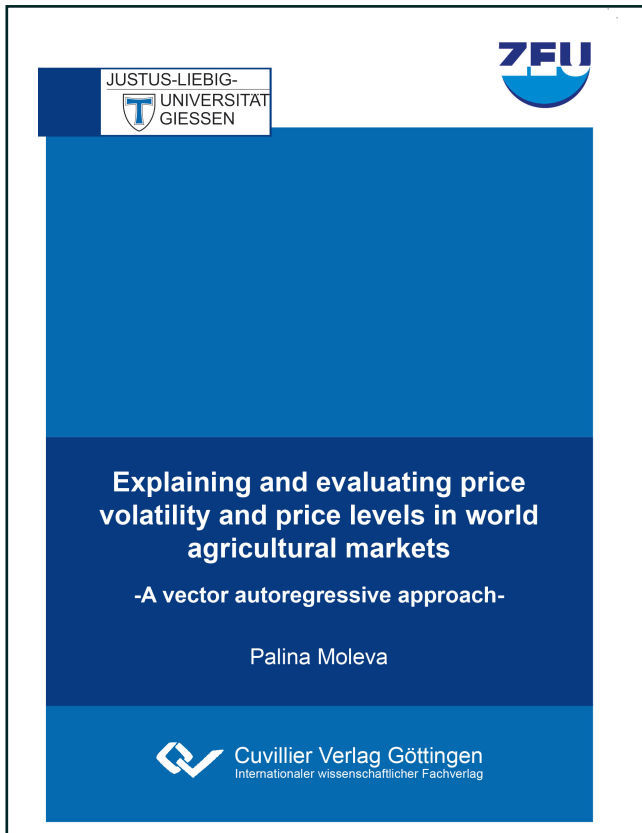




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**Explaining and evaluating price volatility and price levels in  
world agricultural markets**  
*A vector autoregressive approach*



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## 1. Introduction

### 1.1. Problem statement and objectives of the thesis

The worldwide explosions of agricultural commodity and staple food prices in the years 2007/08 and the subsequent recession-related decline in 2009 have not only surprised many market observers, but has also caused an intensive discussion about the causes, the consequences and the necessary policy responses. The new price spike in the years 2011 until 2013 and the current price crisis, especially for dairy and meat products since 2014/15, revived this debate again and raised the question, of how to explain and to evaluate such extreme level shifts and volatilities of agricultural prices, and where the prices move in the long run.

First, the question was in the foreground, whether high and volatile prices threaten the world food security. In particular, in many food-importing countries, several violent protests and riots against the dramatic increase of food prices raised within this context, because mainly the urban population was affected. International research and development institutions picked up this issue quickly and found a clear answer: High and volatile agricultural prices exacerbate hunger and poverty in developing countries. The same institutions blamed decades before the low agricultural prices for weak purchasing power and malnutrition, however initially this remained unnoticed by the public (SWINNEN, 2011; SWINNEN et al, 2011; ANDERSON et al, 2013; FAO, 2005; IFPRI, 2008). Only recent scientific studies took up this contradiction and proposed a more sophisticated approach (cf. Chapter 3.5) explaining that high agricultural prices have the potential to improve poverty and hunger in the long-run (HEADEY, 2014; IVANIC and MARTIN, 2014b; CAMPENHOUT et al, 2013).

Similarly, negligence was considered during the search for the causes of the sudden price spikes and subsequent price volatilities on international agricultural commodity markets. Two culprits had been spotted quickly: speculators and biofuel producers. The G20 group under the French Presidency has agreed in this context during the summit in November 2011 that agricultural commodity markets need a stronger regulation and proposed measures for price damping, and thus, for improving the food security worldwide. Former French President Nicolas SARKOZY saw particularly in the speculators the main cause of volatility and overheated markets with record prices. Especially banks, index funds and hedge funds were and still are in the crossfire of criticism (SCHUMANN, 2011; GILBERT and PFUDERER, 2013). Since the strong financialization of agricultural mar-



kets, stricter regulations of commodity futures markets were proposed and partially implemented. These include upper and lower price limits for futures prices, position limits for contracts, a higher capital requirement for futures transactions, extended vesting periods for contracts or restrictions for algo-trading<sup>1</sup>, and last but not least, a financial transaction tax (FTT) (BÜYÜKSAHİN and ROBE, 2014).

These culprits seem to be clear defined in the public and published opinion as well. The UN Special Rapporteur De SCHUTTER maintains that biofuel promotion destroys the rainforest and drives food prices up (AGRA-EUROPE, 2011). Welthungerhilfe (World Hunger Aid) together with the International Food Policy Research Institute (IFPRI) provide in its report to the Global Hunger Index (2011) a clear statement that “the main cause of higher and more volatile prices are biofuels”. Finally, the United Nations’ High Level Panel of Experts on Food Security (WILKINSON et al, 2013) uniquely positioned in its report that biofuels played since 2004 a dominant role for the increase of level and volatility in food prices. OXFAM (2012) goes one-step further and encourages the EU to stop promotion of biofuels, what could help millions starving people. Not least, against the background of this public pressure, the EU Commission revised the expansion plans for biofuels of the 1st generation of biofuels and limited it to a maximum of 7% (instead of 10%) share of conventional fuels. In the US, a rethinking in the biofuels policy took place as well. Especially the 2<sup>nd</sup> generation of biofuels find a stronger attention (De GORTER et al, 2015). Notwithstanding this reluctance in the EU and US, the biofuel production based on agricultural commodities will be further expanded in many countries (OECD/FAO, 2015). Therefore, the highly controversial food-versus-fuel discussion is still very present, as the stubborn assertion that biofuels are to blame for the hunger in the world.

The turbulent international price development on agricultural commodity markets has even triggered the heated discussions on a different level (Wiss. Beirat, 2011). Almost simultaneously, in the EU agricultural policy the market orders have been gradually liberalized, so that particular formerly highly protected products and markets (with stable prices) were increasingly exposed to the world market developments. From the perspective of European farmers, this meant a double challenge. On the one hand, they deal with larger price fluctuations on domestic markets. On the other hand, they should be prepared for other simultaneously growing price volatilities in world markets. Many market participants expect that, for example, climate change increases the frequency, duration and

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<sup>1</sup> High-frequency-computer trading



intensity of weather extremes and can spread some new animal and crop diseases in globalized markets quickly (ibid.). Therefore, an increase in the price and yield risks is widely expected, and the efforts of risk management should be strengthened accordingly. Nevertheless, in the course of the recent price lows, new proposals come up again for direct interventions in the volume and price structure of the markets, in order to stabilize the situation (BDM, 2016). However, the public forget that these collective acting instruments like production quotas have been proved as ineffective. Nevertheless, politics does not seem to be disturbed with and follows the spirit of times with an increasingly stronger market rejecting attitude, even if the previously used instruments unfold not only as ineffective, but may even aggravate the situation. Ethic of ultimate end seems to be more important than ethic of responsibility (STARR, 1999).

The turbulent price action on international agricultural commodity markets has not only triggered a discussion in politics and economics, but has also occupied the science intensively. Until nowadays there is no consensus about the main determinants of price patterns; the paradigm of a long-term decline of real prices has been questioned as well (OECD/FAO, 2015). Therefore, it is welcomed that a growing number of authors follow up on the phenomenon of pricing using larger data sets. With advanced methodological empirical approaches, they investigate the question, what the true causes of price developments in world markets are. Only using the sound causality analysis, the right economic policy could be taken and wrong political, symptom driven decisions can be avoided.

This is the starting point of the present work. The main objectives, using the international corn market as an example, are

- to identify the main determinants of the price formation in the period from January 2000 to December 2014 (2015) and bring them into a hierarchy;
- to demonstrate the temporal dynamics of the corn price due to the shocks in relevant variables, as well as their interaction among each other, and to determine their contribution to the variance of the corn price on a monthly basis;
- to investigate the economically relevant question, whether the state intervention leads to the possible market calming and covers the food security needs, and what are the right instruments for that.

The methodological aim of this work is to apply a Vector Autoregressive (VAR) analysis on the question of the causes and development patterns of the world market price. This is about the Structural Vector Autoregression (SVAR Model), which, unlike the standard



VAR-Model, use some restrictions, in order to embed theoretical plausible considerations.

Concerning this question, such models have not been applied so far with a larger number of variables. The quite new issue in this thesis is the explicit inclusion of ad hoc trade interventions in numerous countries, a variable, which is supposed to increase price fluctuations and is connected with other determinants (ANDERSON and NELGEN, 2012). Finally, a globally relevant weather variable on a monthly basis finds an application that is depicting the El Nino – La Nina – phenomenon. The empirical analysis refers on an extended and most recent dataset, covering 180 months until December 2014.

## **1.2. Structure of the thesis and limitations**

After introduction (CHAPTER 1) the dissertation divided into four large main chapters. CHAPTER 2 presents facts and trends. It starts with the presentation of the price development of various agricultural products from 1960 until 2015 and the elaboration of similar or divergent historical patterns or correlations. This is followed by a longer subchapter about the price volatilities in agricultural and oil markets. After a brief explanation of the concept of price volatility, and how to measure it, own estimations will be presented and interpreted on basis of historical annualized volatilities using monthly data from 1960 until 2015. Since biofuels play a major role in the discussion about turbulent world markets, a separate subchapter is dedicated to them and to the international corn market as main feedstock. Finally, the question will be answered, how the world food situation has developed, and whether it is possible to recognize some connections with the price development. CHAPTER 2 concludes with a brief conclusion and the warning not to mix correlation with causality.

CHAPTER 3 contains theoretical approaches and empirical findings on the main factors for the global price developments discussed in the literature. It starts with the treadmill theory, accepted by agricultural economists for decades, and their recent challenge. Thereafter, using the referenced literature the various determinants are analysed separately under ceteris paribus assumptions, in order to investigate their impacts on the price development. The macroeconomic and sectoral examples will then show that partial analyses of the influencing factors in simultaneously occurring shocks of multiple variables can cause some miscalculations. Therefore, a structural Vector Autoregressive time series model (SVAR) is superior to a multiple regression analysis. Finally, the chapter addresses the issue, to what extent the price situation on world markets is transmitted to



domestic markets of developing countries, and whether high and volatile prices actually exacerbate hunger.

The methodology used in this dissertation is presented in the CHAPTER 4. Starting with the standard VAR model, the specific features of a structural VAR model are worked out. This involves the identification problem and the explanation of the analytical tools of the Impulse Response Function and the Variance Decomposition.

Subsequently, the statistical methods of a unit-root test and the Granger Causality test are used to examine the stationarity of time series and cointegration between them. The chapter closes with technical issues of the data transformation, the model stability and serial correlation.

The empirical CHAPTER 5 begins with a literature review on the SVAR models. The section prepares the econometric estimation with help of a detailed description of the data used, makes the necessary testing procedures and formulates the necessary restrictions for SVAR models. Subsequently, the empirical part of the chapter concludes with the own estimates of eight different model variations.

In CHAPTER 6 the dissertation is summarized and the main conclusions are drawn. The dissertation is closed with a translation of Chapter 6 into the German language, the used literature sources and the statistical annexes of the work.

Finally, it should be noted that the present study focuses primarily on the international corn market and examines its determinants. Corn is particularly suitable for the present issues, because it

- accounts a significant proportion of the ethanol production;
- is traded on spot and futures markets;
- plays an important role as feed worldwide and
- serves as food for a large share of population in Africa.



## 2. Development of international markets for agricultural commodities, biofuels and of food security

For a better understanding of the great attention on the world agricultural markets, experienced since 2007/08, the price situation will be explained in more detail below. It focuses first on the development of the price levels for individual agricultural products since 1960, including forecasts up to 2024. At the same time, with the price explosion in 2007/08 and the subsequent price drop in 2009 due to the financial crisis, the issue of price volatility has increasingly attracted attention. Therefore, after a brief introduction, the special measuring of volatility extent for different products will be presented in the second step.

Third, since biofuels are seen as a reason for exacerbated hunger and poverty in developing countries, as well as for high and volatile agricultural and food prices the world bio-fuel and corn markets and their developments are described in more detail. Fourth, against this background, it is interesting to look closer the facts about the world food situation and its evolution over time.

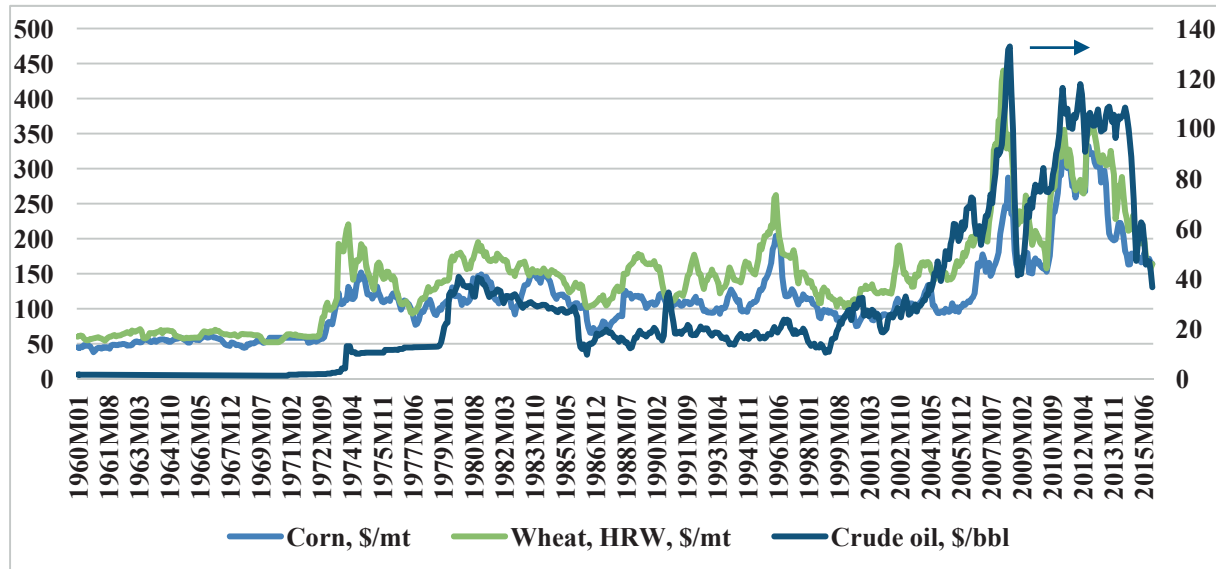
### 2.1. Development of price levels

Figures 2.1 to 2.4 present the nominal monthly prices for major agricultural commodities from January 1960 until December 2015. The observation results in a similar pattern of price development for the six plant products. Until the end of 1972, the prices move without large swings at a lower level. Only rice and sugar have some upward outliers in this period. With the beginning of the first oil crisis in 1973, the price levels for wheat, corn, soybean and rice increased by about 150%, sorghum and sugar prices increased by only about 100% with larger variations, especially in rice and sugar prices. These higher levels are maintained up to 2005. Since 2006 it is followed by a further significant level shift upwards, namely parallel to the oil price increase from 40 \$ per barrel in 2005 to about \$ 130 in 2008. The corn, rice and wheat prices have almost tripled from the beginning of 2006 until mid-2008, while soybean prices have more than doubled. Sugar and sorghum prices increased two and half times. After a short steep decline in the price level due to the financial and economic crisis in 2009, prices rise again in 2011/12 on a broad front. For corn, soybean, sorghum and sugar prices the levels were even higher than in 2008. A comparatively lower level was observed in wheat and rice prices. Until mid-2014 the prices remained at these levels with quite low variations and follow since that time a massive downward trend, which remains even in spring 2016. Figures 2.1., 2.2 and



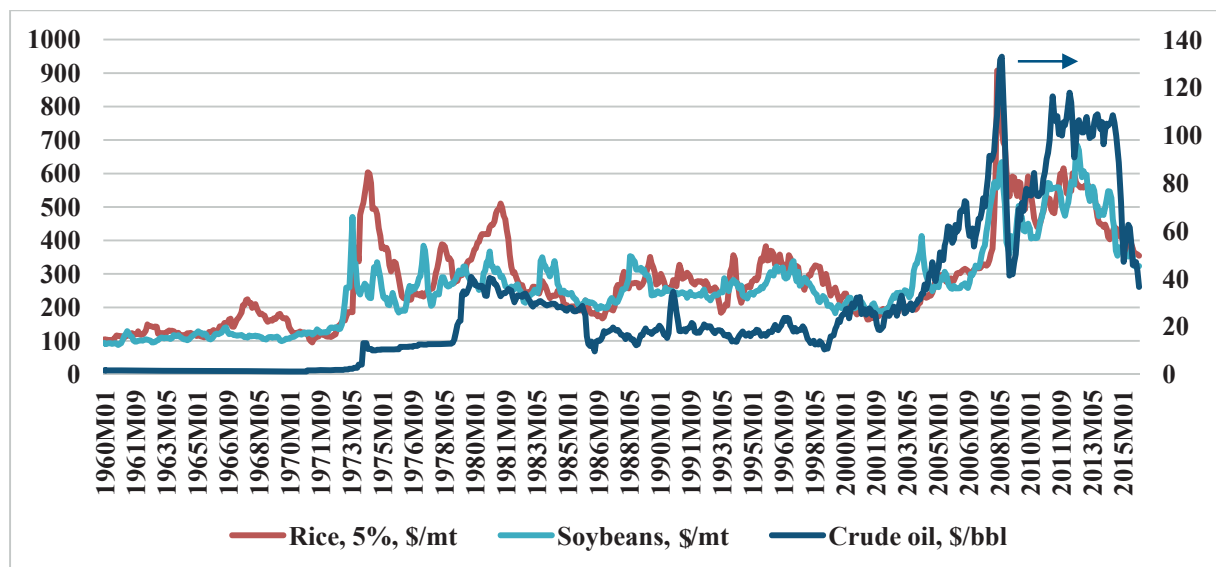
2.3 display as well the oil price development. Except sugar and rice prices, all crop products are closely correlated with the oil price, with a coefficient of correlation of approximately 88%.

**Figure 2.1: Development of corn, wheat and crude oil prices worldwide, January 1960-December 2015**



Source: Own depiction (database: World Bank)

**Figure 2.2: Development of rice, soybeans and crude oil prices worldwide, January 1960-December 2015**



Source: Own depiction (database: World Bank)

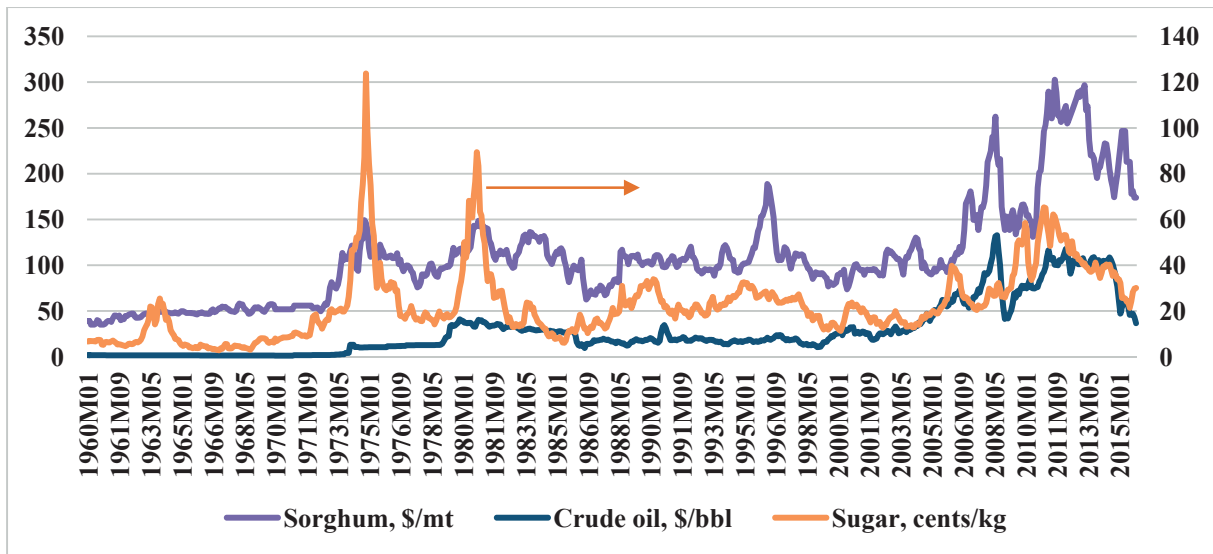
Also, the meat prices (except for pork) show up a close relationship (with more than 80%) with oil prices. However, in contrast the meat prices show completely different development patterns as prices for crop products (cf. Figure 2.4). Chicken prices increase with minor fluctuations steadily and have eight-fold from 1960 till the end of 2014. A





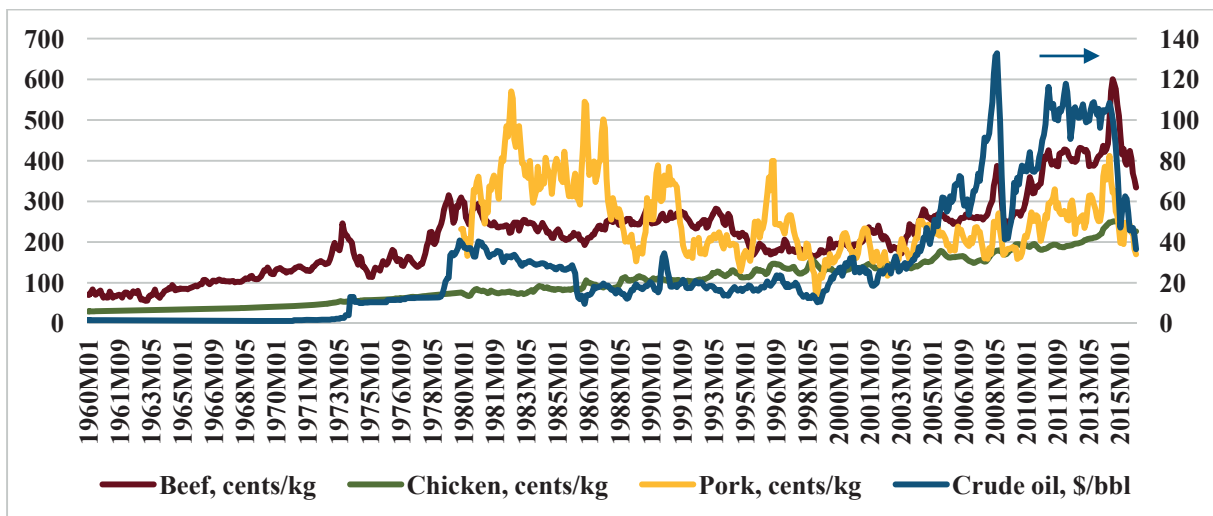
price decline is emerging in 2015. Pork prices, which are available in a monthly frequency since 1980, are highly fluctuating and lost half of their value till 2000; however, they rose till 2014 up to approximately 80% of the initial value in 1980s, but declined significantly in 2015. Since 1960 the prices for beef pass through three phases. First, the value tripled till 1980, then remained around that level until 2003, and finally, expects to triple again till 2014. But the price of beef suffers on significant losses in 2015. It lost more than a third of its value.

**Figure 2.3: Development of sugar, sorghum and crude oil prices worldwide, January 1960-December 2015**



Source: Own depiction (database: World Bank)

**Figure 2.4: Development of meat prices and crude oil prices worldwide, January 1960-December 2015**



Source: Own depiction (database: World Bank and Index Mundi)



Looking at these figures and numbers, one can summarize that

- first, since 1960 the prices of crop products have very similar patterns and are closely correlated with each other (except sugar) (cf. Table 2.1);
- second, with exceptions of sugar and rice, the corn, wheat, soybeans and sorghum prices are closely correlated with the oil price;
- third, the meat prices, compared to the crop products, show different course patterns (also among themselves), and therefore, are probably also affected by other determinants;
- fourth, the price increase in crop products from 2007 on came very abruptly and with extreme growth rates, while meat prices also increased, but the growth began much earlier.

**Table 2.1: Correlation coefficients of selected agricultural commodity and crude oil prices in the period from January 1960 to December 2015**

Prices	Beef	Chicken	Corn	Wheat	Sugar	Soybean	Sorghum	Rice	Pork	Oil
Beef	1.00									
Chicken	0.84	1.00								
Corn	0.80	0.74	1.00							
Wheat	0.79	0.76	0.93	1.00						
Sugar	0.53	0.46	0.66	0.65	1.00					
Soybean	0.83	0.78	0.94	0.93	0.65	1.00				
Sorghum	0.85	0.79	0.98	0.93	0.66	0.93	1.00			
Rice	0.71	0.64	0.84	0.85	0.74	0.85	0.83	1.00		
Pork	0.63	0.56	0.49	0.51	0.26	0.49	0.50	0.36	1.00	
Oil	0.84	0.82	0.87	0.88	0.55	0.88	0.88	0.76	0.51	1.00

**Source: Own estimations**

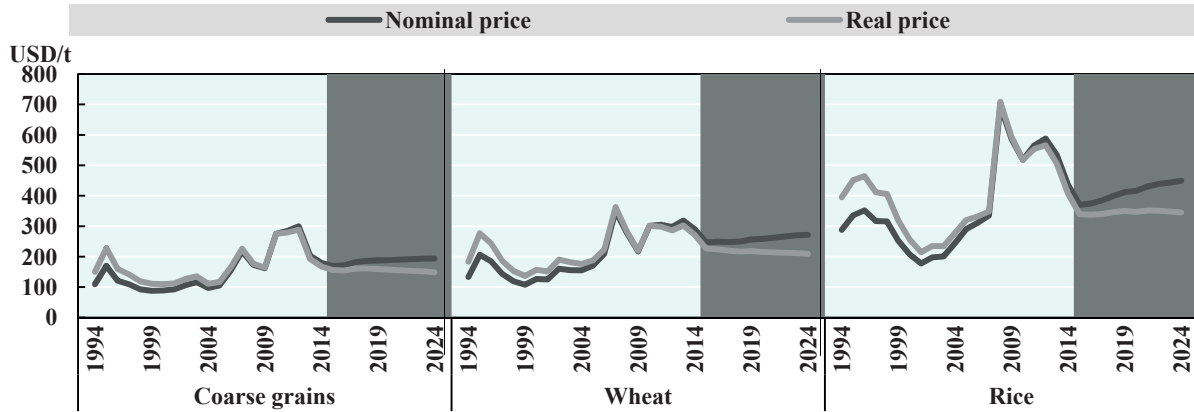
The reference to the bilateral correlations between commodity and the oil prices should not be misunderstood (LIU, 2014). There is no proof of causal relationships. This should be examined in the empirical part of the dissertation. At least there are certain indications for further research.

For the next ten years until 2024 OECD and FAO expect in their “Agricultural Outlook” a lower price level than in 2012-2014 for all crops and animal products, but compared to the last two decades



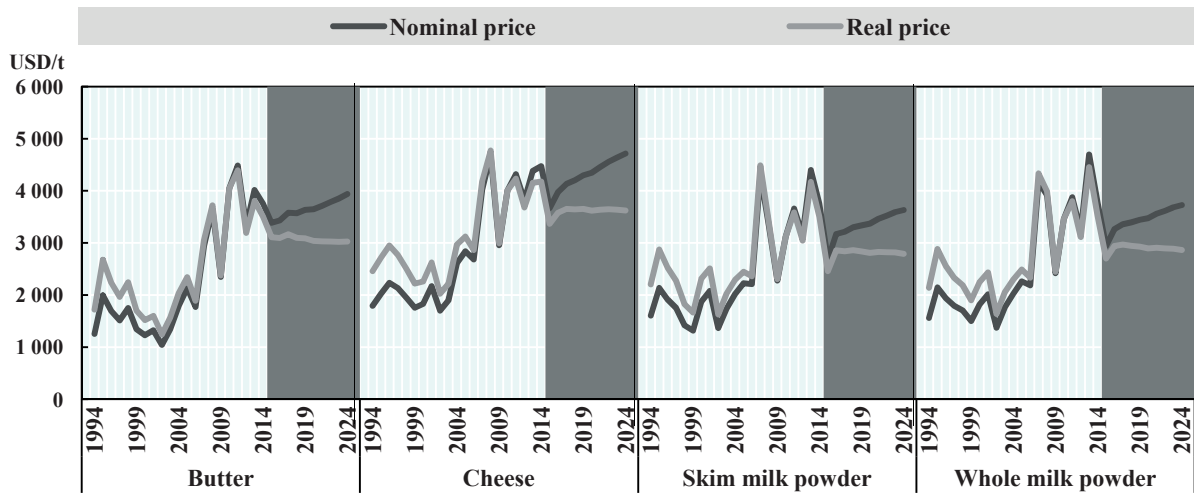
- a slight increase in nominal grain prices (cf. Figure 2.5),
- an average increase in nominal meat prices and
- a significant expansion of nominal dairy product prices by 2024 (cf. Figure 2.6).

Figure 2.5: World cereal prices since 1994, projection till 2024



Source: OECD/FAO (2015), “OECD-FAO Agricultural Outlook”, database: OECD Agriculture Statistics

Figure 2.6: Development of world milk product prices until 2024



Source: OECD/FAO (2015), “OECD-FAO Agricultural Outlook”, database: OECD Agriculture Statistics

In general, the demand forces are considered to be stronger and more effective than the supply-side determinants. Not least, the population and income growth, as well as the changing consumption habits are supposed to make a certain contribution.