil price clearly is an important factor in the determination of the price of wheat, corn and soybeans, where an extra percent of the growth rate increases the growth rate of agricultural food commodity prices with between 0.12 and 0.15 percent. However, it has no significant effect on the price of rice. This is quite contrary to what one would expect based on the energy intensity of the production process of the different agricultural food commodities. In 2013, fuel and electricity accounted for 9, 12 and 15 percent of the total operating cost of respectively wheat, corn and soybean production in the United States (USDA, 2014). Rice production in 2013 in the United States was the most energy intensive, with fuel and electricity accounting for 25 percent of the total operating costs (USDA, 2014). It is therefore reasonable to think that the oil price affects the prices of wheat, corn and soybeans for more reasons than just as a cost of production. Other reasons can be that commodities provide an opportunity for investors to hedge their exposure to inflation induced by high oil prices (Ji & Fan, 2011), or that wheat, corn and soybean all can be used as biofuel and rice can’t. As the demand for biofuels increase when the price of oil increases it can therefore increase the prices of wheat, corn and soybeans (Ji & Fan, 2011).

Worldwide money supply has no significant effect on any of the four agricultural food commodities and worldwide GDP has a significance effect on the prices of corn and rice. This means that during the sample for wheat and soybeans demand is determined by other factors than these macroeconomic financial indicators and that having more money available to spend on commodities will not be translated into a price increase. When the worldwide GDP growth is significant, it has a strong positive effect of 4.233 for corn and 3.378 for rice. This means that a worldwide increase of income clearly increases demand that is translated into a higher price.

The effect of biofuel production only significantly influences the price of wheat. This could be explained by the fact that the biofuel production used in this paper is the United States production of bioethanol, for which wheat is one of the main inputs. However, the negative sign of the coefficient is different from previously found relations in the literature (Rosegrant et al., 2008). As wheat is the one of the main inputs for bioethanol, it is expected that the increased production of biofuels has increased the demand for wheat and its price. However, the negative sign found here might indicate that the same applies for biofuel production as for the fertilizer price. Rather than an indication for demand, the biofuel production change could be an indication for production of the inputs for biofuel. Aiming for the extra demand that new technologies have brought, farmers might have switched to production of commodities used for biofuel. This extra production causes the price of futures in wheat to decline.

Speculation appears to have a clearly significant negative effect on the prices of futures of all four agricultural food commodities. As discussed previously, the presence of financial traders could have two effects: either increased demand causing an increase in the prices, or lower risk premiums paid by commercial traders causing a decline in the prices. In this sample it appears that the latter dominates and an increase of 1 percent in speculation causes the price of agricultural food commodities to decrease with an effect of ranging between 0.16 percent for rice and 0.42 percent for corn.

Market liquidity is only significant for the price of a future in rice and only with a small coefficient: an increase (decrease) in market liquidity of 1 percent causes the price of rice to increase (decrease) with 0.002 percent. The insignificance of market liquidity could mean that the market for futures in commodities has already reached the point where there is a low liquidity risk and the liquidity risk premium is not affected anymore by additional liquidity.

The most striking of the empirical results is the effect that is found that the trade weighted US dollar exchange rate has on agricultural food commodity prices. Overall, the academic literature states that as most agricultural food commodities are denoted in dollars, the exchange rate should have a positive effect on agricultural food commodity prices (Gilbert, 2010). However, in this sample the exchange rate has a clearly significant negative effect with a coefficient ranging from -1.068 for rice to -1.786 for wheat. The differences between the results here and those of Gilbert (2010) could be due to sample period differences, a difference in the inclusion of United States trading partners in the trade weighted exchange rate or the agricultural food commodity prices that are used. The strong negative result that is found here may be induced by the way financial investors position commodity futures in their investment portfolio. Namely, commodity futures are also used for portfolio diversification, as their returns seem to be negatively correlated with the returns of equities and bonds (FAO, 2010; Gilbert, 2010). When the dollar depreciates (appreciates) against its trading partners, all dollar denoted become cheaper (more expensive) which might create other investment opportunities to have higher (lower) expected returns than commodity futures. This can be an explanation for financial investors to move away from (switch back to) commodity futures, creating less (more) demand and lower (higher) prices.

4.2 Comparing specifications

As the model contains explanatory variables that are insignificant for one or more of the four agricultural food commodities, it is tested whether the model produces different forecasts when the insignificant variables per commodity are excluded from the model. Using a Diebold Mariano (1995) test it can be seen whether the two specifications make significantly different forecasts and which of the specifications results in the lowest SFEs. When regressing the difference between the SFEs of the specification with all variables and the SFEs of the specification with only significant variables on a constant, it can be seen whether one of the specifications performs significantly better. For the price of futures in wheat the comparison of specification (1) and specification (2) in Table 2 it can be seen that the fertilizer price and biofuel production become also insignificant at the 90% significance level and the R^2 increases by only a negligible level. Also the comparison yields a Diebold Mariano test statistic of 1.239, which is lower than the 95% significance level statistic of the normal distribution 1.96. Therefore, the forecasts made by both specifications are not significantly different. As specification (1) contains more significant variables this specification will be used to compare its predictive ability with the random walk.

For the price of futures in corn the comparison of specification (3) and (4) in Table 2 it can be seen that the most striking change is the coefficient of the effect of worldwide GDP on the price of corn from 4.2335 to 3.6364. Also, the R^2 shows a negligible decrease from 0.1499 to 0.1488. The Diebold Mariano test statistic for equal SFEs is 1.661, making the models not forecast significantly different compared to the 95% significance level statistic of the normal distribution. As specification (3) contains more variables this specification will be used to compare its predictive ability with the random walk.

For the price of futures in soybeans the comparison of specification (5) and (6) in Table 2 shows that there are no striking differences and the R^2 decreases only by a small amount from

0.1459 to 0.1433. The Diebold Mariano test statistic is 4.333, meaning that the specifications provide significantly different forecasts. As the constant is positive and the difference between the specifications is calculated by subtracting the SFEs of specification (6) from the SFEs of specification (5), specification (6) performs better. Therefore, the specification with the exclusion of clearly insignificant variables will be used to compare its predictive ability with the random walk in forecasting the price of futures in soybeans.

For the price of futures in rice the comparison of specification (7) and (8) in Table 2 shows that the differences are not appealing, with only R^2 declining from 0.1005 to 0.0991. The Diebold Mariano test statistic testing for equal forecasts is 2.790, meaning that the specifications provide significantly different forecasts. This time the constant is again positive, while the difference between the specifications is calculated by subtracting the SFEs of specification (8) from the SFEs of specification (7). Therefore, the specification with exclusion of clearly insignificant variables will be compared to the random walk.

4.3 Comparison with the random walk

As the models performing best per agricultural food commodity are identified in the previous section, these will now be tested on their predictive accuracy. The model to beat is the random walk[10] introduced by Meese and Rogoff (1983). The models will be compared using the Diebold Mariano (1995) method, the same method that was used in the previous section to identify the best specifications. . This test calculates the difference between the SFEs of the model of this paper and the SFEs of the random walk using the following equation

$$SFE_{m,t} - SFE_{rw,t} = \alpha + u_t \,, t = 1, \ldots, T,$$

where $SFE_{m,t}$ is the squared forecast error of the model at time t, $SFE_{rw,t}$ is the squared forecast error of the random walk at time t, α is the constant drift that might me significantly present in the difference between the two SFEs, u_t the unforecastable error term and T the total sample size. The SFEs are calculated by the squared difference between the actual value of the change in the agricultural food commodity price and the forecasted value provided by the model. When performing the Diebold Mariano test, a value for α that is significantly larger (smaller) than zero indicates that the model of this paper performs worse (better) than the random walk. As

[10] The predictive ability of the forecast model will only be compared with the random walk without drift, as the random walk with drift is not significant for all four agricultural food commodities that are used in this paper.

the constant drift follows a normal distribution (Ferraro et al., 2012), the 95% significance level statistics are -1.96 and 1.96.

The Diebold Mariano test statistics for all four agricultural food commodities are displayed in Table 3. As can be seen, for all four agricultural food commodities the Diebold Mariano test shows that there is a clearly significant constant drift in the difference between the SFEs of the model and the SFEs of the random walk. All coefficients are negative, meaning that this drift is negative and the SFEs of the random walk are larger than the SFEs of the model. Thus, over the sample the model performs better in forecasting the price of futures in wheat, corn, soybean and rice than the random walk does.

Table 3. Diebold Mariano test statistic comparing the forecast model and the random walk

Agricultural food commodity:	Wheat	Corn	Soybean	Rice
Specification	(1)	(3)	(6)	(8)
Diebold Mariano test statistic	-7.9607	-8.6733	-8.5945	-8.4737
Coefficient	-0.0026	-0.0028	-0.0018	-0.0013
P-value	0.0000	0.0000	0.0000	0.0000

Section 5. Conclusions

This paper has developed a model to forecast the agricultural food commodity prices of wheat, corn, soybeans and rice that performs better than the random walk, the benchmark that is still the most important to beat. The model of the paper contains variables that can be placed in four groups: cost of production, changes in demand, speculation and changes in exchange rate. The model was tested using a sample period running from January 2004 until December 2013. The analysis of the model has revealed some important and noteworthy results about explaining the development of agricultural food commodity prices.

First, agricultural food commodity prices are negatively impacted by the fertilizer price, the production of biofuel and speculation intensity. The price of fertilizer has a negative impact on the prices of futures in wheat and corn. This is a striking result, as the price of fertilizer is not translated in the prices of the futures as a cost of production. Therefore, it rather may be a determinant of production, which is negatively impacting prices through supply. The same can be seen for the effect of biofuel production on agricultural food commodity prices. The production of bioethanol has a significant negative impact on the price of wheat, the main input for bioethanol production. As this effect is negative, the new application of wheat and increased demand has not led to an increase in the prices. This result could be parallel to the result for fertilizer, the new technologies could have led to increased production of wheat. Speculation intensity has a negative effect on all four agricultural food commodity prices, as it reduces the risk premium paid by commercial traders.

Second, agricultural food commodity prices are positively impacted by the crude oil price and worldwide GDP growth. The crude oil price provides significant results for the price of futures in wheat, corn and soybeans. As the effect is not significant for the commodity with the most energy intensive production process, rice, the crude oil price is more than just a cost of production raising the prices. Another reason can be that wheat, corn and soybeans all can be used as inputs for biofuel and are therefore affected more by the crude oil price. GDP growth impacts the prices of futures in corn and rice and therefore worldwide income rises create an upward pressure on their prices.

Third, a striking empirical result is that the trade weighted US dollar exchange rate has a negative result on the prices of futures in all four agricultural food commodities. In the literature it is thought that a depreciation (appreciation) of the dollar to the rest of the world would make commodities denoted in dollars become cheaper (more expensive) and make the prices of their futures increase (decrease). However, as all commodities and products denoted in dollars become cheaper (more expensive) following a depreciation (appreciation), apparently traders move away from the agricultural food commodities wheat, corn, soybean and rice towards other products.

After assessing the empirical outcomes of the model, the forecasts made by the model with time-varying coefficients are compared to the forecasts made by the random walk. Using the Diebold Mariano (1995) test it can be proven that the forecast model provides significantly better forecasts than the random walk does for all four agricultural food commodities that are considered in this paper. Therefore, using the forecast model of this paper, policy makers and other stakeholders are provided with a framework that might enable them to anticipate better on agricultural food commodity price volatility.

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Appendix A. Descriptive statistics

Category	Variable	Unit	Frequency	Mean	Median	Minimum	Maximum	St. Dev	# Obs
Agricultural food commodity price	Price of future in wheat	$	Weekly	5.78	5.74	2.90	12.23	1.92	522
	Price of future in corn	$	Weekly	10.29	9.99	5.03	17.68	3.29	522
	Price of future in soybeans	$	Weekly	4.38	3.92	1.86	8.31	1.79	522
	Price of future in rice	$	Weekly	12.46	13.08	6.49	23.85	3.51	522
Cost of production	Fertilizer price	Index, January 2002 = 100	Weekly	401.64	377.19	160.90	925.04	168.98	522
	Crude oil price	$ per barrel	Weekly	76.43	76.25	33.73	140.97	22.50	522
Change in demand	Worldwide money supply	$m	Monthly	37,736,245	37,750,699	24,147,155	54,266,544	9,536,240	121
	Worldwide GDP	$m	Quarterly	24,850,326	25,063,417	22,308,589	27,019,750	1,503,036	41
	Biofuel production	1,000 gallons	Monthly	769,173	842,016	258,510	1,248,156	343,977	121
Speculation	Speculation in wheat	Ratio	Weekly	1.21	1.20	1.09	1.46	0.07	522
	Speculation in corn	Ratio	Weekly	1.13	1.10	1.04	1.37	0.07	522
	Speculation in soybeans	Ratio	Weekly	1.12	1.10	1.04	1.26	0.05	522
	Speculation in rice	Ratio	Weekly	1.15	1.12	1.00	1.94	0.13	522
	Market liquidity in wheat	Ratio	Weekly	9.15	5.62	1.92	154.41	11.84	522
	Market liquidity in corn	Ratio	Weekly	8.91	5.79	1.88	161.95	10.70	522
	Market liquidity in soybeans	Ratio	Weekly	5.27	3.56	1.28	46.25	5.00	522
	Market liquidity in rice	Ratio	Weekly	21.72	11.96	1.63	313.76	34.21	522
Exchange rate	Trade weighted exchange rate of the US dollar index	Index, January 1997 = 100	Weekly	104.22	102.70	93.73	117.87	5.77	522