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A NEW GLOBAL WHEAT MARKET MODEL (GLOWMM) FOR THE ANALYSIS OF WHEAT EXPORT PRICES

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To my parents

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INTRODUCTION

Cheap food has been considered as a normal condition for almost 30 years. After the price peak registered during the 1970s crisis, real food prices constantly declined during the 1980s and 1990s reaching the lowest level in the beginning 2000s after the Asia financial crisis. According to this trend many countries saw little convenience to invest in agricultural production considering food imports as a safe and efficient means of achieving national food security. However, as international food commodities prices have increased abruptly since 2002 and especially since late 2006 all these perceptions quickly collapsed. The IMF's index of internationally traded food commodities price increased 130 percent from January 2002 to June 2008 and 56 percent from January 2007 to June 2008 (Mitchell, 2008). The FAO food price index reached its peach in June 2008 increasing 55 percent between June 2007 and June 2008. Rice prices doubled within just five months of 2008, from US$ 375/ton in January to $ 757/ton in June (Baffes and Haniotis, 2010). The increase in food commodities prices was triggered off grains which began a sharp increase in price in 2005. Maize price tripled from January 2005 until June 2008; wheat prices increased 127 percent and rice prices increased almost 170 percent during the same period (Mitchell 2008). Furthermore, although food price are now lower than the peck reached in 2008, real food price have been still significantly higher in 2009 and 2010 and a large number of institutions predict that real food prices will remain high until at least the end of the next decade. The OECD and FAO outlook 2008-2017 expects prices to come down again but not to their historical levels. In particular, over the coming decade, prices in real terms of cereals, rice and oilseeds are estimates to be 10 percent to 35 percent higher than in the past decade.

There are a number of factors that have contributed to the rise in food price. The identification of the main factors is still under debate. A large number of research studies have attempted to identify the factors behind the prices crises but only a few have attempted to define their relative importance by adding explicit orders of magnitude to each factors. Obviously it is not an easy task to depict a clear picture of prices crisis because it is a global phenomenon that involves a large number of distinct events. Much of the non academic debate was not based on evidence derived from appropriate research. On the other side, much academic research was also "quick and dirty" because the lack of time and the need to provide a theoretical basis for the policy makers (Headey and Fan, 2010).

Despite this complexity, this piece of research presents a briefly review of existing literature on food crises with the objective to analyze the nature of the recent boom in food commodities by examining which key factors played a main role. According to the most common literature, some explanations seem to be more reliable and rigorous than others.

Unfavourable weather condition in major producing countries have been viewed as one important factors according to OECD report (2008), Tangermann (2011) and OECD-FAO (2011). Despite of this, Headey and Fan (2008) suggest that production shortfalls are a normal occurrence in agricultural and low production in several countries were offset by large crop in other regions. Macroeconomic conditions such as strong GDP growth and subsequent stronger demand for food in some developing countries have also been considered as a permanent factor behind the recent prices spike (see Von Braun, 2007; Trosle, 2008; Carter et al., 2011; Krugman, 2011). Other studies have argued that low level of real interest rates and growing money supply diverted investments away from financial assets towards physical assets, including commodities. This excess of liquidity in the global economy, with a depreciation of US dollar, resulted in inflation and in its turn, in rising commodity prices and an increased commodities demand for importing countries (see Calvo, 2008; Abbot et al. 2008; Mitchell, 2008; Timmer, 2009; Gilbert, 2010a; Tangermann 2011).

The excess of liquidity fostered financial investments in commodity future markets convincing some authors that speculation and not fundamentals were behind the commodities price boom and bust (Baffes and Haniotis, 2010; Masters, 2008; Soros ,2008; Calvo, 2008). Cooke and Robles (2009), Gilbert (2010b) and Gutierrez (2013) found evidences that financial activities in future markets may be of use in explaining the change in food price. However, a large strand of literature challenged the arguments proposed by the bubble proponents through logical inconsistencies, conceptual errors and empirical evidences showing that speculation did not have a significant role in rising commodities food prices (see Krugman, 2009; Wolf, 2008; Wright, 2009; Irwin et al., 2009; Sanders and Irwin, 2010; Baffes and Haniotis, 2010).

Other possible causes analysed in literature include the decline of commodity stocks, the rising of crude oil price, biofuels production and finally panic buying, ban and export restrictions.

The competitive storage model explains how commodity stocks can play a main role in buffering price volatility (see the pioneering work of Gustafson 1958; but also Samuelson 1971; Wright and Williams 1982; Scheinkman and Schechtman 1983; Williams and Wright 1991 and Deaton and Laroque 1992). Starting on the years 1999-2000, the global stock level for major cereals has been declined reaching its historical low level in 2007 (Dawe, 2009; Wright, 2011; Tangermann, 2011). Therefore, it is not surprising that literature has identified the reduction of commodity stocks as one of the main factors in recent food price spike (Piesse and Thirtle, 2009; Trostle, 2008; Dawe, 2009). Empirical evidence have been provided by Kim and Chavas (2002), Balcombe (2011), Carter et al. (2011), Hochman et al. (2011), Serra and Gil (2012). Nevertheless, Dawe (2009) and Roache (2010) remain less than convinced about the empirical importance of stock depletion in food prices spike both in the short and long term.

The oil price represents a permanent factor in food price formation and some authors have highlighted its possible importance as major factor in the recent prices boom (see Baffes, 2007; Baffes and Haniotis, 2010; Balcombe, 2011 among others). Moreover, as oil price increases, biofuels becomes more competitive. Mitchell (2008), Baffes (2007), OCSE-FAO (2011) and Tangermann (2011) suggest that biofuels contributed to the price crisis in 2006-2008. Hochman et al. (2011) provide a complete literature about quantitative estimates of biofuels impact on food commodity price index.

Finally, in response to rising food prices, some countries introduced protective policy measures. Unfortunately, the final result of these measures is always a deeper prices volatility and higher prices into global markets as described in Headey and Fan (2008), Trostle (2008), OECD-FAO (2011) and Tangermann (2011).

Rising food prices mainly affects lower income consumers especially in poor countries where households spend a great part of their income on food. This is particular true for cereals and especially wheat. We focus on wheat market for two reasons. First, it represents the most relevant source of food in developing countries. Second, this market is deeply changed during the last decades evolving from an oligopoly between US and Canada with the latter as a price leader (MaCalla, 1966) to a tripoly including also Australia (Alouze et al. 1978) and hence to a price leadership model with US price leader

(Oleson 1979; Wilson, 1986). More recently, Westcott and Hoffman (1999) recognize that, although US is the largest word wheat exporter, its market share is not enough to be considered a price leader anymore. In essence wheat market is nowadays characterized by a small number of wheat producing and exporting countries that sell to a relative large group of importers, mostly developing countries.

While new market assumptions can be introduced for example in general equilibrium models, more flexible models can be provided and used for the analysis of worldwide commodity markets. The aim of the thesis is to model the impacts of the main factors behind the wheat export price dynamics.

To this end, in this study we introduce a innovative worldwide dynamic model for the analyses of short and long-run impulse responses of wheat commodity prices to various real and financial shocks. Specifically, we propose a GLObal Wheat Market Model (GLOWMM) to study the dynamic of wheat export prices.

The model is specified by using the Global Vector AutoRegressive (GVAR) model proposed by Pesaran et al. (2004) and Dees et al. (2007). The methodology allows the analysis of wheat export prices for the six main export countries, USA, Argentina, Australia, Canada, Russia and EU.

The GVAR approach is particular appealing for the analysis of the worldwide wheat market for two reasons. First, it is specifically designed to model fluctuations and interactions between countries. This is a crucial asset given the features of world wheat market and the global dimension of the food prices crisis that cannot be downsized to one country, rather involves a large number of countries.

Secondly, the GVAR allows to model the dynamic of wheat export prices as results of the effects exerted by the country-specific and by foreign-specific variables. The foreign-specific variables are defined as weighted average of wheat export prices, the stock to utilization ratio and the effective exchange rate fluctuations in all competitor countries. Thus both country-specific as foreign-specific effects can be jointly modelled. For each country model we hypothesize the weak exogeneity properties for both foreign-specific and global variables. This accounts to assume the small economy hypothesis for each country and, consequentially, that wheat export prices are determined in the worldwide market.

Finally the GVAR model combines a number of atheoretic relationships. Unlike structural models, as for example general equilibrium models, the approach does not attempt to make restrictions, for example on the basis of economic theory. Causal relationships are analyzed by means of the impulse response functions that, built from the GVAR estimates, allow to highlight how shocks on wheat stocks and demand, exchange rates, input prices or global oil price propagate at domestic and global level.

The research is organized into chapters. The first chapter is divided in five sections. The first one presents a literature review of existing literature on food commodities prices crisis. After that, the following sections consider some particular factors related to food price increases that we think to be most important in explaining the price crisis. In fact, the second major section focuses on the relationship between crude oil prices and commodities prices. In the past, price of energy and agricultural commodities markets have been studied by two distinct point of view. Today, it is clear how increasing oil price can affect food prices both through the supply and demand side. Here we'll focus on two supply-side costs of agricultural production such as inputs and transport and one demand side factors such as biofuels. A large strand of literature considers the price of crude oil closely connected to the price of corn because of biofuels. In fact, as showed by Abbott et all (2008), crude oil price determines the gasoline price which is in competition with the ethanol price. As soon as the ethanol price become competitive with respect to the gasoline price, the incentive to the ethanol capacity increases and this pushes up the corn demand for ethanol industry and finally the corn price. In this section the relative importance of subsidies and mandates in determining the corn price will be also examined.

The third section deals with the exchange rate and particularly the US dollar depreciation. This theme has been mentioned by a large strand of literature as a factor that might be important in explaining the recent rising food prices. In this piece of research a background on the economic forces that determine the low level of exchange rates in 2006-2008 will be provided. It will be also showed how commodities prices have historically changed in function of the exchange rate. In essence we discuss the relationship between exchange rate, commodities prices, inflation and international trade.

The fourth major section focuses on speculation in the commodity futures markets. A large number of studies take into consideration the great amount of index funds investments in the commodity markets in order to explain current commodities price increase blaming speculators for a good part of this prices trend. However, different authors consider the role of speculators as an important role in functioning of commodities market as we will see. It will be analysed in more detail whether the increased speculation activity, as sustained by a large strand of literature, is a driver for increased price volatility and the overall level of commodity price.

The last section describes the roles of another key driver of agricultural markets and price volatility, the stock level. Commodity storage clearly plays an important buffering role by mitigating the gap between demand and supply level at least in short term and reducing the price volatility (see OECD-FAO, 2011). In essence, when stocks level is low, supply becomes very inelastic and even a small additional difference between demand and supply can result in a huge price increases. Price crisis in cereal markets have often occurred with a low stock to use ratios such as in 2006-2008 as noted by a large strand of literature.

Considering the main role played by stocks level in agricultural market, the second chapter presents the competitive storage model described by Williams and Wright (1991), which views inventories as the main determinant in commodity price behaviour. In order to explain commodity booms and busts, the model provide a deep understanding of what determines stock levels and, in particular, what may cause inventories to be depleted.

The third chapter explores the price formation mechanisms of word wheat market presenting different theoretical models discussed since the 60's in order to provide a theoretical framework for analysing wheat price behaviour. Particular attention will be reserved on the recent annual model for the United States wheat price firm used by USDA in short term market analysis and long term base line projection.

The fourth chapter is closely connected to the previous one providing a complete picture of world wheat market in terms of production, consumption and trade using data covering the last decades and focusing on the last three years. According to these data, it will be clear how a few countries strongly influences global wheat market producing and exporting a large portion of global wheat availability. Also the ending stocks of wheat in global markets appears concentrated in few countries or regions. On the other hand, world wheat import market is not so concentrated. In essence it will be seen how the global wheat market is characterized by a small number of wheat exporting and producing countries that sell to a relative larger group of importers. China and India represent a particular case. They are two major wheat producing countries with a marginal role in trade focusing mostly on domestic market.

Chapter five describes the empirical model used in this piece of research. For our research it will be used a worldwide dynamic model that provides short and long-run impulse responses of wheat prices to various real and exogenous shocks. We used the Global Vector Autoregressive modelling approach with exogenous variables, to estimate a Global Agrifood Vector AutoRegressive model. The methodology allows to model EU and non-EU countries, and to aggregate the single regional VARX models into a global model by using weighting matrices mainly based on the share of wheat international market (measured in term of export) of each country involved in the research.

In essence the model provides a general and practical modelling framework for quantitative analysis of the relative importance of different shocks on agro-food sectors. Specifically, using this strategy we analyze channels of transmission from external shocks that affect crops productivity and, in its turn, wheat prices. The dynamic properties of the GVAR model will be investigated by means of the Generalized Impulse Response Function (GIRF). In order to investigate how export prices are affected by some shocks we assume a negative standard error shock that affect the main exogenous variables in all export countries and simulate the effect on wheat export prices up to a limit of 24 months. More in details, we analyze the implications of five different external shocks:

- A one standard error negative shock to US stock to utilization ratio
- A one standard error negative shock to global stock to utilization ratio
- A one standard error positive shock to oil price
- A one standard error negative shock to real effective exchange rate
- A one standard error positive shock to fertilizer price

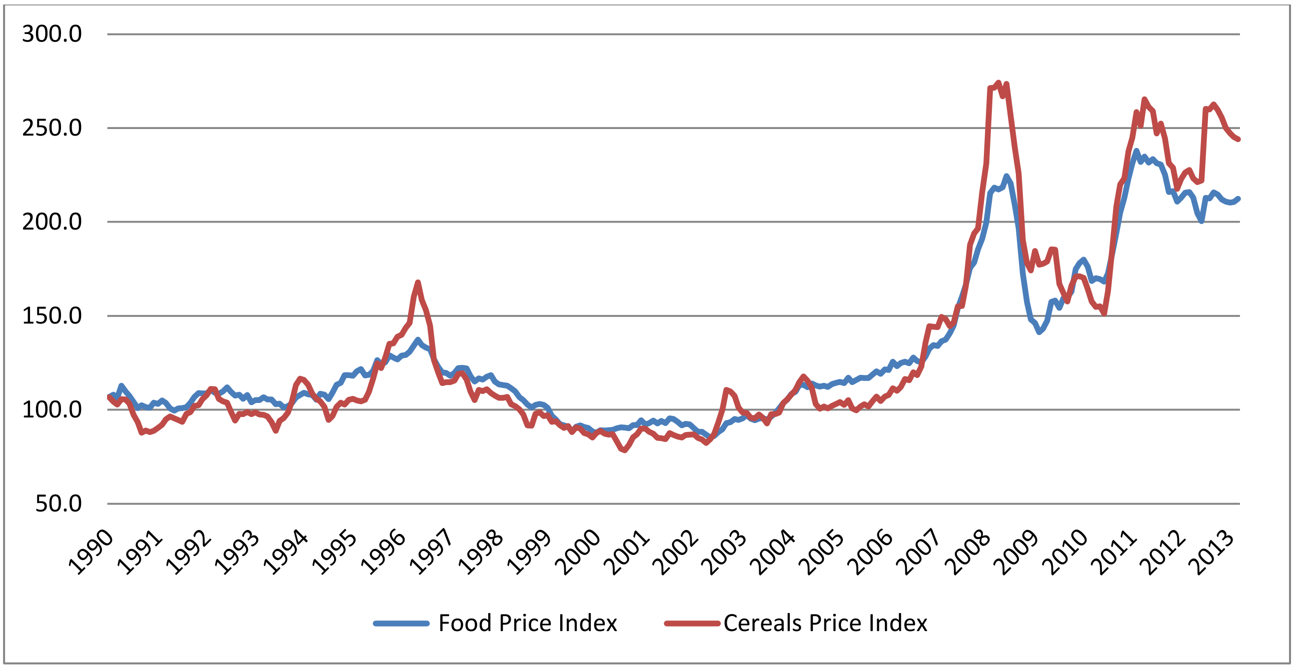
Impulse response analysis reveals that a decrease of wheat stocks with respect to the level of consumption, increasing oil prices and real exchange rate devaluation have all inflationary effects on wheat export prices although their impacts are different among the main export countries.

Finally, the last chapter concludes.

1. LITERATURE REVIEW

Between 2002 and 2008 nominal prices of energy and metals increased by 230%, those of food doubled. The IMF's index of internationally traded food commodities price increased by 130% from January 2002 to June 2008 and by 56% from January 2007 to June 2008 (Mitchell, 2008). The FAO food price index reached its peach in June 2008 increasing 55% between June 2007 and June 2008. Figure 1.1 below shows the FAO Food Index of monthly prices for food commodities that are the basis for human consumption. Between 1980 and 2002 prices, measured in nominal dollars, had a slightly downward trend although there were several peaks such as in 1980, 1988 and 1996. After 2001 prices began to rise slowly but constantly reaching in 2004 the same level that they registered in the middle of 1980s. However in early 2006, commodity food prices began to rise more quickly until 2008 reaching new historical high.

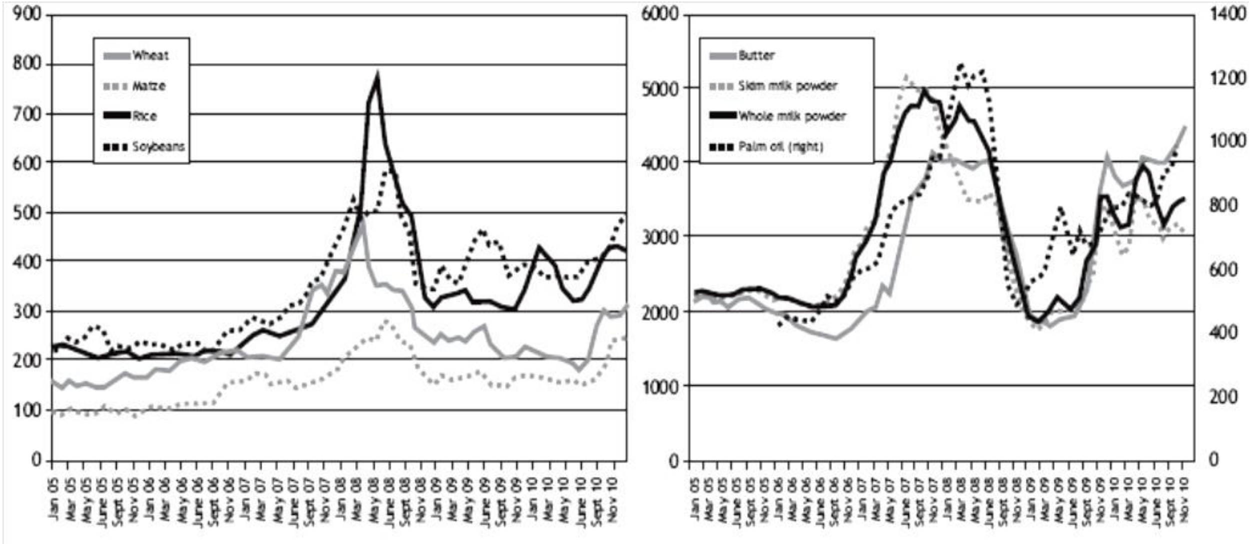
Figure 1.1: FAO Food Index, 2002-2004=100



Source: Fao Food Index in nominal price 1990.1 – 2013.3

The same upward trend is well represented by FAO international Commodity price cited by Tangermann (2011) that shows monthly prices of selected agricultural products in international trade between 2005 and 2010 (figure 1.2).

Figure 1.2: Monthly prices of selected Agricultural products, 2005-2010, (US$ per ton).

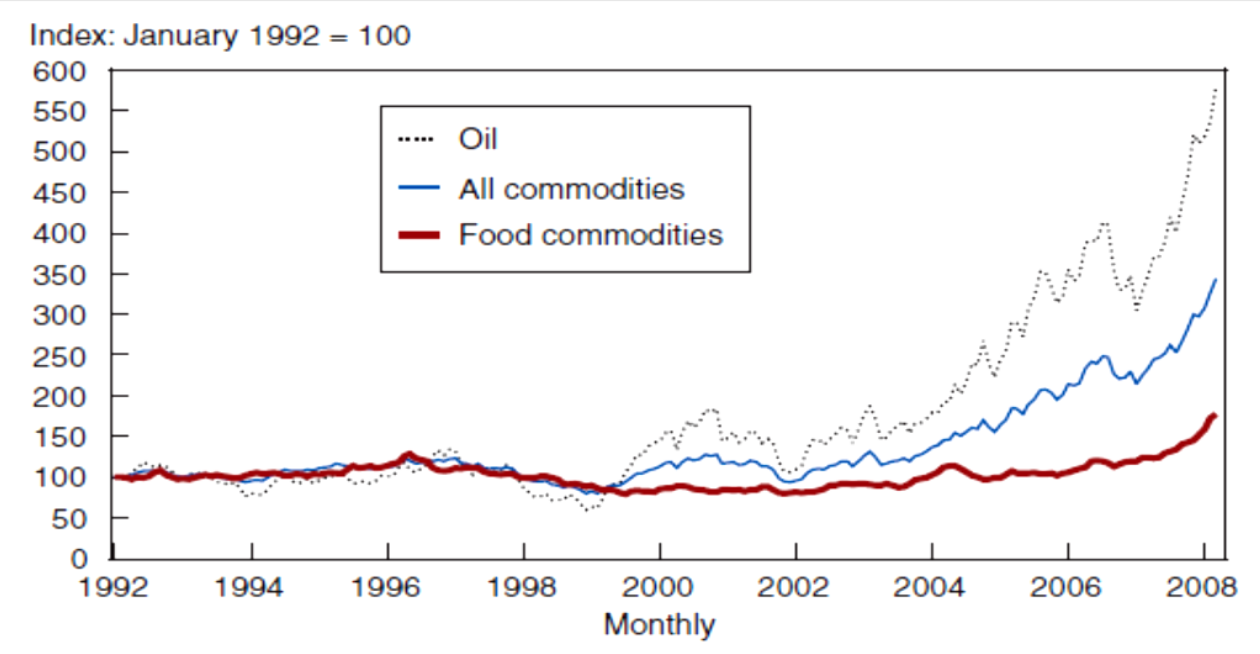


Source: FAO International Commodity Prices cited by Tangermann (2011).
http://www.fao.org/es/esc/prices/PricesServlet.jsp?lang=en

The recent boom presents some similarities with the two previous commodities prices crisis, the Korean war crisis and the 1970s energy crisis. According to Baffes and Haniotis (2010) and also Vaciago (2008), each crisis happened during a period of high and sustained economic growth and in an expansionary macroeconomic environment. Moreover, all the crisis considered were followed by a severe slowdown of economic activity. Despite of these aspects, the three crisis shows also some important differences. The recent crisis has been the longest in term of time length and the broadest in term of numbers of commodities involved. Baffes and Haniotis (2010) noted that the recent prices boom has been the only one to involved all three main groups of commodities (energy, metals and agricultural); it was not associated with high inflation unlike the other two previous crisis and, finally, it ends with the simultaneously development of two other crisis, in real estate and in equity markets whose end, in turns, led to the recent recession.
Figure 1.3 shows the price index for food commodities but also the index for the average of all commodities and an index for crude oil in order to better understand how the recent price crisis involved not only food commodities prices. As clearly described by Trostle (2008), until 1999 all three index were at about the same level. From 1999 to March 2008 food commodities prices has risen almost 98% while the index for all commodities has risen 286% during the same period and the index for crude oil has risen 547%. If compared to these index, the recent uptrend of food commodities index might not seem so

huge after all. However, because rising food prices tend to negatively affect lower income consumers more than other, food price boom is socially and politically sensitive. Moreover, despite the price down trend after mid-2008, cereal prices increased again in the second half of 2010 recalling back the negative memories of 2008 crises even if the 2010 situation differs from the 2008 price crises in some important aspects as well described by Tangermann (2011).

Figure 1.3: Oil, all commodities and food commodities index.



Source: Trostle (2008:2) from International Monetary Fund: International Financial statistics.

In the case of agricultural commodity prices spike, numerous proposal have been made about which factors were the most important drivers in the 2006-2008 crisis. Commodity prices were affected by a combination of factors including droughts in major grain producing regions, low stocks of cereals and oilseeds, increased use of feedstock to produce biofuels and rising crude oil price. Moreover, the depreciation of the US dollar is also responsible since the price for the key commodities is typically quoted in US dollar. A period of strong growth global economy and a large amount of liquidity also appears to have contributed to a substantial increase in speculative interest in agricultural futures markets (OECD, 2008b).

Headey and Fan (2008), suggested the hypothesis of the so called "perfect storm" based on the interaction and conflagration of these factors. In fact, according to the authors it should be considered the complex interactions between factors that reinforced each other creating the condition for the perfect storm.

A few number of studies try to define the share of the prices increase that can be attributed to each cause, but the larger part do not, rather indicating that the total effect on prices derives from the combination of all these factors.

Moreover, policy response introduced by some countries in 2008 in order to offset the rising food prices, such as export ban for the rice or prohibitive taxes, contributed to make even worsen increasing the demand for commodities (Baffes and Haniotis, 2010; Sarris, 2009, Tangermann, 2011).

At the end of 2008 the weakening or reversal of these factors induced a quick prices fall across most commodities sectors. The sharp declined was stressed by the simultaneously financial crisis and the subsequent global economic downturn.

Although food prices are now lower than the peck reached in 2008, real food prices have been still significantly higher in 2009 and 2010 and a large number of institutions predict that real food prices will remain high until at least the end of the next decade. The OECD and FAO outlook 2008-2017 expects, over the coming decade, prices in real terms of cereals, rice and oilseeds to be 10% to 35% higher than in the past decade. According to the European Commission prospects 2010-2020 (2010), commodity prices are expected to stay firm over the medium term supported by factors such as the growth in global food demand, the development of the biofuels sector and the long-term decline in food crop productivity growth.

More in details, the medium-term prospects for the EU cereal markets depict a relatively positive picture with tight market conditions, low stock levels and prices remaining above long term averages. A similar picture is depicted for the medium-term prospects for the EU oilseed markets characterized by strong demand and high oilseed oil prices.

In the next paragraphs will be reported some of the important studies summarizing the major causes of food commodities prices boom.

The OECD Report (2008) divides factors behind the recent prices crisis between transitory and permanent factors. The reduction of crop yields for some key agricultural commodities due to unfavourable weather and water constrains in major producing regions should be viewed as a temporary factor. In fact, unless permanent reduction in yields, normal higher output can be expected in response to negative yield shocks. By the way, the result of adverse weather in 2007 was a second consecutive drop in global average yields for grains and oilseeds. Two sequential years of low global yields occurred only three other times in the last 37 years according to Trostle (2008). As reported by Tangermann (2011) cereals production in Australia, that is a wheat exporter country, was affected by persistent drought in a row of years before 2008. In Canada, that is another wheat exporter country, yields in 2006 and 2007 were substantially below the average levels. Also in the EU, because unfavourable weather, cereals production fell by 8% from 2005 to 2007. Finally, Russia and Ukraine, two large exporter countries, were affected by severe drought in 2007 and 2008. Moreover, this lower production forced the decline in the global stocks and created a world market environment characterized by concern about future availability of major commodities among importers. Despite of the low crop yields between 2005 and 2007 demand for wheat and vegetable oil increased two percentage points more than output (OCSE 2008b).

OCSE-FAO (2011) states that in 2010, adverse weather condition played an important role in the commodity price spike registered also in that year. In particular drought reduced the grain supply in the Russia Federation and Ukraine and flooding affected the grain harvest in some important regions of Australia. Both these events shown their impact on world commodity price volatility. The same OECD-FAO (2011) report suggests that long term climate change will impact in a more adverse way tropical areas than temperate areas. In particular Sub-Saharan Africa is expected to be the most affected.

Despite of this, a closer inspection of the data suggests that this low level of production, through attractive, is not convincing as it first appears in order to completely explain rising food prices (OCSE-FAO, 2011). As suggested by Headey and Fan (2008) it should be keep in mind that production shortfalls are a normal occurrence in agricultural production and in wheat production in particular. Moreover low production in several countries in 2007 were largely offset by large crop in Argentina, Kazakhstan, Russia and United States.

Macroeconomic conditions such as strong GDP growth and subsequent stronger demand for food in some developing countries should be considered as a permanent factor but not as a new factor. It means that these change in macroeconomic conditions will be a permanent factor in future price determination but have had no role in recent rising prices.

Trostle (2008) includes strong growth in demand in the long term factors that have affected demand for commodities putting additional upward pressure on world prices. The author identifies three factors at the basis of the strong growth in demand over the last decade: the increasing population, the rapid economic growth especially in China and India which account for 40% of the world's population and the rising per capita meat consumption. In essence, according to Trostle (2008:7) "as per capita income rose, consumers in developing countries not only increased per capita consumption of staple foods, they also diversified their diets to include more meat, dairy products and vegetable oils, which in turn, amplified the demand for grains and oilseeds". Cartel et al. (2011) define China as a big force in the commodities prices spike. Its strong and increasing demand of corn, wheat but also copper and oil pushed up commodities price during the recent crises.

These aspects are confirmed by OECD-FAO (2011) that show how growing demand in China and India has contributed to the decreasing of stocks and the increasing of prices. However growing demand explanation in emerging economic is unconvincing for several reasons. As suggested by OECD-FAO (2011) ,Tangermann (2011), Baffes and Haniotis (2010), food demand in China and India had already grown rapidly before 2007. Moreover, the price crises has been particularly pronounced in the cereals sector; a sector where China and India are almost self sufficient.

Macro economic developments, in particular in the US, represented by low level of real interest rates and growing money supply, diverted investments away from financial assets towards physical assets, including commodities. This excess of liquidity in the global economy, with a depreciation of US dollar, resulted in inflation and in its turn, in rising commodity prices (see Calvo, 2008; Abbot et al. 2008; Mitchell, 2008; Timmer, 2009; Gilbert, 2010a; Tangermann 2011).

Rapid economic growth in developing countries led to a rapid growth in the demand for crude oil. For instance, Trostle (2008) states that the oil import of China alone increased more than 21% per year from 194 million barrels in 1996 up to 1.37 billion barrels in 2006. This huge increase crude oil demand has contributed to a rapid rising oil price.

The oil price represent permanent factor in price food formation and is seen by OECD (2008) and OCSE-FAO (2011) as major factor in the recent prices boom leading to higher average prices level in the future. The long term link between energy, in particular oil price, and food prices is stressed by Tungermann (2011). However, the same author challenges the contribution of the energy price to the severe price spike of agricultural commodities in 2006-08. This is because there should be, typically, one year lag in the response of agricultural production to price signal. In essence, the spike in oil price should not be simultaneously transmitted to commodity prices. Wright (2009) argued that the prices of most fertilizers increased after and not before the cereals price boom.

The oil price spike is strongly correlated to biofuels production. As oil price increases, biofules becomes more competitive. A large strand of literature (see for instance Mitchell, 2008; OCSE-FAO, 2011; Tangermann, 2011) considers highly likely that biofuels contributed significantly to the price crisis in 2006-08 because an important part of cereals and oilseeds production is used to increase biofuels supply and because land substitution effect as it will be better explained.

Low inventory levels, expressed by the ratio stock to use, played an important role in the 2006-08 food commodity spike according to a large strand of literature (see Hochman, 2011, Tangermann, 2011, Wright, 2009). In 2007, stocks of wheat and vegetable oil have reached their lowest levels relative to use reducing the buffer against shocks in supply and demand. “When stocks are low, supply become very inelastic and even small additional gaps between demand and supply can result in rather large price increase” (OECD-FAO, 2011). The reduction of stocks level is related not only to the gap between demand and supply. An important role was played by political decisions of some important countries such as China to reduce stocks. Stable food prices registered until 2002 allowed to adopt the so called “just in time” inventory management based on buying commodities in the world market instead to increase stocks holding. In addition, more liberalized trade policies were largely adopted by a wide number of countries during the last decade reducing the need for individual countries to hold high level of stocks. These new level of low stocks are not expected to increase over the coming decade, hence representing a permanent factor in price formation. Headey and Fan (2008) argue that stocks declines are consistent with price boom but they should be consider a symptom of deeper causes and not as one of the major factors behind rising prices. Furthermore, Dawe (2009) have challenged the role of low stocks during the crisis arguing that the decline in global stocks was due to a decrease in china’s stocks that are, historically, not used in stabilizing international cereals market.

Finally, the recent wave of investment in futures commodity markets from non traditional traders may have short term price effects. “Financial speculation which involves trading in future markets and commodity derivatives without any link to the underlying cash market has been suggested as one of the possible causes of volatile agricultural commodity price movements" (OECD-FAO, 2011:64). This is particularly true for investment bank, hedge fund, swap and other money managers whose role in future commodity market greatly increased since the mid-2000s (Tungermann, 2011). Moreover, given the size of funds recently involved in futures exchange markets, this new factor is considered by OECD (2008) as a permanent element in future price volatility.

In response to rising food prices, some countries introduced protective policy measures in order to reduce the impact of rising world food commodity prices on their own consumers. Unfortunately, the final result of these measures is always a deeper prices volatility and higher prices into global markets. This because world prices adjustments had to be made by the smaller number of countries trading in the world that had not introduced protective policies. We should distinguish between policies introduced by exporting countries and polices introduced by importing countries. The formers have the aim to discourage exports in order to keep domestic production within the country and so keep the prices low. The most commonly used are the introduction of export taxes, export quantitative restrictions, export bans, the elimination of export subsidies and so on. The latter aim to reduce the impact of rising prices on consumers by reducing import costs and hence providing lower prices to consumers. Import tariffs or subsidizes to consumers are the most common import policies used by import countries during food prices crisis.

A detailed lists of policies responses to rising food prices introduced by some countries is reported by Trostle (2008:23).

Headey and Fan (2008) discuss a series of commodity-specific factors that probably had a role in increasing the price of some commodities. Government action and in particular export ban or export restrictions, had a major role to the food price crisis during the 2006-2008. This aspect is particularly true for rice market (OECD-FAO, 2011) where export restrictions seems to be a major explanation because a large number of important exporting countries had imposed export ban and also because only 7% of global rice production is traded over the last five years making the rice market really thin. From August 2005 until November 2007 rice prices increased constantly but significantly by about 50% in real terms. In November 2007 India imposed the first major export ban. From November 2007 to May 2008 rice price increased by 140% despite high level of production patterns and the absence of any significant increase in demand. The rising rice

price continued until May 2008 when Japan withdrew its ban and realised 200,000 tons of rice to Philippines. From then, prices fell almost immediately (Headey and Fan, 2008).
As well explained by OECD-FAO (2011), the timing of this export constraints was important for the impact on the world market because the export restrictions limited the traded volumes in the worst moment, when the price rise on international markets was already accelerating. The final result was a greater uncertainty and a faster increase in commodity prices.
This is in line with Tangermann (2011) that considers policy actions on export and import side an important driver for the prices spike but much more important is considered the effect of these policies in reinforcing the sentiment of excitement and panic in the market. Tangermann (2011:30) provides also a complete and detailed list of policy measures adopted in selected developing countries and in the major emerging economies in response to the 2006-08 food crises analysing, for each kind of action, their impact and outcome.
Cooke and Robles (2009) dived the explanations for the rising agricultural prices in demand and supply-side explanations. A correlated model is the timeline of events' model proposed by Trostle (2008) which distinguishes between supply and demand side factors, as already seen, but also between long term factors (such as increasing demand and slowing agricultural production), medium term factors (dollar devaluation, rising crude oil prices, biofuels production) and short term factors (such as adverse weather and trade shocks).
In particular the model provides eight demand driven explanations and five supply driven explanations. Demand side explanations include the notion of rising world demand for food products in developing countries such as China, India, Brazil and other populous nations that have achieved a better standard life in recent years and the subsequent change in the consumption behaviour with a larger amount of meat instead of vegetables. Secondly, they consider the increasing production of ethanol and biodiesel from agricultural commodities. Thirdly, they note the increasing activities and speculation in futures markets of agricultural commodities. The fourth demand side explanation is represented by the easy monetary policy in the US which is the basis for the weakening dollar which in turns lead to higher prices in order to keep parities in other currencies. Beginning in 2002, the US dollar began to depreciate, first against OECD country currencies, and later against many developing countries. As the dollar is weak in

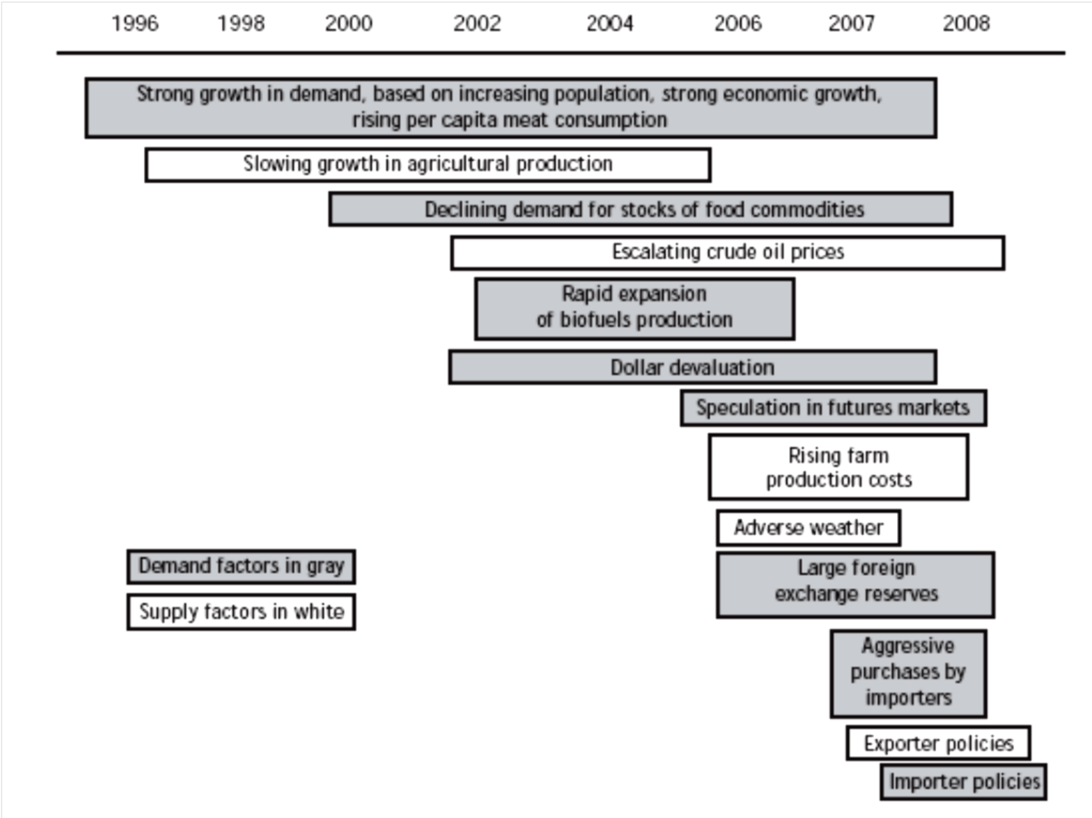
comparison to other currency it means that for importing countries is cheaper to import. Since the US is one of the major export countries for a large range of commodities, import countries increased their commodities demand from US adding upward pressure on US price for those commodities, which in turn, lead to higher world price since the world prices of exported commodities are typically in US dollars.

Supply side explanations include low research and development investments in agricultural in the last twenty years, higher oil prices affecting key input prices and transport, climate change and supply shocks related to weather conditions and finally trade barriers and export restrictions imposed by some countries as a response to higher food prices.

In term of agricultural production, Trostle (2008) shows how the annual growth rate in the production of aggregate grains and oilseeds rose an average 2.2% per year between 1970 and 1990 while, since 1990, the growth rate has declined to about 1.3%. Similar conclusions could be done about the growth in productivity, measured in terms of average aggregate yield. This indicator roses an average 2.0% per year between 1970 and 1990 but declined to 1.1% between 1990 and 2007. According to Trostle (2008), the declining in productivity may have related to the reduced agricultural research and development by governmental and international institutions. In fact, stable food prices during the last two decades may have provided a reduction in R&D funding levels as noted also by Hochman et al. (2011). They state that low food commodity prices, at least since 2001, reduced incentives for funding research and development to increase yields. However, Trostle (2008) showed how private sector funding of research has increased the amount of funding level but private sector research is generally oriented to cost-reducing rather than yield-improving. In essence private sector focuses on innovation that could be sell to producers whereas public research is generally involved in innovations that would increase yields and productivity and would be convey to small and poor farmers for free.

The figure below provide a picture of Trostle's (2008) time line of events model.

Figure 1.4: Timeline of events related to the prices crisis

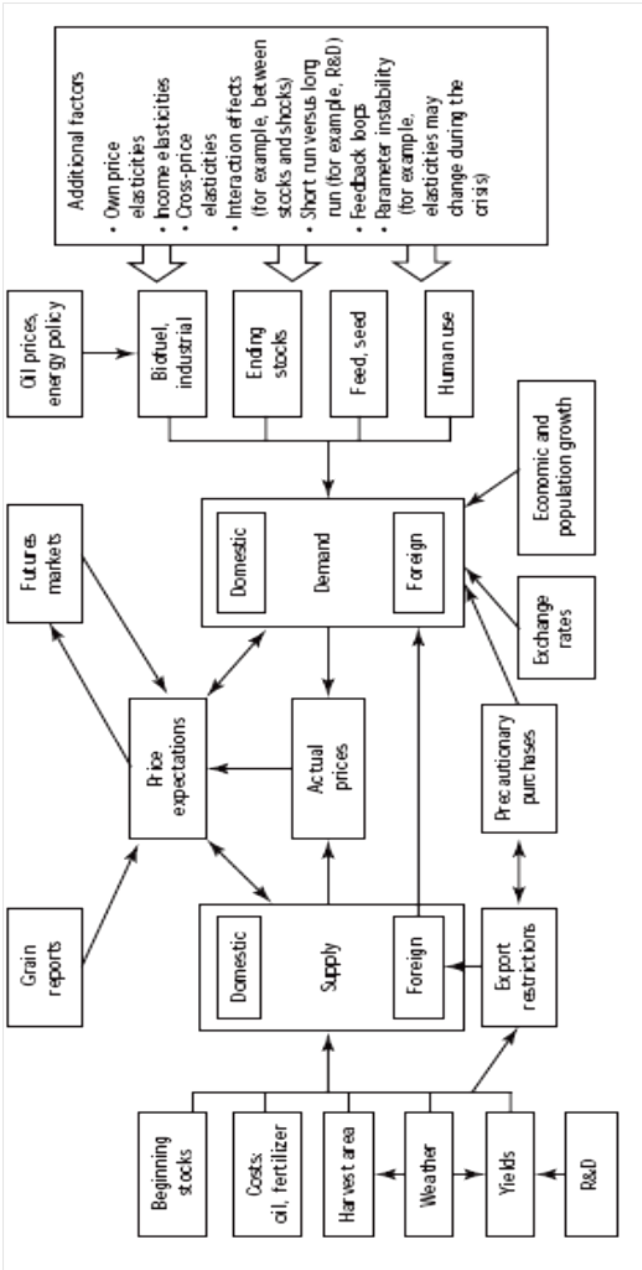


Source: Headey and Fan 2010

Headey and Fan (2010) decide to modify Trostle's timeline model adding speculation in future markets to the original figure as short term factor from the demand side.

In order to better understand the causing of rising food prices, it would be useful to describe a clear model of commodity prices formation. There seems to be little agreement about how international commodity prices are formed. Despite this fact, the model proposed by Headey and Fan (2010) seems to address the price formation in major international grain market in a more explicit way. The model, reported in figure 1.5, is based on the complex interaction between four main elements: supply, demand, actual prices and price expectations.

Figure 1.5: Price Formation model in International grain markets



Sorce: Headey and Fan 2010

Buyers and sellers of grain, represented by demand and supply respectively, get price arrangements based on supply and demand but also price expectation because grains are storable commodities. Moreover, supply and demand are strongly influenced by a large number of conditions. Price expectations themselves are influenced by current prices, supply, demand but also grain report and futures markets. Finally, the model's price transmission includes also a range of parameters and relationships that are called "additional factors" in the figure such as supply and demand elasticities, interaction effects among factors and so on. In addition to the general model presented in figure 1.5, Headey and Fan (2010:7) suggest to consider some basic facts strictly related to the international grain markets such as:

1. *Dominance of the US grain markets and importance of US specific factors.* The US is a global leading exporter in maize (with 60% of global export) and wheat (25%) and is the third world exporter of soybean. The rice market is the only one dominated by Asian countries. Hence, all US grain prices, but not the rice, are quoted as international price. Because its leading position in global market export, any event in US economy or in US grain market can be seen as a possible factors for the food prices crisis such as the increased biofuel production, the depreciation of US dollar and movements in commodity futures markets.
2. *Degree of competition and market efficiency in the United States.* The US grain markets are highly competitive with a complex market organization based on a sophisticated and highly reliable information service of the US Agricultural Department (USDA) and the price discovery functions played by futures markets.
3. *Seasonality and inelastic supply and demand functions.* Most of grains are limited to a single annual harvest. New supply sources can be represented only by domestic stocks or international sources. These aspects make supply function very vulnerable to relatively small shocks related to the level of stocks or international sources. To be honest, this is not completely true for wheat that is much more stable than maize for instance. As noted by Schepf (2006), there are two annual crops for US and two counter seasonal wheat exporter in the south hemisphere. Similarly, demand elasticity tends to be low. Changes in grain prices generally have a little impact on retail food price and therefore little impact on grain demand at least in developed countries. Anyway, in developing countries demand is still inelastic because poor people have no choice. Higher grain prices force poor people to concentrate their consume on this essential grain.
4. *Peculiarity of the rice market.* As said before, rice market presents some particular characteristics. First of all, only 6% of the global rice production is exported (Timmer, 2006). Then, the leading exporter countries are Asian countries such as Thailand, Vietnam and India. Finally, rice is the major food staple for a large part

of population in Asia. This fact makes rice demand highly inelastic with international price generally more volatile than the other grains prices but local price much more stable because substantial existing trade barrier for import and export.

The price formation model discussed in figure 1.4 and the description of the most important facts related to international grain markets provide a useful background in order to better understand the causes of prices crisis discussed in the following sections. Next paragraphs describe in details four of the major drivers of the recent prices crisis.

1.1 Increases in the price of crude oil

International fuel and food prices are historically linked. Headey and Fan (2010) and Tangermann (2011) note that also in the 1972-1974 crisis rising oil price was closely related to the rising food prices. This strong linkage is confirmed by recent researches based on econometric evidence such as in Baffes (2007), Vaciago (2008) and Balcombe (2011) that show how oil price volatility may be used as a significant predictor of volatility in agricultural commodities. In essence, rising in oil price affects food price through both supply and demand sides as stated by De Filippis and Salvatici (2008). On the supply side, Headey and Fan (2010) highlight how oil and oil-related costs of production represent an important component of production cost of many agricultural commodities. For instance it should be consider the huge impact in fertilizer prices, most of which are directly derived by energy products such as natural gas or require a great amount of energy to be produced. Moreover, the storability nature of grains means that transport cost should be also take into consideration. According to Mitchell (2008:6), high energy prices have contributed about 15-20% to higher export prices of major US food commodities between 2002 and 2007. Similar conclusion were reached by Baffes (2007 cited by Gilbert 2010) that estimated the effect of higher crude oil price on rising commodity prices as 17%. In a simulation realized by OECD (OECD-FAO, 2008) it was shown that a 10% change in crude oil price results in a 2,3% change in wheat price and 3.3% change in maize and vegetable oil price that are more sensible to the oil price.

On the demand side, rising energy prices result in growing demand for bio-energy and biofuel which are often cited as an important driver of the recent prices spike.

Headey and Fan (2010) argue that biofuels and its import surges by developed countries have been highly significant sources of demand growth for grains. Mitchell (2008) suggests that improved biofuels production in recent years has been the largest part of the rise in food prices. However Gilbert (2010a) challenged this view attributing only a modest proportion of food price rises to biofules demand. Also Baffes and Haniotis (2010) state that biofuels account for no more than 1,5% of global area used in grain production and for this reason biofules could not have a major role in prices crisis.

Biofuels include ethanol from corn or sugarcane and biodiesel from oilseeds or palm. Higher energy prices have increased the biofules production which in turns has increased the demand for food commodities used in biofuels production. Obviously, land uses changed reducing supplies of wheat and crops used as food commodities. Mitchell (2008:10) states that the US maize area expanded almost 23% in 2007 because of high maize prices and rapid demand growth from ethanol production. This change in land use resulted in a significant decline in soybean area (16%) which in turn reduced soybean production and "contributed to a 75% rise in soybean price between April 2007 and April 2008". On the other hand, oil seeds used in biodiesel production displaced wheat in EU and in other exporting countries. In response to the increased demand and higher price for oil seeds the land used in rapeseed production in the 8 largest wheat exporting countries increased by 36% between 2001 and 2007 while the area in wheat fell by 1% in the same period (Mitchell 2008). Moreover, biofuels have substantially contributed to the depletion of grain stocks. Headey and Fan (2010:29) explain this stocks depletion arguing that not only new land was diverted to maize production for ethanol but "most of the maize provided for biofuel production came from existing land and from production that would otherwise have been used to feed people or livestock". The same conclusion could be drawn for the wheat stocks in Europe.

As showed by Tangermann (2011:21) biofuels now account for a significant share of global use of a large number of crops. "On average in the 2007-09 period that share was 20% in the case of sugar cane, 9% for both vegetable oil and coarse grains, and 7% for sugar beet. With such share it should be not a surprise that world market prices for these corps are now higher than they would be if no biofules were to be produced at all"

In essence, as noted by Headey and Fan (2008), biofuels has a direct influence for maize price but can also explain price rises in wheat and rice because of substitution effects. Several researches argue that biofuels account for 60-70% of the increase in corn prices and maybe 40% of soybean price increase (Collins, 2008; Lipsky, 2008), while Rosegrant et al. (2008) find that the long term impact of accelerated biofuel production on maize prices is about 47%. The substitution effects on wheat and rice price is estimated about 26% and 27% respectively (World Bank, 2008). Hochman et al. (2011) provide a complete and detailed literature report about quantitative estimates of impact of biofuels on food commodity price calculated on the global food index varying from 6% (Hoyos and Medvedev, 2009) to 75% (Mitchell, 2008).

Feedstock demand for biofuel production is expected to increase over the coming decade even if at a slower rate than in recent years. Demand for cereals in biofuel production is projected, under current policies, to almost double between 2007 and 2017 (OECD b, 2008).

Also according to the European Commission (2010:5), “the domestic use of cereals and oilseeds in the EU is expected to increase, most notably thanks to the growth in the emerging bioethanol, biodiesel and biomass industry in the wake of the initiatives taken by Member States in the framework of the 2008 Renewable Energy Directive (RED)”.

However, as noted by Helbling et al (2008) biofuel industries seem to have a great impact on food prices and a very small impact on crude oil price.

In the next paragraphs biodiesel and ethanol’s role in the recent rising food prices will be discussed more in detail.

1.1.1 Biodiesel

Between 2001 and 2008, biodiesel production from edible oil seeds such as soybean, oil palm and rapeseed expanded six fold from 2 billion liters to 12 billion liters (Hochman et al., 2011).

The global leader in biodiesel production is the European Union with the 76% of the global production in the 2006. In the same year, United States had 20% of global production. Biodiesel is so important in the UE because the high share of automobiles using diesel while in USA gasoline is preferred, for which ethanol is a substitute. According to Abbott et al (2008:42), “in the USA, biodiesel produced from plant material has enjoyed a greater subsidy (1$ per gallon) than ethanol but even with this higher subsidy, biodiesel is not profitable as ethanol because the soy oil prices have risen to the point that it cannot be economically converted to biodiesel in most circumstances". The same authors state that only 35% of world expansion in soybean oil use since 2004/2005 has been for fuel purpose with the rest used in food industry. In contrast, for rape seed oil, 80% of world increase since 2004/2005 has been used in the industrial category and in particular related to the production of fuel for the European market. In essence, the production of biodiesel from soybean oil is not an important driver of the higher vegetable oil price because the low percentage of world expansion in soybean oil used for fuel and also because the EU programme based on oilseed instead of soybean oil. In fact, according to the European Commission (2010), the medium term prospect for the EU oilseed markets shows a positive picture with a very strong demand and high oilseed oil prices which lead to both yield growth and expanding oilseed area with some reallocation between crops.

1.1.2 Ethanol

Between 2001 and 2008 production of ethanol from maize and sugarcane more than dubled from 30 billion litres to 65 billion litres (Hochman et al., 2011). For ethanol the global leaders are USA and Brazil with a percentage of global production in 2006 around 37% for both countries (Abbott et al, 2008). USA ethanol derives mainly from corn whereas Brazil uses sugarcane.

Mitchell (2008) observes that Brazilian ethanol production has not contributed appreciably to the recent increase in food commodities prices because Brazilian sugar cane production has increased rapidly and sugar exports have nearly tripled since 2000. Only half of Brazilian sugar cane production is used in ethanol industry for domestic consumption and export, the other half is used in sugar production. More in detail the sugar production increases from 17.1 million tons in 2000 to 32.1 million tons in 2007.

In the USA ethanol has been subsidized since 1978. At the beginning, with the price for the crude oil ranged between 10$ and 30$ per barrel with some exception, the subsidy was fundamental for the ethanol industry to grow slowly. Abbott et al. (2008) state that without the subsidy ethanol would have been profitable only with the crude oil quoted above 60$ per barrel. Also IFPRI (2007), Headey and Fan (2010) and Schmidhuber (2006) calculated that when oil prices range between US $60 and $70 a barrel, biofuels are competitive with petroleum in many countries, even with the existing technologies. When oil prices are above US $90, the competitiveness is of course even stronger. Since

2004, crude oil price has been changed drastically increasing from 60$ in April 2006 to 120$ in May 2008. The high oil price, in addition to the subsidy and low corn price until 2008, lead to a huge investment in ethanol production, which in turns lead to a higher demand for corn. But this increased demand for corn used to produce ethanol led to higher prices in corn as a final result.

A large strand of literature (Abbott et al , Headey and Fan 2010, Schepf 2008, Von Braun 2008) concludes that the diversion of the US maize crop from food to ethanol uses represents one of the most significant demand-factor of rising food price.

According to Mitchell (2008) between 2004 and 2007, 70% of the increase in global maize production was used for ethanol. In the same period, ethanol use grew by 36% per year while feed use grew only 1.5% per year.

The use of maize for ethanol especially in US has important global implications because the strong position of US in global maize production (about one–third) and its leadership in global maize exports (about two-thirds). Mitchell (2008) states that the US used about 25% of its maize production in ethanol.

It is not an easy task to estimate the contribution of biofules, and in this case ethanol, to food price increases. In fact, estimates can differ in a wide way in function of different length of time considered, different prices considered such as export price, retail price, food product, currency and so on. Moreover, using general equilibrium model instead of partial equilibrium would lead to different estimates. Despite all these different approaches, many researches recognize biofuels as a fundamental driver of food prices. The International Monetary Fund (IMF) cited by Headey and Fan (2010) estimated that the increased demand for biofuels accounted for 70% of the increase in maize prices and 40% of the increase in soybean price (Lipsky, 2008). Collins (2008) estimates that about 60% of the increase in maize price from 2006 to 2008 have been due to the increase in maize used in ethanol production. Also Rosengrant et al. (2008) quoted by Mitchell (2008) calculated that, because of increased biofuel production, maize price have increased 21% in real terms, wheat prices increased 22% and rice prices almost 21%.

The important contribution of biofuels in food prices crisis raises pertinent policy issues about the opportunity to carry out with US and EU government policies based on subsidies to biofules production.

Anyway, Abbott et al. (2008:44) state that, at present, most of the corn price increase is related to the higher oil price and only for a little part due to the subsidy. In other words,

“as oil has increased, corn-based ethanol is demanded to substitute for gasoline. At high oil price, this would happen with or without the subsidy.” Removing the subsidy does not decrease the corn price until the oil crude price fell as well. Despite of this, a study by the Food and Agricultural Policy Research Institute (FAPRI) reported by Headey and Fan (2010) estimates that the joint implementation of both subsidies and tax credits for ethanol supports maize prices by about 20%.
Despite of this large strand of literature in favour of the so called “fuel vs food debate” a recent work by Bastianin et al. (2013) analyzes the relationship between the price of ethanol and agricultural commodities using data from Nebraska which is deeply involved in ethanol production. In their piece of research the authors used advanced statistical techniques to define long run relation and Granger causality linkages between ethanol and the other commodities. The findings of this study show no evidence to state that ethanol price should be considered a long run driving force for the price of food commodities.
Finally, biofuels lobby groups argue that the role of ethanol as a driver in rising food prices is overestimated. In fact they point out that ethanol production uses only the starch in maize. Hence, maize oil and protein could still used in animal feed system.

1.2 Exchange rates and us dollar depreciation

Commodities prices increases not only because of supply-demand events in individual markets but also because of macroeconomics events that changed the environment within the markets find their own equilibrium. The common literature considers different macroeconomic variables to explain prices increase. The exchange rate and the US dollar depreciation is one of the most analysed variable. A large number of recent studies cites the depreciation of US dollar as one of the major causes of current high commodity prices. Few of these studies, as it will be seen, try to quantify the role played by dollar depreciation in commodity prices crisis. Generally speaking, when the dollar is weak, agricultural exports and in particular grain and oilseed exports grow. Since the US dollar is used in the international trade of agricultural commodities, it should be clear that a depreciation of the US dollar lead to higher prices in the United States but, at the same time, lower prices for the rest of import countries. Before analysing the relationship between exchange rate and commodities price, it would be useful introduce some background on dollar depreciation in order to better understand its real impact and role in commodities price increase. According to Abbott et al. (2008), the recent dollar depreciation is surely related to the huge trade deficits that the United State is still realizing. In fact the authors state that the US trade deficit reached the record of 5.75% of GDP in 2006. In the 2007 the depreciation of dollar brought some small improvement leading the deficit to the value of 5.1% of GDP. Between 2006 and 2007, the increased agricultural export was a significant contributor to the small improvement in the trade deficit. The higher agricultural commodities price had an important role in diminishing the US trade deficit. On the other hand, the depreciated exchange rate, resulting in smaller prices increases in the rest of the world, have sustained the export quantities in the face of higher US price. However, the trade deficit is well linked to a capital account surplus as money from OPEC and China flows to finance the US deficit. The IMF (2007, cited by Abbott et al 2008) noted that OPEC investment in the US economy and Chinese treasure bill purchases were fundamental to keep up the dollar's relative strength until the recent financial crisis and the subsequent interest rate cuts. The dollar depreciation was also worst after the Fed interest rate cuts. Vaciago (2008) provides a complete view on the monetary expansion policy applied in US and in other important developed countries, the low rate of interest that increased the amount of money and subsequence depreciation of US dollar showing how these aspects lead to the rising food prices.

For how long the US dollar is going to stay weak will depend on several factors such as the confidence of foreign investors in the US economy, the increases of export due to the US dollar depreciation and the decrease of import, the extend of inflation and finally interest rate in US and abroad.

Since 2002 to 2008, corn prices in nominal dollar have increased 143%. In real Euros the increase is only 37% (Abbott et al, 2008). In the 1995-96 a similar price run-up experienced a nominal $ increase near to 143% and a real Euro increase of 94%. The comparison between the 1995-96 prices crisis and the recent price increase lead to conclude that in the former the corn price increases were due in an extensive part to supply and demand balances with exchange rates playing almost no role, while the latter looks quite different with dollar depreciation playing a much more important role in price increases.

More in details, the US dollar depreciated against the Euro about 35% from January 2002 to June 2008 and the depreciation of dollar has been shown to increase dollar commodity prices with an elasticity between 0.5 and 1.0 (Gilbert 1989). Cooke and Robles (2009) using data from Federal Reserve Branch of St.Louis, show a US dollar depreciation against euro close to 65% since 2002.

Mitchell (2008) calculated that the depreciation of the dollar has increased food prices by about 20%, assuming an elasticity of 0.75. Abbott et al. (2008), using USDA's agricultural trade-weighted index of real foreign currency per unit of deflated dollars, find that from 2002 to 2007 the US dollar depreciated 22% and the value of agricultural exports increased 54%.

1.3 Speculative and investor activity

During the recent prices crisis it has been argued (Baffes and Haniotis, 2010) that fundamentals have played a major role in commodities prices crisis but demand and supply considerations are not enough to completely explain the prices boom. Many researchers and analysts argue that excess liquidity and speculation have to be taken into consideration. Various aspects related to speculation have been discussed. In particular; excess liquidity, index funds activity, speculation, the role of commodity futures exchanges and speculative bubble have received more attention than others. Obviously, the complexity of each aspect and the interrelationship between them has led to different conclusions and mixed results about their role in rising food prices. The next paragraphs of this section try to summarizes some of these results.

1.3.1 Excess liquidity and index funds activity

Baffes and Haniotis (2010:6) note that the low interest rate environment supported by many central banks lead to an excess of liquidity, part of which was invested in commodity markets. Low interest rate represents only one of the three sources of new money that found its way into commodities markets. The same authors suggest diversification of investment vehicles and rebalancing of investment portfolios as other sources for "new money".

The former is related to the investment funds managers searching for new and uncorrelated assets. Thus, funds managers began to invest in commodities, including agricultural commodities, just to diversify their investments into uncorrelated assets. The rebalancing of investment portfolios towards commodities added further inflows into commodity markets. The effect of this rebalancing is less permanent than diversification and depends on investors' risk attitude.

The key investment vehicles for this new money into commodity markets are index funds. The Down Jones-AIG and S&P Goldman Sachs Commodities Index (also known as DJ-AIG and S&P-GSCI) are the two most used indices. According to Baffes and Haniotis (2010), about 95% of funds indexed to commodities are replicated by these two indices. The funds buy long position contracts in commodities futures markets exchanges and, prior to expiration, rolling them over. Romano (2009) calls them long-only commodity index funds.

Baffes and Haniotis (2010) report that there are not a precise estimates on the funds' size but a realistic range seems to be $230-240 billion in 2009. Although these amount of money represents only one percent of the global value of pension and sovereign wealth funds holdings, they are really large in comparison to the size of commodity markets. In essence the effect of the new money on commodities prices has been associated with speculation and subsequent price bubble. However, the view on this subject have been quite extreme and still under debate. In order to better understand the core of this debate in the next paragraphs it will be discussed what speculation is and the mechanism of commodities trading activity in futures exchanges.

1.3.2 Speculation

A large strand of literature have suggested speculation in commodities future markets as one of the major cause of rising food prices. However, the recent debate on speculation shows extreme positions of opinion leaders and insufficient and not always clear empirical evidences. This extreme complexity on the subject partly reflects the different types of "speculative activity" that analysts and economists refer to. Indeed, in order to understand the complexities of speculation it will be discussed the different sources of speculation, the place where transactions take place, the actors involved and their motivation.

As suggested by Baffes and Haniotis (2010), the traditional separation of the place in which transactions take place (physical versus financial) and the actors involved (hedgers versus speculators) does not exist anymore. A more complex picture should be now considered with speculators engaged in financial transaction but also in physical transactions by holding inventories and, on the other hand, hedgers involved in physical but also financial market transactions.

1.3.3 Actors involved

The hedgers include producers and consumers both involved in physical transaction of commodities. These are called commercials in Commodity Futures Trading Commission (CFTC) terminology. They have an exposure to the price of the physical commodity that is long in the case of producers and short in the case of consumers (processors). They are used to offset their positions (at least partially) by taking an opposite position in the futures market. Behind the hedgers two more actors should be considered that operate with pure financial motivation and are not involved in physical markets transaction: Speculators and investors. Speculators are often trend followers. They may take long and short positions but they hold positions for only short periods of time. Hedge funds and commodity trading advisors (CTAs) are typically included into this category.

In particular, hedge funds are involved in a large range of asset including commodity markets. A hedge fund may invest in commodity markets mainly to "hedge" the diverse risks of their portfolios.

In such a case, investing in commodity markets represents an investment in a non-correlated asset that provides diversification benefits to the overall portfolio. Hedge funds are not new instruments and they may have short term effects on commodity prices.

Commodity trading advisors (CTAs) are asset managers that operate almost exclusively in commodity markets looking for profits from market volatility. For this reason, CTA activity is thought to reduce price volatility since they trade on the basis of market fundamentals and technical analysis.

The third category of actors involved is represented by investors. They take usually long positions in commodity futures market in order to diversify their portfolio. During the past few years, as said before, this class of actors generally called investment funds and including pension funds and sovereign health funds have dramatically used financial markets' products. According to Baffes and Haniotis (2010) investment funds include sovereign wealth and pension funds. As said before, in the few past years they began including commodities in their portfolio mix in order to diversify with uncorrelated assets. The major concern about investment funds is represented by their relative size compared to commodity markets and the subsequent possibility to unbalance the markets itself. Soros (2008) asserted that investment in instruments linked to commodity indices had become the "elephant in the room" and stated that investment in commodity futures might exaggerate price rises.

1.3.4 Place of transaction

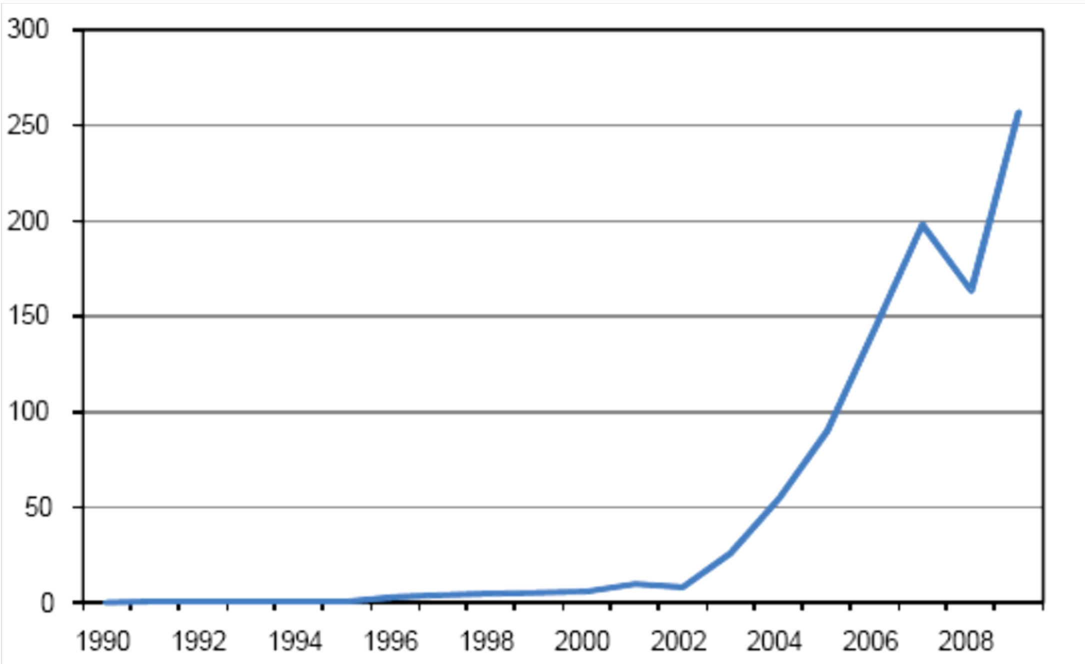
Commodity transactions take place either in physical market or in future exchanges board. Futures markets evolved gradually during the last century. At the beginning, commodities exchange were mostly cash markets where physical commodities were bought and sold. As the volume of trading increased, buyers and sellers began trading forward contract. This type of contract can be defined as an agreement in which a seller agree to deliver a cash commodity to a buyer sometime in the future. In essence, quality, quantity, delivery time and location, as well as the price, are defined in advance. The advantage of cash forward contract in comparison with an immediate cash sales transaction is that it allows both buyers and sellers to know in advance the price of the specific commodity. Moreover, they can postpone delivery until they have possession of the grain (sellers) or they are ready to process it (buyers).

Nevertheless, forward contracts presented different negative aspects. First of all they are privately negotiated. Secondly there are some risk to both parties in the agreement. One side may negotiate in bad faith or without sufficient funds or may not able to fulfil the contract. In order to avoid these problem and make easier and safer the transaction in 1865 the Chicago Board of Trade (CBOT) introduced the first standardized commodity futures contracts. Futures contracts are standardized and meet specific requirements of buyers and sellers for a variety of commodities (not only agricultural commodities) and financial instruments. With this contract, quantity, quality, delivery locations are previously established. The only variable that is not fixed yet is the price, which is discovered through a kind of auction process on the trading floor of an organized futures exchange.

Currently, Chicago Mercantile Group (CMG), which is the sum of the Chicago Board of Trade and the Chicago Mercantile Exchange, is the world's largest market place for trading futures and options. In 2007 it saw trading volume of 2.2 billion contracts with three-quarters of the traders executed electronically. The huge and increasing use of futures contracts is due to the standardized terms and the possibility to offset them. Commercial firms realized that future markets could provide financial protection against price volatility whereas speculators found that, thanks to the standardize terms, futures contracts could be bought and later sold in order to achieve some profit with correct forecast of price movement. In this case, the risk is transferred to hedgers form speculators. In essence, risk transfer and price discovery power are the two major benefit of futures contracts markets.

Despite of these benefits, there are different concerns about futures contract. First of all, futures contract allow a large number of so called non-commercial participant to take part in trade. Non-commercial participants are all those who are not directly involved in agricultural production, distribution, and delivery to markets. Us Commodity Futures Commission gradually changed the roles over who may trade in agricultural futures leading to a greater index funds participation in future markets. Headey and Fan (2010:41) accounted the index funds participation for almost 40% of the futures contract trading in wheat in 2008. The figure below show how massive has been the investment of commodity index funds during the last decade.

Figure 1.6: Commodity index fund investment in billion US dollar.



Source: Barclays cited by Irwin and Sanders (2010b).

The concern about this is that non-traditional participants can now speculate on food price trends since futures contracts value varies in relationship to the commodity spot prices market. In essence, the variation of commodity prices is an opportunity for the speculators to bet on futures contracts just like for any other asset class. So, as summarized by Headey and Fan (2010), a short futures position (referred to contracts within 6 months) protects against price decreases, whereas long position (involving contracts of longer than 6 months) may benefit from price increase in long term run. Most commercial agricultural traders play in short futures market but most non-commercial player, the so called speculators, prefer long term position. Hence, a common measure to quantify speculative activity is based on long term market contracts such as the share of long position taken by index funds.

1.3.5 Speculative influence on commodity futures price

Cooke and Robles (2009) use a large range of proxies for participating in agricultural commodity futures markets and in speculative activity such as the volume in futures contracts, open interest in futures contracts, the ratio of volume to open interest in futures contracts and finally the amount of positions in futures contracts by non-commercial traders.

In particular, the monthly volume in futures contracts indicator expresses the total number of trading on a commodity futures contract in the Chicago Board of Trade (CBOT) on a monthly basis. According to the authors, in recent years traded volumes in futures contract in agricultural commodities have deeply increased until 2008. In 2006 the average monthly volume in futures for wheat and corn grew by more than 60% with respect to the previous year. In 2007, volumes grew significantly for all the most important commodities with a monthly average 40% larger than in 2006. Monthly open interest in futures contracts has also grown between 2003 and 2008 with great differences in function of the commodity considered. The last two indicators studied by Cooke and Robles (2009) are the Ratio of volume to open interest in futures contracts and the importance of non-commercial positions in futures contracts. The former is used to capture speculative market activity under the assumption that a speculator prefers to buy or sell contracts on a short period of time increasing the monthly volume in futures contracts without affecting the monthly open interest in futures contracts. The results achieved by the authors show how the increasing of the ratio would be interpreted as a potential speculative behaviour between 2005 and 2008. The latter indicator (importance of non-commercial positions in futures contracts) represents an amount of the speculative activity in search for financial profits. The importance of the non-commercial position is expressed as the ratio of non-commercial position to total positions. According to Cooke and Robles (2009) this ratio seems to be growing during the period of time studied. For corn they report that the ratio for long position only was on average 0.29 in 2005, and in the first five months of 2008 it reached an average of 0.49. In the case of short positions there is less evidence of upward trend of the ratio. Since both commercial and non-commercial increased their participation in the futures market. Hence, Robles and Cooke (2009) find an econometric linkage between futures market activities and spot market prices using time series analysis. They conduct 23 tests with four different commodities and proxies for speculative activity described before providing evidence that financial activity in futures markets and proxies for speculation can help to explain the observed change in food price . Their results show evidence of Granger causality in 6 of the 23 tests. Finally, they try to explain the relationship between speculation and spot price arguing that in agricultural futures markets producers try to hedge their futures income selling short, whereas industrial processors take long position hedging their costs. The volume of these two different positions does not always match and hence non-commercial or speculators traders play the important role to provide liquidity to the market closing the gap between the two positions. However, when speculators activity increase significantly on both sides of the market this may affect spot prices. In essence, if a large groups of speculators take part to the market with long position betting on higher future spot prices, futures price may be driven upward up to the point they start to attract further speculators. At this stage, signals for higher prices are transmitted to the spot market confirming the expectation of higher prices and providing positive feedback on further expectations. Romano (2009) calls this step as self-fulfilling expectations.

Similar conclusions have been reached by a large strand of literature providing theoretical and empirical evidence on how speculation has contributed to the crisis.

Gheith (2008), Masters (2008), Masters and White (2008) assert that speculative activity by index funds create a “bubble” with the result that commodity prices (but also crude oil price) was not driven by only fundamental values. Masters (2008) clearly stated that “Institutional Investors are one of, if not the primary, factors that contribute to price determination in the commodities markets". Soros (2008) defined commodity index trading as potentially destabilizing for their relative size compared to the commodity markets size. Calvo (2008) stated that commodity rising prices are the result of rebalancing of investment portfolios by index funds. He also noted that speculation activity and low inventories are not necessarily inconsistent with each other challenging one of the major motivation of speculation thesis' opponents as it will seen later. Plastina (2008, cited by Baffes and Haniotis 2010) highlights the role of investment fund in rising cotton price between January 2006 and February 2008. Finally, Gutierrez (2012), using a bootstrap method, provides evidence of explosiveness in the future prices of wheat and rough rice in 2007-2008.

However, the impact on price is hard to quantify and most studies do not find that such activity changes prices from the levels which would have prevailed without speculation. In essence, to provide theoretical and empirical evidences showing the role of speculation in prices crisis is not an easy task. A large school of thought highlights logical inconsistencies in the arguments proposed by bubble proponents and several observed facts that challenge the speculation proponents' theory. Krugman (2009) challenged the belief that speculation was a major factor in rising prices and also rejected the idea that commodity trading in futures exchange may have influenced commodity prices arguing that a future contract is a bet about the future price without direct effect on the spot price. Wolf (2008) stated that inventories were low during the rising price and this fact is in contrast with the speculation activity since in presence of speculation, one would expect to see commodity inventories increase. Similar conclusion has been reached by Wright (2009) that noted that if long futures positions were behind the grain price boom in 2008, stocks would have increased. Two IMF studies (2006, 2008) cited by Baffes and Haniotis (2010) found no econometric empirical evidence that speculation had a role in rising commodity prices.

Irwin et al. (2009) and Sanders and Irwin (2010) challenged the conclusion that speculation has influenced agricultural futures prices leading to a bubble price. They both review the theory and the evidences against the main role of speculation in rising food prices adding new data and empirical analysis. In particular they discuss three conceptual errors, that reflect fundamental and basic misunderstandings of how commodity futures markets actually work, and five logical inconsistencies with the arguments of bubble proponents. The first and most fundamental conceptual errors challenged by the authors is to equate money flows into futures markets with demand. Investments into long or short position of futures markets in not the same as demand for physical commodities. "With equally informed market participants, there is no limit to the number of futures contracts that can be created at a given price level" (Sanders and Irwin 2010:26). Index funds long positions should be considered as new "demand" such as, at the same way, index funds short positions should be considered new "supply". In essence, put in this way, money flows do not necessarily impact prices. It should be clear that this argument is true only if all the participants are perfect informed. If this is not the case, it is possible that a huge increase in long side positions should be interpreted by some trades as a result of reliable private information about commodity prices evolution. Anyway, because the publicity about index funds buying activity and because trading methods is very transparent, the authors consider highly unlucky that something like that would happen in a wide enough scale to drive prices out of fundamentals.

The second conceptual error is to state that index funds affect futures and spot commodity prices since they only participate in futures markets. More in detail, in the short-run, commodities prices are defined in the futures markets and translated from futures to spot markets. However, in the long run, equilibrium prices are only discovered in the cash markets where demand and supply of physical commodities reflects fundamental forces. As also reported by Headey and Fan (2008), index funds do not participate in the futures delivery process or in the cash markets or in the purchase of the cash commodity. "Index investors do not participate in the futures delivery process or the cash market where long term equilibrium prices are discovered" (Sander and Irwin 2010:26). Irwin et al. 2009 observe that in order to affect the equilibrium of commodities in the spot markets, index funds would have to take delivery and hold these stocks off markets. By the way, there is no evidence that index funds have been involved in delivery or hoarding process.

A third conceptual errors made by speculative bubble proponents is a scholastic and unrealistic definition of hedgers and speculators. Usually, hedgers are seen as risk-avoiders whereas speculators are considered active risk-seekers. This basic distinction is no any more in line with the most common literature that better describe the behaviour of hedgers and speculators as a continuum between pure risk avoidance and pure speculation. Moreover, many commercial firms labeled as hedgers speculate on prices direction whereas some speculators are engaged in hedging activities. In other terms index funds investments into commodity futures markets did not disturb the perfect equilibrium between hedgers and speculators, but instead the funds entered into a dynamic a much more complex equilibrium between commercial firms (hedgers) and speculators with various motivation and strategies that cannot be defined simply as risk-avoiders or risk-seekers.

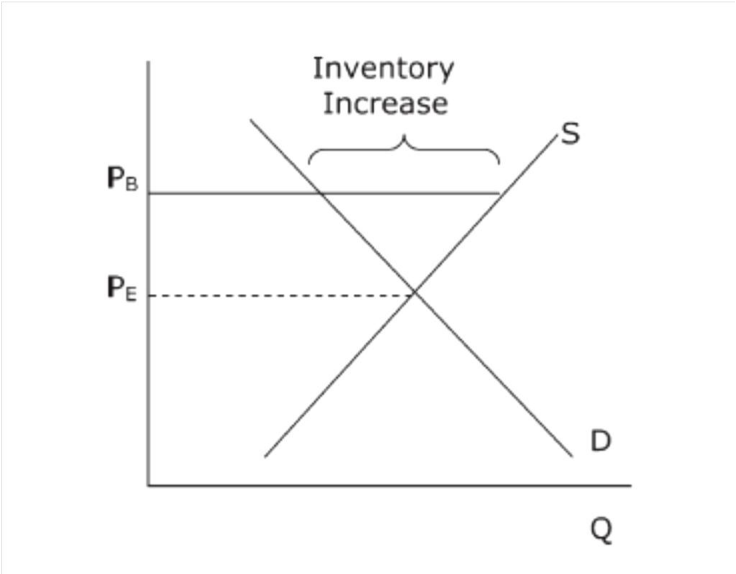
In addition to these conceptual errors, Irwin et al. (2009) and Sanders and Irwin (2010) describe five facts about commodity markets that are clearly inconsistent with the arguments of bubble proponents. Firstly, the statistics on index funds investment tend to focus on absolute position size and activity. A quantification of speculation activity should be done always in relative terms comparing speculative activity to hedging needs. Sanders et al. (2008) demonstrate that the level of speculation in nine commodity futures markets from 2006 to 2008 was not excessive but within the historical levels. In essence, the rise in index funds activity was more than offset by commercial participation.

The second inconsistent fact is that if it is true that index funds buying drove commodity prices higher, then markets with the highest concentration of index funds positions should have registered highest prices increase. Despite of this, Sanders and Irwin (2010) show how the size of index funds investments in different markets is not strictly correlated to the prices movements. They show how future market with the high index funds investments such as livestock markets had little or no prices increase, whereas other markets with lower level of index funds participation such as grains and oilseeds registered the largest prices increases.

A subsequent inconsistent fact, also observed by Headey and Fan (2008) is that high price were discovered in commodity markets not connected to index funds investments such as rubber and onions for instance. This would suggests that other macroeconomic factors may influence commodities rising prices.

The fourth inconsistent fact is related to inventories for storable commodities. The theoretical market equilibrium occurs when supply and demand curves intersect. The result is the equilibrium price. If we admit a bubble in the market, the new price is now above the equilibrium price. It means that at the bubble price the quantity supplied exceed the quantity demanded as showed in the figure below.

Figure 1.7: Theoretical impact of a price bubble in a storable commodity market



Source: Irwin et al (2009)

It should be expected an increase in inventories when bubble is present in a storable commodity market. Nevertheless, the level of stocks for corn, wheat and soybean decreases since 2005. By the way, Gilbert (2010:408) argue that even if this argument is correct “it may take time to play out”. In the case of food commodities, with the inventory supply curve near vertical in the short or medium term, the increase demand can only be met by an increase in the cash price.

The last inconsistent fact is related to the nature of commodity index trading. Theoretical models show how a group of uninformed traders (the so called “noise traders”) can significantly drive prices away from fundamental values making a gap between market prices and fundamental values. In the case of index funds, it is highly unlikely because the transparency of commodity index trading. In fact, they are used to publish their portfolio (market) weights and roll-over periods. In essence, index funds do not attempt to hide their current position nor their next moves. Hence, if index funds drive prices away from fundamental values, other large rational traders would trade against index funds. Despite this fact, as reported by De Long et al. (1990 cited by Gilbert 2010), informed traders may push away from the fundamental values rather than to return to fundamental if they have a short time horizons.

Sanders and Irwin (2010) provide an empirical test of this inconsistent fact using data from Commodity Futures trading Commission (CFTC)' report[1]. In particular, the authors test if the relative index funds participation is correlated to subsequent returns across markets analysing the relationship between index funds positions and returns across 12 commodities futures markets. However, using both Fama-Macbeth method and traditional cross-sectional tests, the null hypothesis of no cross-sectional impact (it means that index fund positions do not impact returns across futures markets) is only rejected in one of 12 models.

Moreover, Irwin and Sanders (2010) fund not only a negative Granger cause relationship between index funds positions and market return but, more important, a statistically significant negative relationship between positions and market volatility. In other words the authors show consistent evidence that increases in index trader positions are followed by lower market volatility. Anyway, they also suggest to interpret this result with great caution. In fact, another third variable not included in the model could be involved in market volatility decline.

Gilbert (2010b), using data from the CFTC's Supplementary Commitments of Traders reports for twelve agricultural futures markets which distinguish positions held by index providers, indicates that index-based investments in commodity futures markets may have been responsible for a significant and bubble-like increase of energy price, although the estimated impact on agricultural price is smaller. In the case of agricultural commodities the maximum impact may have been to rise prices by the order of 15%.

In conclusion, Baffes and Haniotis (2010:9) argue that any financial activity related to the commodity markets is unlikely to affect the long term price trends which is ultimately influenced by market fundamentals. In essence there should not be any linkage between rising spot prices and rising futures prices. However, "such activities can induce higher price variability as the most likely did during the perfect storm of 2007/2008". This conclusion is supported by Headey and Fan (2008:379). They conclude that "futures markets are unlikely to be a leading cause of the overall price surge, since there is little evidence that these markets significantly influence real supply and demand factors". The same authors admit the possibility that futures markets may have only exacerbated the volatility in agricultural markets showing how the contract price volatilities of corn and

[1] CFTC's Commodity Index Traders

wheat futures price indexes have increased from 19.7% and 22.2% since 1980 to 28.8% and 31.4% in 2006-2007, respectively (Schnepf, 2008). This positive trend for volatility has been observed also by Sarris (2009) using historical yearly cash price volatility index of Chicago Board of Trade (CBOT). Thus, speculation may be more a symptom than a cause of underlying volatility. When markets are flat, futures contracts tend just to reflect the discounted future value at today's prices but when markets are in turmoil, expectations of future prices may vary considerably opening rooms for speculation (CBC 2008).

1.4 Decline of commodity stocks

Besides the above mentioned factors, the list of possible causes analysed in the recent literature includes the decline of commodity stocks (Abbott, Hurt and Tyner, 2008).
Economic theory has described how commodities stock can play a main role in buffering price volatility. The theoretical background, as we'll see later in details, includes the pioneering works of Gustafson (1958), Samuelson (1971), Wright and Williams (1982, 1984), Scheinkman and Schechtman (1983), Williams and Wright (1991) and Deaton and Laroque (1992). All these authors focused on the competitive storage model under the assumption of rational expectations showing how stocks are a key factor in commodities price behaviour. In essence, storage model states that storage building can mitigate demand and supply shocks. On the other hand, low level of stocks will increase price volatility.
Starting on 1999/2000, the global stock level for major cereals has been declined. In 2007, world stocks of cereals, expressed in terms of stocks to use ratio, had reached its historically low level (Dawe, 2009; Wright, 2011) even in comparison to the levels reached in the early 1970s food crisis (Tangermann, 2011). For both events, 1973-1974 and 2007-2008, the literature has generally recognized the critical role of commodity stocks. Piesse & Thirtle (2009) argue that the single most important factor in agricultural prices was low inventories. The stocks/utilization ratio for grains and oilseeds dropped to 15% in 1972 and 1973 and did not touch such a low level again until 2008. Trostle (2008) recognizes the importance of fundamental supply and demand factors, emphasizing the decline in stocks to use ratio for wheat, rice and corn grains leading up to the boom witnessed in 2008.

Indeed stocks have played an important role in price stabilization policies in the past and remain a core topic today in discussions about achieving food security. For example, the announcement of the release of Japanese rice security stocks is thought to have acted as a depressant during the rice spike (Dawe, 2010). Therefore, it is not surprising that the usefulness of holding public stocks has been the subject of debate by scholars in recent years (see Timmer 2010, and Von Braun & Torero 2009).

The level of stocks represents the difference between output and use. The low level simply reflects that since 1985 to 2007 the worldwide demand for cereals had been larger than the worldwide supply. The decline in inventory resulted in commodity prices being more sensitive to any given shock.

The decline in global cereals stocks just before the price spike was due to different factors.

First of all, unfavourable weather conditions reduced cereals productions in some important exporters countries. Moreover, the shortfalls in output coincided with a continued growth of global use (Tangermann, 2011).

The low stock levels observed in recent years have been also attributed to policy adjustments of price support and intervention purchase schemes in some OECD countries, as well as to correction of the quality of information on private and government held stocks in important producing and consuming countries. Tangermann (2011) notes that both China and EU have changed their storage strategy reducing the minimum required levels.

Moreover, overall demand for food and feed due to economic growth and population growth, at least in developing countries, and demand for biofuels, especially in developed countries, accompanied by slow rates of increase in output because declining productivity growth have meant demand exceeded production since 1985 leading to the lowest level of stocks.

All these factors, resulted in a decline of stock to use ratio of world grain and oil seed stocks from 35% in 1985 to less than in 15% in 2005 (Trostle, 2008). In essence, during the last 25 years, stock to use ratio declined by more than 50%.

When stocks are depleted, commodity price become highly linked to information on stocks. On the other side, when stocks are in abundance price volatility is historically low. In other words, stockholding behaviour provides an important clue to expanding commodity booms and busts, along with other fundamental factors such as supply and demand shocks. Tangermann (2011) shows how when stocks are low, many agents may be nervous and change their rational behaviour. For instance, in expectation of rising price, farmers may sell their production a little bit later and, on the other side, traders, processors and distributors may buy a little bit earlier. The result of these change in behaviour is that a higher quantity of the involved commodity can get absorbed in the food chain in comparison to a normal condition represented by a normal volume in stock. Also importers may adjust their buying behaviour. Trostle (2008) has observed that by late 2007, when commodity prices were in their spike, some importers were buying larger volume in order to cover their need for a longer period of time (5-6 month instead of 3-4 month).

While much discussion has been held on the main role played by stocks in food price crisis, however, empirical literature has, so far, provided only little attention to this topic mainly because the scarcity of empirical data on public and private stocks.

Kim and Chavas (2002) have found results that are consistent with the theory of competitive storage model under rational expectation for the US not-fat milk market. Balcombe (2011) analysed the volatility of different world agricultural prices showing how volatility can be also explained by stock levels having a downward impact on volatility. He noted how when stocks are low, the dependence on current production in order to meet short-term consumption demands is likely to rise. Even small shocks to supply may have a severe dramatic effect on prices. Similar results have been obtained by Stigler and Prakash (2011) using a two stage analysis in the US wheat market.

In line with these empirical results, Cartel et al. (2011) state that high levels in storage provide a buffer against supply and demand shocks. In response to such shocks, inventories can be depleted, mitigating the impact on prices. When inventories are low, the lack of a buffer leaves the markets vulnerable to price spikes. Not only low stocks are important in order to increase volatility price but also uncertainty about stock levels in some parts of the world and even expectations of depleted stocks may lead prices to rise sharply.

Hochman (2011) developed an empirical model that also included crop inventory adjustment behind the most common drivers for the price spike in 2006-2008. His research shows that, if inventory effects are not taken into account, the impacts of the various factors on food commodity price inflation would be overestimated showing, in this way, the important role of storage in explaining the price crisis. Finally, Serra and Gil

(2012) showed how stock to disappearance forecast has a key role in corn price instability in line with the competitive storage theory by using a MGARCH model which is estimated both parametrically and semi-parametrically.

However, no consensus has yet be reached on the role played by low stocks level during the 2006-2008 price crisis. Several economists remain less than convinced about the empirical importance of stock depletion and the relationship between high price and low stocks level, both in the short and long term. For instance, Dawe (2009) concludes that the link between volatility and world rice stock levels was rather weak during the 2006-08 event. Roache (2010), who used data from the last one-hundred years, came to similar findings showing that long-term volatility in commodity prices is not influenced by commodity stock levels.

Thus, to explain commodity booms and busts, we need an understanding of what determines stock levels and, in particular, what may cause inventories to be depleted. In order to do this, next chapter will provide a deep description of the competitive storage model, which views inventories as the main determinant in commodity price behaviour.

2. THE STORAGE MODEL

2.1 Introduction

Large volatility in output and prices are key features of agricultural commodities markets. A clear understanding of storable commodity prices' dynamics and the relationship between prices and the fundamentals of supply and demand is yet to be reached. The recent periods of prices crises and extreme volatility has stressed the need to better understand the characteristics of price dynamic in order to construct good policy. The need to understand the complexity of commodity price dynamics has became even more urgent against the recent tendency to remove traditional governmental stabilization schemes. A plethora of potential methods of studying large fluctuations in output and prices for agricultural markets have been developed since the Great Depression of the 1930s. Obviously, volatility implications are strictly correlated to the assumptions assumed about consumption demand, supply curve, risk aversion and the nature of other fundamentals. The traditional and easier approach to market stabilization issue is often a simple and static supply-demand analysis. Storage implication and the effects of storage interventions in subsequent periods are typically ignored or, in the better case, broadly estimated in spite of the abundance of storage examples in nature. Nevertheless, many econometric models have stressed the role of commodities storage starting with Allen (1952) who defined an explicit demand curve for inventories as function of current price. In other empirical models, such as Lovell's (1961), firms adjust inventories slowly toward some optimal level. Bivin (1986) challenged this approach for not being obtained from any optimization behaviour. However, there is a theory about commodity price behaviour including storage effects that tends to dominate: the storage model. This model has a long history moving from the contribution of Gustafson (1958) who studied the properties of the optimal demand for commodity stocks, and with the work of Muth (1961), who introduced the assumption of rational expectation. During the last twenty years, the basic model has been implemented in several different directions. Samuelson (1971) and Scheinkman & Schechtman (1983) extended the model including the effects of economic incentives on supply function. Williams and Wright (1991) made a deep exploration of the model and its economic implications extending it in many important directions including the effects of speculative attacks and government interventions. Williams and

Wright (1991) highlighted the endogenous nature of the demand curve for inventories as function of current price. In essence in their model the collective level of inventories is an endogenous variable in contrast with MacAvoy (1988) approach, who considered inventories as a variable explaining price. In fact, high quantity stored occurs when prices are low and, on the other side, low quantity stored occurs when prices are high. However, according to Williams and Wright (1991) both variables, prices and inventories, respond endogenously to the exogenous shocks in supply or demand. Finally, Bobenrieth H. et al. (2010) implemented the model to present a rational explanation for episodes of high volatility in price series.

However, the empirical relevance of competitive storage model in explaining commodity price behaviour was delayed for decades by the absence of satisfactory time series of aggregate production and stocks for the most important staple commodities. Deaton and Laroque (1992) provided a first attempt of empirical estimation of the model. After that, the same authors furnished a larger number of empirical evidences (Deaton and Laroque, 1995, 1996, 2003) challenging the ability of the model to explain the observed price behaviour of major commodities. By contrast, Cafiero et al. (2011) presented a revised version of the model which can generate the same high level of serial correlation observed in commodity prices.

As well summarized by Stigler (2011:28), the storage model studies how speculators will engage in commodity transactions based on their expectations of futures price changes. Obviously, when the actual price is below the expected future price, speculators will store the commodities in order to sell it the next time and achieve a profit. On the other hand, when the current price is above the expected future price, speculators have no incentives to store the commodity (stock-out case) and the price simply follows the market' fundamentals. Clearly the storage model is better applied for commodities which are easily stored like staple commodities and whose production is unpredictable depending on weather conditions.

In the following paragraphs Williams and Wright's basic storage model will be used to assess the role of storage in a system where production is stochastic and both production and storage are performed by competitive profit-maximisers who form rational expectations about the returns to their activities. The model used in this piece of research considers in an explicit way how storage affects a commodity's price over time using a competitive partial equilibrium model for a single storable consumption commodity,

deriving the important interactions among production, price expectations and storage (Wright and Williams, 1982).
At the beginning, the model will be implemented considering only a single period of time, one crop year. Then, it will be expanded in order to include time and inter temporal connections of storage.

2.2 Outline of the basic model

In the following paragraphs the basic storage model presented by Williams and Wright (1991) will be illustrated. However, many economists have recently suggested more sophisticated models, that are extensions of the basic one, including learning about changes in the agricultural environment such as global weather changes or biological innovation. Focusing only on the basic model, in the next paragraphs, some assumptions will be introduced at the beginning and its outline will be defined.

2.2.1 The weather and yields

First of all, the basic model deals with an annual agricultural crop whose planting intensity can be adjusted but not for the lag of one period that is defined in one crop-year. The yield obtained depends mostly on the weather condition that should be seen as a shock to production unknown in advance of the harvest except for its density function. According to Williams and Wright (1991) the weather uncertainty in the model is exogenous and it does not arise from lack of knowledge about others will act. Also, no investments in weather forecasting will reduce this uncertainty. In essence, the weather in one crop year is independent of weather in previous crop years. In statistical terms, weather and yields are pure white noise. Storage across crop-years helps to reduces the potential fluctuation in yields.

2.2.2 The groups included

Secondly, the model considers only three distinct groups such as consumers, producers and storers. They are all price-taker and they are also risk neutral with respect to income. Producers, who must plant in advance of the harvest knowing only the cost of the input at

the planning time, and storers, who always try to arbitrage, have to form expectations about the prevailing price at the harvest. It should be keep in mind that these groups form rational expectations. The assumption of rational expectation is usually one of the most controversial in the economics literature and in this case it seems quite weird to consider farmers and storers familiar in lag operators or others sophisticated forecasting techniques. By the way, for the sake of the model, it will be enough to think that farmers and stores making objective calculations based on currently available information about the probability distribution of yields and about price response to the production shocks.
Also the assumptions concerning consumption demand and new production are simplified in order to keep the model as simpler as we can. In essence, consumers' demand curve and supply curve for planned production are considered stationary functions from crop-year to crop-year. It simply means that past levels of consumption or production does not affect the current level. In other words there are no trends. It is also assumed that consumers spend only a small share of their budget on agricultural commodities that is a common condition at least for developed countries. On the production side, it is also assumed that producers have a fixed quantity of land that should be used only for one commodity. Hence, the only way to increase production is through a more intensive use of production inputs beside land although these have diminishing marginal productivities. Moreover, only a small portion of these inputs, with respect to the world availability, are used for the crop since their prices do not change with movements in planned production. The last assumption about producers is that they experience the same weather condition and the aggregate behaviour is not affected by the behaviour of singular farmer.

2.2.3 The nature of storage

Third, the storage considered in the model is that which occurs between two subsequent crop-years. For most of non perishable food commodities such as grain, the unit cost of storage per period may be considered as independent of the size of stocks for all level of stocks. The model is based on an infinitely long sequence of discrete periods in which a random disturbance related to the weather affects the size of the harvest. Obviously, the new production from the harvest is physically identical to the stored one. For the sake of clarity, fixed costs of ordering, capacity constraints, or transportation in the different location network are not considered. Also transaction costs associated with adding or removing storage are considered irrelevant. Because of the assumption of the minimal fixed costs, firms in the storage industry can easily entry and exit from the market. Hence, it is reasonable to admit a large number of price-taker firms.

The fourth assumption is the so called no negative aggregate storage. It means that the aggregate storage should be equal to zero or positive in any particular period. The quantity stored cannot be negative. If current stocks are zero, it is impossible to borrow from the future.

2.2.4 The system

The last assumption is that the system we are considering is a closed model. It means that all the behavioural relationships are included. In this way, given a particular set of technical parameters such as supply and demand elasticity, marginal storage costs and the curvature of demand curve, the basic model has all the information to solve for the most important endogenous variables: price, current consumption, storage and planned production. In other words given a particular set of technical parameters, the basic storage model is able to evolve on its own in response to the realizations of the disturbances.

If all these assumptions hold, the economic problem is a double choose problem. The first choose is referred to the optimal total amount available from the carryin (from the previous year storage) plus the new production that should be allocated between the current consumption and the carryover for the following year. The second choose is related to the optimal level of planting for the following period's harvest. The weather affecting the current harvest represents the unforeseeable influence on price.

In essence the carryout and the planned production in an uncertainty atmosphere are the equilibrium quantities that the market clears each period in a sequence of equilibria. However, in a model with storage, the important connection from one period to the next have to be taken into account. In fact, the collective storage in a particular current period affects the possible equilibrium in the following periods.

2.3 The basic model

In the case of commodity storage, unlike other production, the transformation is only a matter of time. There are not physical change. Wright (2001:831) defines storage as "any activity that transforms a commodity available at a given point in time into a similar commodity available later". Because of the element of time, storage of a commodity is like an investiment with a minimal planning horizon of one period.

2.3.1 Storers' arbitrage relationships

Using Williams and Wright's (1991) notation the total physical cost of storing an amount S_t from period *t* to period *t+1* faced by the storage industry is the simple linear function of the quantity it stores:

$$K(S_t) = kS_t \text{ with k>0} \quad (1)$$

Where *k>0* denotes the constant marginal and average physical storage cost.

It should be clear that the number of firms in the storage industry, their level of vertical integration or any other characteristics is not the main issue of this model. The most important element to keep in mind is the collective storage S_t that represents the result of the aggregate storers'decision taken during the period *t* about the carryout provided to the period *t+1*.

The decision taken by the storers in order to define the amount S_t is just an entrepreneurial decision based on a simple criterion that Williams and Wright (1991:25) summarize as follow: "store until the expected gain on the last unit put into store just matches the current loss from buying it or not selling it now". As said before, storers are assumed to be risk neutral, hence, their net gain can be measured as discounted expected profits. Moreover, from the storage firm's point of view, storage decision is not considered as an irreversible decision that affects many period ahead. In other words, storage industry can act without look farther ahead than the next period.

Profits obtained by firm *i* from the quantity stored s_t^i from the period *t* to the period *t+1* are the difference between revenue obtained in period *t+1* and the spot market price paid for the quantity s_t^i in period *t*. Physical storage costs should be also considered as showed in the equation below:

$$E_t[\Pi_{t+1}^i] = \frac{E[P_{t+1}]s_t^i}{(1+r)} - P_t s_t^i - ks_t^i \quad (2)$$

That is the arbitrage equation for an individual price taker private storer where:

-*r* denotes the rate of interest that is assumed constant across periods;

- $k\, s_t^i$ is the physical storage cost;

- $E_t [P_{t+1}]$ is the expected price that could be realized in period $t+1$. $[P_{t+1}]$ is a random variable depending on weather condition that, in its turn, affects the harvest maturing in period $t+1$;

If the expected price for the period $t+1$ is assumed above P_t (the spot market price in period t) by more than physical storage cost and interest, an individual firm would take advantage in expanding storage by a huge amount. In an opposite situation, with the expected price lower than P_t, the same firm may consider convenient storing a negative amount. Neither of these situation is possible for the market as a whole because a market equilibrium will be reached. In fact, if the expected price for the next period is higher compared to the current spot price, it will be convenient for storers to increase their stocks. On the other hand, this increased storers demand will raise the current spot price up to a no more convenient point. Similar conclusion will be reached if the expected price is below the current spot price. In this case, because the low expected price, storers sell as much as they can until aggregate stocks are zero. For assumption it was said that stocks cannot be negative.

Considering storage industry as a whole, the relationships between the quantity stored collectively and the expected net profit from it can be written as follow:

$$P_t + k - E_t[P_{t+1}] / (1+r) = 0, S_t > 0$$

$$P_t + k - E_t[P_{t+1}] / (1+r) \geq 0, S_t = 0 \qquad (3)$$

The system expressed by equation (3) is the central condition for a competitive equilibrium with storage.

So far, the focus has been on the profit maximization behaviour of competitive storers with respect to the relationships between expected price and current spot price of the quantity stored. Next paragraphs will be focused on how price, storage and consumption are determined in the market.

2.3.2 Market level price and quantities

Consumption, as usual, is related to price. Using an inverse consumption demand curve, without considering the income of consumers, the relation between price and consumption can be written as below:

$$P_t = P(q_t) \tag{4}$$

With $\frac{dP}{dq} < 0$.

The model assumes an instantaneous relationship between consumption and price. It means that when the consumers choose a level of consumption, at the same time, the price is perfectly defined. There are no issues of expectation formation for consumers. Moreover it is assumed that the short run demand curve is the same compared to the long run demand curve.

The quantity of goods consumed collectively by all the consumers in the current period t is the difference between the marketwide availability and the quantity stored in that current period.

$$q_t = A_t - S_t \tag{5}$$

where:

-A_t denotes the amount on hand in period t due to the aggregate realized production plus the quantity stored in the previous period t -1. It can be written that:

$$A_t = h_t + S_{t-1}$$

Where:

-h_t represents the production derived from the harvest. Production in each period is subject to a random disturbance.

It should be clear that with a stable supply or demand in different period of time, there would never be any storage in the model since storage has a positive net marginal cost. The presence of storage is due to the weather variation v_t in yields that is a random disturbance with a mean of zero. In essence, the harvest realised in period t is affected by the weather variation as showed below:

$$h_t = \hbar_t(1 + v_t) \tag{6}$$

where:

- $1+ v_t$ is the random production disturbance with a probability density function of finite variance.

-$\hbar_t$ denotes the collective production planned in the period *t-1* for the period *t*.

So far the consumers demand and the stores behaviour have been analysed. In order to provide all the elements of the model the supply side should be also defined.

For the demand side the instantaneous response of consumption to the price has been assumed. On the supply side this assumption would clearly be unrealistic for agricultural commodities. All agricultural production involves the choose of inputs by planting time usually months before harvest when the output price is known. In the supply case, issues of expectations formation are of major concern to production, that, like private storage, is assumed to be a competitive, expected profit maximising activity. The basic model assumes, for the sake of simplicity, a one period lag in production response. In essence, the one period lag between plantation and harvest means that producers' expectations have relevance for supply. Moreover, producers, like storers, are price-taking competitors for assumption. It means that they do not consider the effect of their own individual actions on prices but, as clearly explained by Williams and Wright (1991:33), "their price expectations are consistent with the distribution of prices that will be generated by their collective behaviour, given those expectations".

As it have been already done for storers, the expected producer's profit from planned production $\hbar^i_t$ can be written as follow:

$$E_{t-1}[\Pi^i_t] = E_{t-1}[h^i_t P_t] - H^i[\hbar^i_t] \tag{7}$$

Where:

-H^i denotes the total cost for the producer *i* to production of $\hbar^i_t$ chosen in the period *t-1*;

-$h^i_t P_t$ is the resulting revenue that will be obtained after the harvest and that nobody knows at the planting time t-*1*. The producer, although a price-taker, recognizes that the yield disturbance due to the weather condition has the same proportional effect on h^i_t as on realized aggregate output h_t.

The first order condition for competitive profit maximisation (7) is:

$$\partial E_{t-1}[h^i_t P_t] / \partial \hbar^i_t = \partial H^i[\hbar^i_t] / \partial \hbar^i_t \tag{8}$$

The left hand side of (8) represents the expected increase in revenue from an increase in planned output. In other words we can write it as follow:

$$P^r_t = \partial E_{t-1}[h^i_t P_t] / \partial \hbar^i_t$$

Where P_t^r is called *producers' incentive price* for production planned in period *t-1* to be realized in period *t*.

2.4 The competitive profit-maximising storage rule

The equations for consumption and the planned harvest complete the models and provide all the tools to deduce the level of current storage S_t and, in its turn, current price P_t.
In fact, private storers receive a price that depends on the size of the harvest, which in turns depends on the amount planted. The amount stored affects what producers expect to receive, so that the amount planted is a function of current storage. Furthermore, the price of what is put into store depends on current storage, because what is not stored is consumed.
Using these arguments the equations system (3) based only on actual and expected prices can be expanded in the same conditions for intertemporal arbitrage including not only prices but also the quantity actually consumed (***A*** $_t$ **-** ***S*** $_t$) and the future available amount (***h*** $_{t+1}$**+*****S*** $_t$ **-** ***S*** $_{t+1}$).

$$P[A_t - S_t] + k = E_t[P[h_{t+1} + S_t - S_{t+1}]] / (1+r), S_t > 0$$

$$(10)$$

$$P[A_t - S_t] + k > E_t[P[h_{t+1} + S_t - S_{t+1}]] / (1+r), S_t = 0$$

Where both h_{t+1} and S_{t+1} are random variables depending on the weather variation v_{t+1}.
If we know S_{t+1} , conditional on A_{t+1}, in a setting with an infinite horizon of periods the relationship between A_t and S_t can be calculated from the system (10).
The competitive arbitrage conditions implicitly determine the amount of current storage as a function of the amount available.
In an example with two periods, *t* and *t+1*, S_{t+1} can be fixed form outside the model. Image that the world ends in period *t*. In this case, Williams and Wright (1991:29) fix S_{t+1} to be zero regardless h_{t+1} since "any carryout from the last period could be said to have no value". In other words, it is quite obvious image that commodity has only a consumption value in period *t* since the carryout stock is zero. Under this special circumstances with S_{t+1} fixed in advance, it is possible to solve for S_t directly from equations (10).
Williams and Wright (1991:29) provide a useful example that "illustrates the nature of an equilibrium under rational expectations." More in details, the authors consider a specific inverse consumption demand curve for both periods: $P[q]=\beta/q^5$ with the constant β

calibrated to have the curve pass through the point 100 units, 100$. The demand curve has a constant elasticity of -0.2. The harvest for the next period (h_{t+1}) has a three point distribution of 80, 100 and 120 units, each one with the same probability. Moreover marginal physical storage costs are k=\$3/unit with r=2%. The current availability A_t is set 110 units without any particular reasons. Given that particular A_t the equilibrium storage S_t* can be found by trial and error using the equations of the model. For the first attempt let try with S_t*=5 units that is half of the surplus of A_t over h_{t+1}. If S_t*=5, A_{t+1}, which is also the consumption q_{t+1}, is respectively 85, 105 or 125 (h_{t+1} + S_t*) with the corresponding prices of \$225.38, \$78.35, or \$32.77. In this way we know that the expected price, E[P_{t+1}| S_t=5] is \$112.17 from 1/3(225.38+78.35+32.77). With the expected price equals to \$112.17, storers would bid up the current price until it equalled ((112.17/1.02)-3.00) which is \$106.97. However, the amount of storage consistent with P_t equal to \$106.97 is 11.34[2] in contrast with the presumed value of S_t=5. The equilibrium storage should be consistent with itself and because 11.34 units is much bigger than 5 units it is not the right equilibrium value. The right value of S_t* is 8.01. This value is the equilibrium for the fixed availability of 110 units. With S_t=8.01, P_t is \$90.62 and E[P_{t+1}] is \$95.50 which is above P_t= \$90.62 by exactly the marginal physical costs of storage plus interest. The value of \$95.50 is also the average price in period t+1 since the arbitrage relationship is true for each storer individually and collectively. If S_t is equal to 8.01, A_{t+1}, which is also the consumption q_{t+1}, have a one-third chance of being respectively 88.01, 108.01 or 128.01 units.

However, generally speaking in an example involving more than two periods, the solution is not so easy because the complication of knowing S_{t+1} conditional on A_{t+1}. The problem is that knowing S_{t+1} depended on A_{t+1} is not easy because it already represents the solution to the relationship between storage and availability in this stationary model. In other words, in order to solve the system knowing collective storage behaviour to deduce collective storage behaviour cannot be a solution.

By the way, the relationship between A_t and S_t in a two periods example is the same if we consider a more than two period example. There is a unique relationship between S_t and A_t regardless the horizon of time. The relationship does not change from period to period, since the nature of the problem does not change, but it depends upon the particular

[2] $106.97 = \beta/(110-11.34)^5$ since $P_t = \beta/q^5$ with $q_t = A_t - S_t$;

specifications of supply and consumption demand as well as on the cost of storage and the interest rate. However, all these additional exogenous parameters are predetermined and do not change from period to period but only the current availability A_t changes in function of the harvest.

This stationary relationship between storage and availability is represented by the so called *storage rule* or the *reduced form equation:*

$$S_t = f^s[A_t] \quad (11)$$

This relationship between S_t and A_t tells us how much is stored collectively for any given circumstance, summarized in the current availability A_t.

The relationship between the equilibrium storage and current availability (11) should be deduced through numerical methods. Several numerical approaches for solving the storage model have been available since Gustafson (1958) all based on recursive logic dynamic programming. These numerical methods have become cheaper and easier to implement as advanced computers in speed and power have been available. The numerical approach developed by Williams and Wright (1991:81) is based on the principle of polynomial approximations considered more flexible and faster compared to the other numerical methods. In essence, this technique approximates the stationary relation between expected price and carryout stocks with an *n*th order polynomial in storage, $\psi(S_t)$, "such that if ψ represents the next period's price expected by storers $E_t[P_{t+1}]$ they should store S_t, ψ is consistent with itself". In essence, the function $E_t[P_{t+1}|S_t]$ is used to deduce the equilibrium storage in period *t* and hence P_t. A deep explanation and a useful example of the polynomial approximations technique is given in the appendix.

Storage rule depends on the particular specifications of supply and consumption demand as well as storage cost and interest rate.

Firstly, the intersection point between demand and supply curves is an important reference in order to determine q^N and p^N at the nonstochastic equilibrium. Under certainty q^N equals h^N since there is no storage at all. Considering a primary food grain such as wheat, the consumption demand curve should be price inelastic, at least in a developed country, and stable from period to period. When demand elasticity is higher, it means that the current consumption changes considerable with respect to the price. In this case, adjustments in current consumption absorb more of the harvest disturbances so that the role played by storage is much less important.

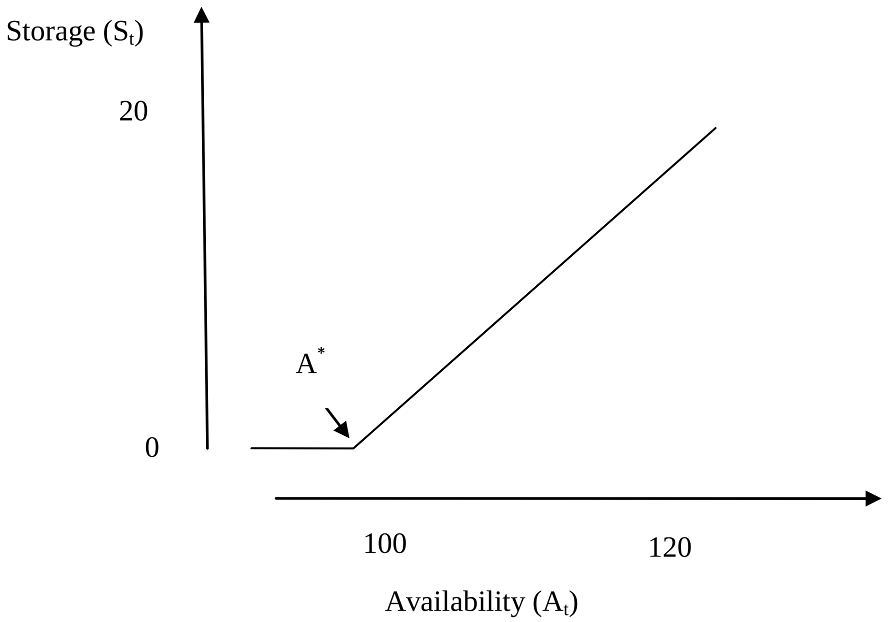
Specifically, according to the base case used by Williams and Wright (1991:37) representing a primary food grain in the United States, let the demand curve be linear with an elasticity at the nonstochastic equilibrium $\eta^d = -0{,}2$[3]. Let the planned production be a linear function of the producers' incentive price P^r_t with an elasticity $\eta^s = 0{,}5$ at the nonstochastic equilibrium[4]. It should be clear that the range of movement of h_t is small if compared to the range of h_t. Moreover, let the yield disturbance v_t be normally distributed with a mean of 0,0 and a standard deviation of 0,10 in term of proportion of planned production. The yield disturbance in each period is independent of those in other period. Finally, to provide all the parameters for this specific example, let the marginal physical storage cost k be set at 2$ per period and the interest rate r at 5 percent. These set of parameters do not change with time. The horizon time is infinite.

After defining the set of parameters, Williams and Wright (1991), using the method of successive approximations, derive simultaneous equilibria in storage and planned production for any given level of availability as shown in figure 1 and figure 2 respectively.

[3] The precise form of inverse consumption demand curve is: $P[q_t]=600-5q_t$.

[4] The specific supply function is $h_t = 50+0{,}5\ P^r_t$.

Figure 2.1: Equilibrium storage as function of current availability



Source: Williams and Wright (1991:38)

In essence, in figure 1, for any value of current availability $A_{t,}$ which includes the current harvest h_t and the carring S_{t-1}, thanks to the *storage rule* (11) it is possible to obtain the corresponding equilibrium carryout S_t. Because the kink point A^*, the storage rule in figure 1 has an evident nonlinearity behaviour. Obviously, the specific current availability corresponding to an exact positive storage depends on the specific parameters, but all the storage rules has a kink point of discontinuity. In our example, according to the set of parameters chosen, the kink point A^* is 99.62 units according to Williams and Wright (1991).

Another important characteristic of the storage rule plotted in figure 1 is the smooth relationship between availability and storage over the kink point A^*. The slope of this relationship represents the marginal propensity to store for each current availability. The storage rule is a line below the 45° over the kink point. It means that equilibrium storage is not a perfect linear function of current availability or, in other words, as higher is the availability as lower is the increased quantity stored.

2.5 The effects of storage on planned production

In a setting with storage, in any period producers and storers allocate collectively the current availability A_t between the aggregate consumption q_t and the current storage S_t. At the same time the amount being planted for harvesting in period $t+1$ ($\hbar_{t+1}$) is setting. Fixed point solution must be found together for S_t and $\hbar_{t+1}$.

In the previous paragraph we have already seen the *storage rule* that tells us how much is stored collectively for any given circumstances as function of the current availability A_t.

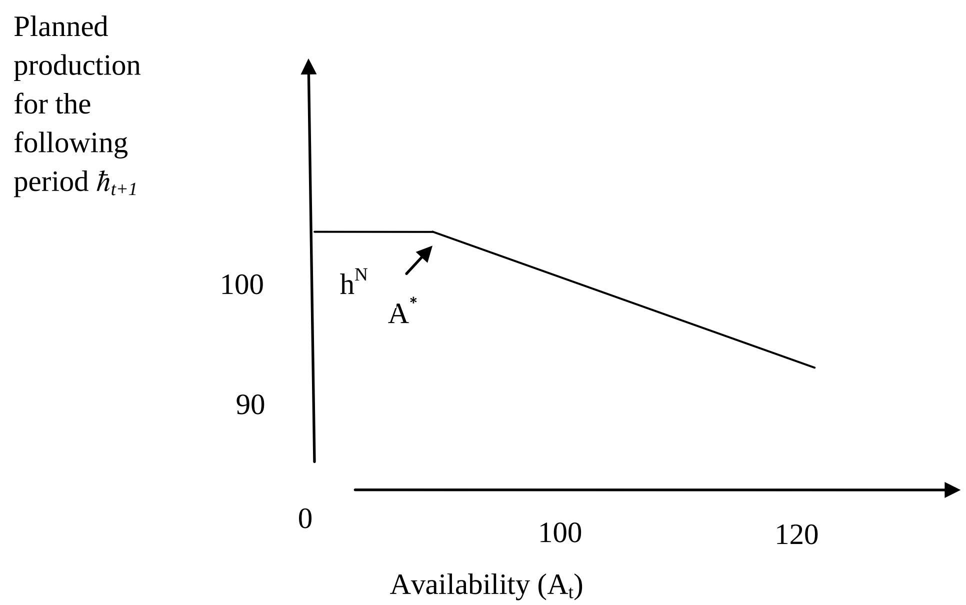
On the supply side there is an associated *planned production rule* which is the reduced form equation giving a unique amount planted to be harvested the next period for each value of current availability:

$$\hbar_{t+1} = f^{\hbar}[A_t] \qquad (12)$$

It should be clear that $\hbar_{t+1}$ is in equilibrium with S_t, because S_t refers to the carryout from the period t and the carryin for the period $t+1$. Both $\hbar_{t+1}$ and S_t are committed in period t. In essence, the reduced form equation for storage (11) and for planned production (12) are simultaneously determined. Note that f^s and $f^{\hbar}$ are different function, of course.

Figure 2 plots the equilibrium planned production as a function of the current availability (12) deduced through numerical methods for the same group of parameters used for the figure 1.

Figure 2.2: Equilibrium planned production as a function of current availability



Source: Williams and Wright (1991:38)

Like figure 1, the rule for planned production as a function of current availability has a discontinuity at the same point A^*. According to the figure 2, planned production $\hbar_{t+1}$ is at least 103.34 units for any availability below the kink point A^*. This is the maximum planned production which represents the level of planned production whenever storage is zero. Moreover, when the availability is below A^* the next period's market is disconnected from the current period's market because the carryout is zero. On the other side, when current availability is such that the equilibrium storage is positive (any value over A^**)*, the value of the exact availability affects the planned production. Generally speaking, the higher is the carryout's level, the lower will be the price. For these reason, as shown in figure 2, to the right of A^*, the marginal propensity to plan is negative, it means that the slope is downward. Although storage is generally considered as a tool for market stabilising mechanism, it clearly destabilizes planned production. In other words, rather than a means of stabilizing production, competitive storage should be thought as a substitute for production. In fact, when le level of current availability is higher and the price of the commodity is low it should be more convenient, under the economic point of view, to deliver supplies next period by increasing storage and reducing production. On the other hand, if current availability is expensive, production is relatively more attractive. However, the combined action of storage and planned production makes consumption more stable.

In both figure 1 and 2, the kick point A^* does not denote an equilibrium value but marks an important transition in the shapes of the reduced-form equations. In particular, below the value of A^*, the equilibrium storage is zero regardless of A_t, since a negative amount cannot be stored. Moreover, all values for S_t and $\hbar_t+1$ represent equilibrium values for the corresponding A_t's.

From the two reduced-form equations plotted in the figures, which denote storage and equilibrium planned production respectively, can be derived the related reduced-form equations for the other endogenous variables as function of A_t.

2.6 The effects of storage on market demand

Under profit-maximising storage, current price can be expressed as a function of the amount in store. Using the inverse consumption demand (4), the identity (5) and the storage rule (11) it is possible to obtain the inverse demand function for storage. Using Wright and Williams notation (1982):

$$P_t = P[f^{-1}(S_t) - S_t] = \Phi(S_t) \qquad (14)$$

Where:

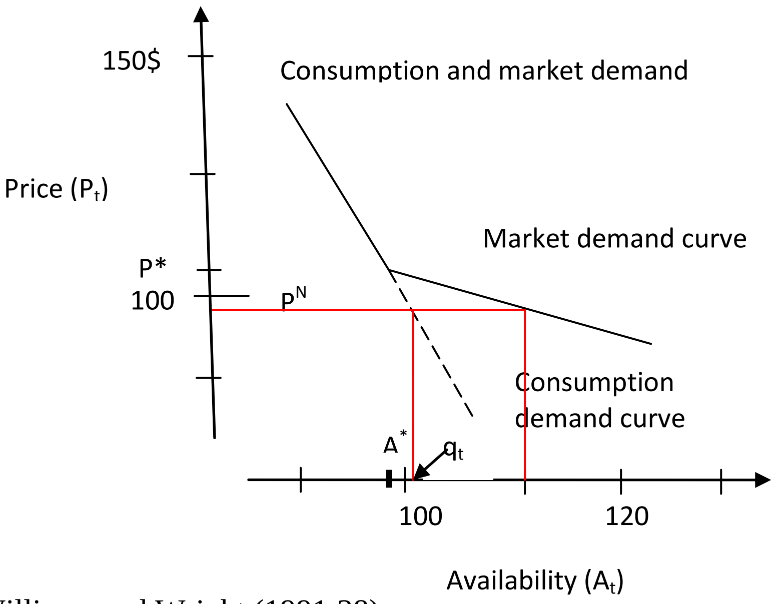
-$\Phi(S_t)$ denotes the current price corresponding to each quantity in store.

Williams and Wright (1991:39) define $\Phi(S_t)$ as “the inverse derived demand for the input of the commodity into the storage production”. The problem in this approach is that the demand curve for inventories as function of current price is not a true structural equation such as the supply and consumption demand curves because its endogenous nature.

When the current price exceeds P*, expected future price net of all storage costs is less than current price, so that there is no profit in storage.

The figure below puts together the storage demand function to the consumption demand curve, which is also a function of the current price, obtaining the market demand function.

Figure 2.3: Market demand with storage



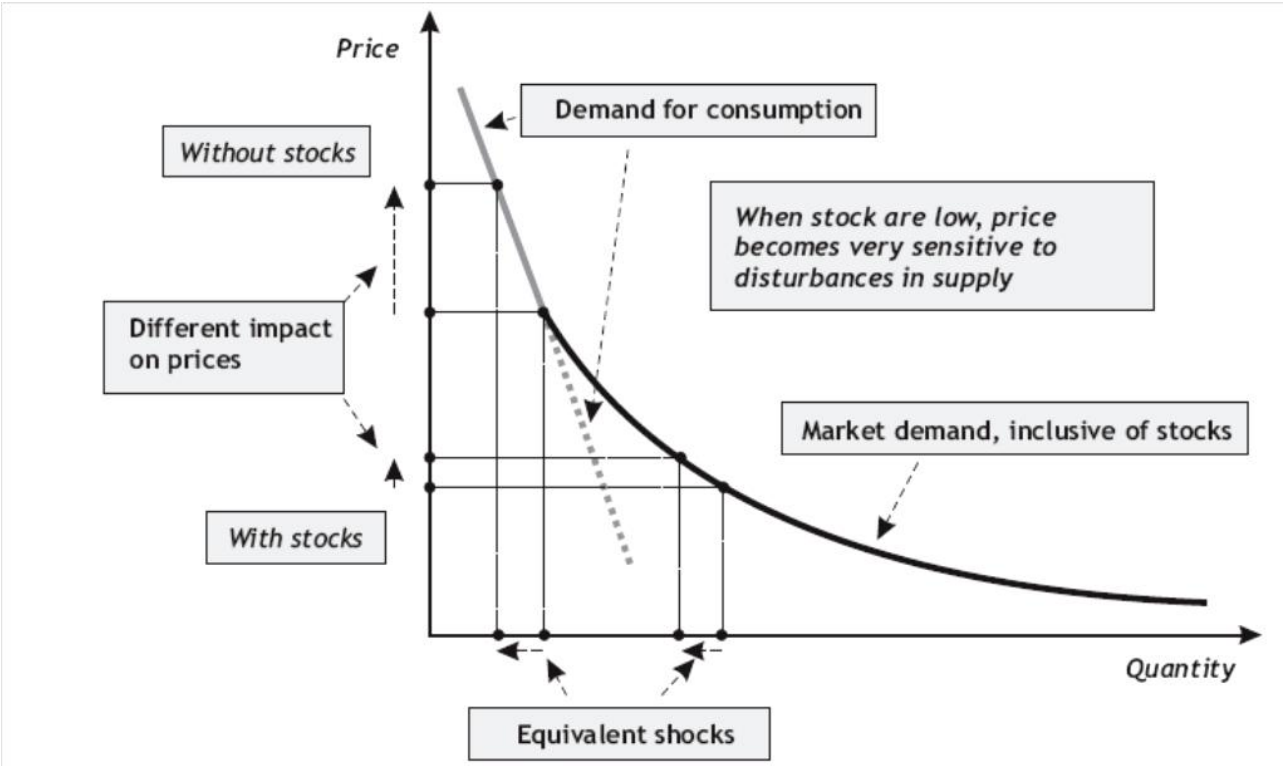
Source: Williams and Wright (1991:38)

At the price P* the elasticity of market demand increases. This increasing in consumption demand below P* by the storage demand function shows that the demand curve with storage is highly non linear, being much less elastic at high prices. It means that a small change in availability deeply affects the price. On the contrary, to the right of A*, small change in availability does not change price considerably.

In figure 3, moreover, for any given availability is possible to determine the corresponding spot price but also the breakdown of availability between consumption and storage. For example, let be A_t = 110. The corresponding P_t is \$93.12 along the market demand curve. On the other side, along the horizontal line at that price, according to the consumption demand curve, q_t = 101.38 units, which implies that, in the same period, S_t = 8.62 units (110-101,38).

The same figure 3 has been used by Carter et al. (2011) stressing and explaining in a better way the storage's role in buffering price spike. In figure n. 4, in any given period, total demand for the commodity equals the horizontal sum of the inventory demand curve and the demand for current use as we have already said. When speculative inventories are positive, the level of stock is high, total demand is relatively elastic since the market can respond to adverse shocks by reducing inventories and improving the supply. On the opposite side, when the level of stocks is low or even zero, total demand is relatively inelastic because there is little capacity to buffer the gap between demand and supply with the storage and also a small negative supply shock can determine a large price spike.

Figure 2.4: The Market demand function



Source: Carter et al. (2011)

2.7 Sequential equilibria in the system

So far, only a single equilibrium example has been considered. How the equations interact through the time is not so easy as the single equilibrium example.

Next paragraphs illustrate, through numerical results, the interactions in the system considering a time of eleven periods. It should be kept in mind that, for each period, the weather is drawn from a random number generator. The weather sequence is plotted in figure 4(a). In our example, given by Williams and Wright (1991: 41), over these eleven periods the weather is quite bad most of the time reducing the realized production compared to the planned production as it will be seen later. However, the system is not affected by the number of time periods included. It means that, provided the situation in the first period (A_0), the sequence of weather condition, the set of parameters seen above, the series of planned production, price and storage are time invariant. In other words they would have been evolved in the same way starting in period 1162 or period 173.

For the sake of simplicity the first period of the sequence is called period 0.

Figure 4(b) illustrates the availability during the sequence of period starting from period 0. At the beginning the current availability is A_0 = 97.73 units because the weather was poor and the carrying small. This value of A_0 is below the kink point A^*= 99,62 units, below which the equilibrium storage is zero as it has been seen in figure 1. For this reason the equilibrium S_0, shown in figure 4(c) is zero. It means that all the current availability A_0 is consumed. At the same time, the equilibrium planned production $\hbar_1$, plotted in figure 4(e), is 103.35 units. This value of $\hbar_1$ can be derived from the relationship between equilibrium planned production and current availability illustrated in figure 2. Finally, figure 4(d) shows the equilibrium spot price in period 0, P_0 = \$111.35.

In period 1 the weather turns out to be a little better than in period 0 but still under average as it can be seen in figure 4(a). The realized harvest h_1, because the weather condition, is 101.44 units, quite different from the expected harvest $\hbar_1$ of 103.35 units. Since in period 0 there S_0 = 0, it means that there is no carrying from period 0 to period 1, the A_1 equals the realized harvest h_1 = 101.44. From the reduced form equations for storage and planned production through the current availability A_1 the new equilibrium can be defined. In fact, the equilibrium carryout S_1 is 1.45 units according to the figure 1, while according to figure 2 the equilibrium planned production $\hbar_2$ for the period 2 is 102.59 units. The difference between A_1 and S_1 shows the current consumption q_1 = 99.99 units. If the full availability A_1 = 101.44 were consumed, P_1 would be \$92.80 but, since only 99.99 units are consumed during period 1, P_1 = \$100.05. In this way it seems that storage supports the price or, in a different perspective, because of storage, price alone does not absorb the exogenous shocks due to the weather condition. The availability in period 2 is close to the availability in period 1. However, in period 2 some carrying from the previous period (S_1 =1.44 units) should be added to the realized production. The quantity stored in period 2, S_2, is 1.81 units that is the carryout for the period 3. Unfortunately for the storers in period 3 the weather turn out in a better way. For this reason, the price at which the storers sell their carryin in period 3 (\$95.59) is below the price (\$99.66) at which they would have sold in period 2. This lost of value does not indicate irrationality or a market failure. Storers cannot forecast the exact weather in advance. Thus, the decision in period 2 was rational although not convenient under the strictly economic point of view.

Period 4 is a good point to talk about because it represents the biggest positive yield disturbance in the eleven period sequence. Because this extraordinary good weather in period 4, A_4 is 118.80 units as result. The reduced form equation indicates storage of 16.24 units corresponding for this availability. If our crop were not storable, it would been consumed in period 4. The possibility to store spreads the disturbance over several periods so that consumption in each of those later periods is slightly higher than otherwise. In fact, both q_5 and q_6 (calculated form P_5 and P_6) are above 100 units.

A reduction in planned production is another way to absorb the shock caused by the exceptionally good weather in period 4. In fact, the equilibrium planned production is now 96.32 units that is lower than the same value calculated during all the previous periods.

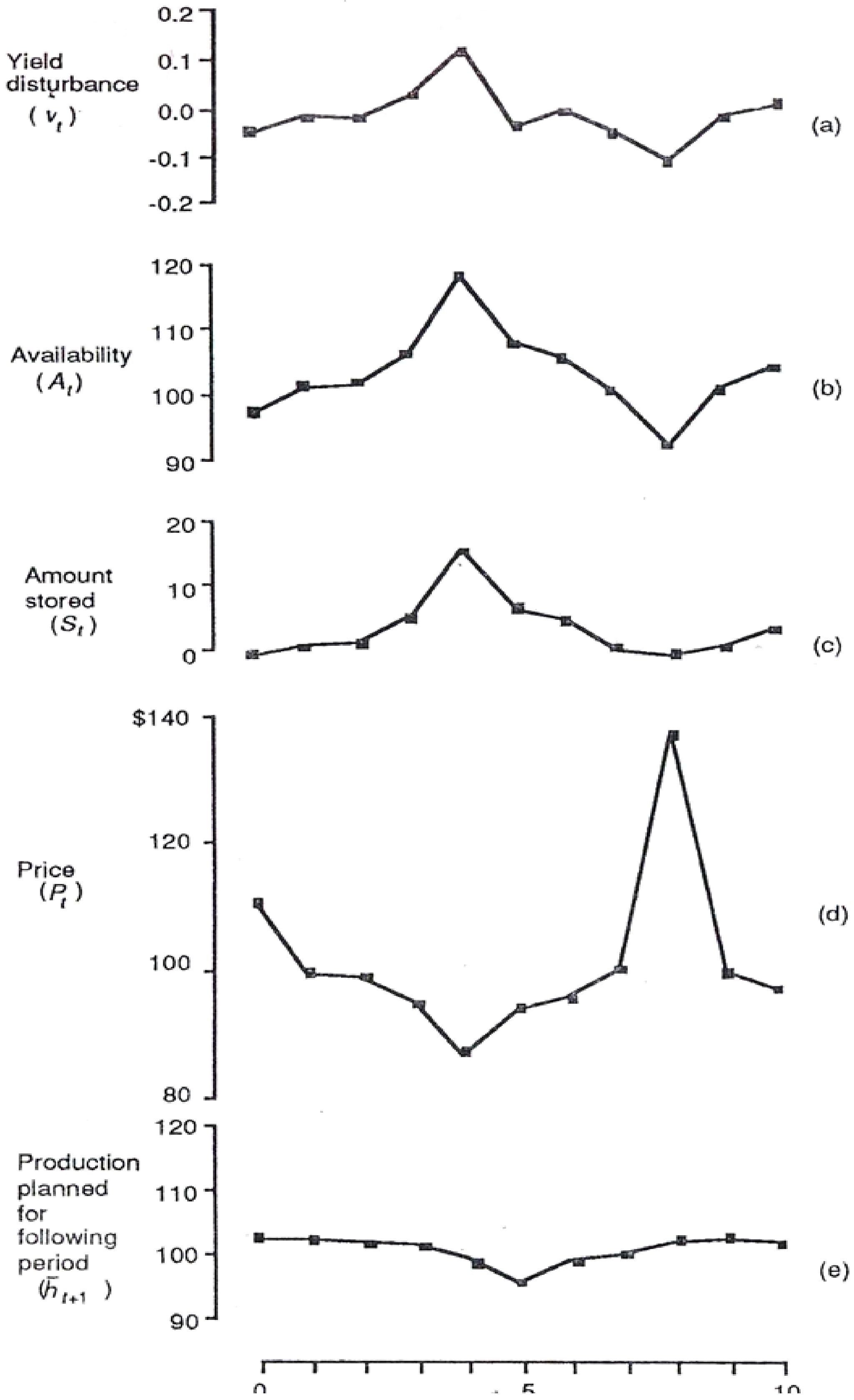
In period 4 it is clear how storage and planned production together absorb much of the shock caused by the weather variance though moving in opposite direction.

Period 4 shows us how high storage occurs when prices are low and, on the opposite side, low inventories occur when prices are high. It follows that expected price is decreasing in stocks for positive levels of stocks but both these variables are endogenous variable that are affected by the exogenous shock in supply and in demand. However, on the supply side, the variability in the harvest is endogenous. Although the proportional deviation in yields is exogenous, the planned production is a decision variable within the system.

Period 8 is an example of a very poor weather. The current availability in period 8 (A_8) is quite poor because the realized production is lower than the expected production but also because the stored quantity from period 7 is not enough to cover the low realized production. Again, the bad harvest could not have been forecast. Since, storage is costly, it makes no sense to store for the rare poor harvest. In period 8 it is clear how the current availability is just a function of past decisions, specifically storage and planned production making the availability a predetermined variable rather than a true exogenous variable. However, when the harvest is poor and the carryout zero, the link between current availability and previous decision about planned production and storage is essentially broken. The current availability during period 9 is not a function of the carryin. In this way period 8 is just like the starting period 0. In both period 0 and period

8 current decisions are solely functions of current availability A_0 and A_8. A new accumulation of a stockpile will be done in periods 9 and 10.

Figure 2.5: Sequential equilibria in a system with storage.



Source: Williams and Wright (1991:38)

If the number of periods is 1000 instead of 100, these patterns will be almost the same and even more evident. In essence, as the number of periods increase, the frequency distributions of the endogenous variables converge to stable distributions. These stable frequency distribution are probability distributions. The joint probability distribution for the various endogenous variables is distinct for each set of parameters.

To summarize, the sequential competitive equilibria can be described thought three key behavioural conditions.

Firstly, in each period farmers plant up to the point at which the marginal expected net revenue from their next harvest equals their marginal planting costs.

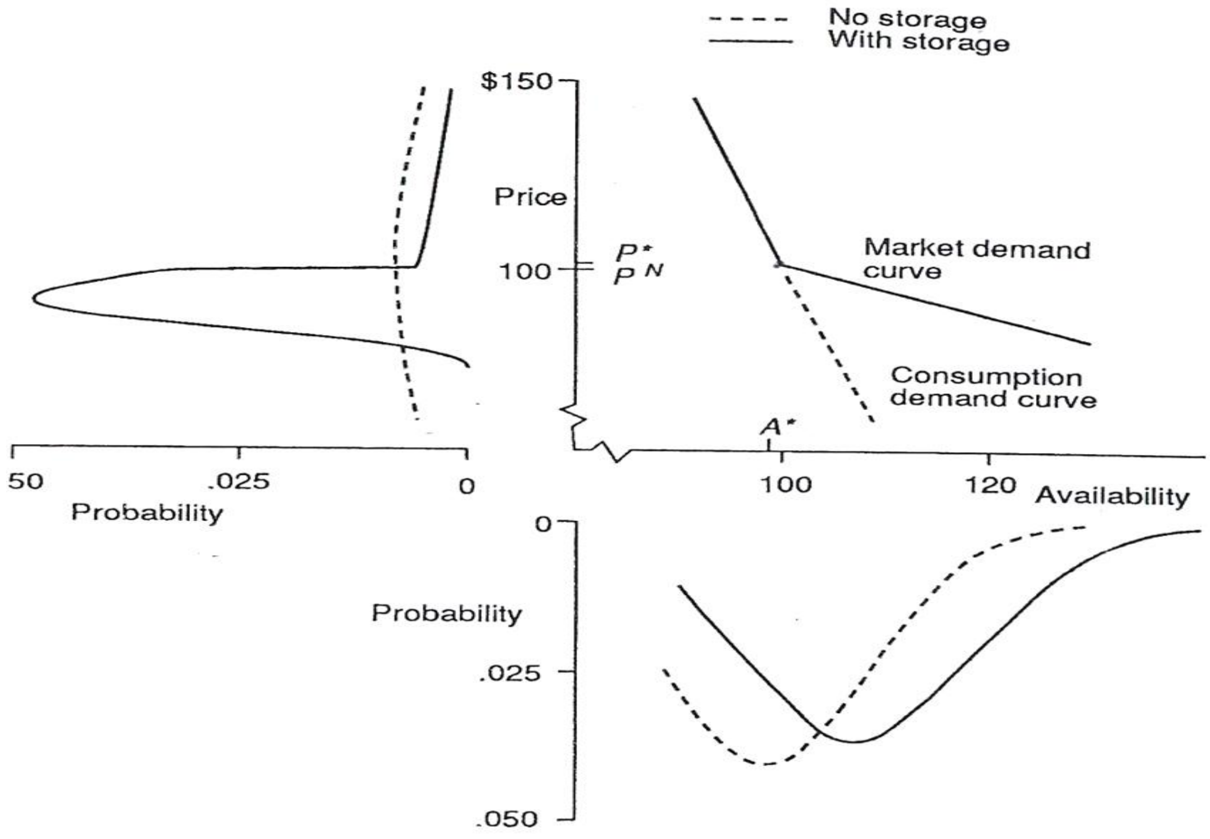
Secondly, in each period storers fix the quantity stored equal to the point where the difference between the current price and the rational expected price for the next period covers interest rate and storage costs.

Finally, as we have already said, the assumption that storage cannot be negative must hold in any period.

The specific probability distributions for the endogenous variables reflect the properties of storage over an infinite number of periods. It means that the realized price in period $t+250$ will depend on the weather and the reaction by storage and planned production over all those 250 periods. The probability distribution for P_{t+250} is well defined since the system is not explosive and any influence of particular circumstances in previous period have been disappeared. Thus, the probability distribution for P_{t+250} is the distribution derived from an infinitely long time series.

Obviously, to generate an infinitely long time series is an hard task. However, Williams and Wright (1991) simulated a probability distribution for 250.000 periods. The value, period by period, for variables such as price were recorded. Figure 5 shows the invariant long-run distribution for price and availability along with the market demand curve.

Figure 2.6: Probability distribution of availability and price.



Source: Williams and Wright (1991:38)

In the fourth quadrant is represented the probability distribution of the amount available due to the sum of carryin and new virgin production. Thought the market demand curve in the first quadrant, derives the probability distribution for price that is shown in the second quadrant.

Figure 5 shows also the probability distributions of price and availability without storage as dotted curves. The differences between the distributions with and without storage is particular useful to better understand the role of storage in commodity markets.

Firstly, as regards the means, for this set of parameters, mean price with storage is higher than mean price without storage. More in details, as well described by Wright and Williams (1982:603), "storage causes a large asymmetry and possibly counter-intuitive change in the distribution of price. Although the production disturbance is symmetric, the

distribution of price is not, because of the non-linearity of the constant elasticity demand curve." Thus, the effects of storage on the price distribution are asymmetric in a fashion that storage is much more dependable in precluding commodity gluts and low price instead that commodity shortage and high prices.
Secondly, the variance in a system with storage is lower than a system without storage. It means that storage stabilizes the price reducing the frequency of both very high prices and very low price. Finally, as can been in figure n. 5, storage makes the distribution highly skewed with the long tail toward high prices.

2.8 Challenging the basic storage model

According to Stigler (2011:30), one the most important characteristics of price series is its persistence defined as "its degree of autocorrelation" that shows "how past changes will influence the course of future changes." Typically, in price series with high persistence, past shocks continue to persist influencing the commodity's future price trajectory. In other words, in the case of low autocorrelation coefficients, shocks effects dissipate rapidly. By contrast, for series with high persistence, with a coefficient of autocorrelation neat to 1, the same shocks have a deeper effect and require many more periods to return to its normal trajectory. In the case of autocorrelation coefficient of 1, the same shocks have a permanent effect and the series show an infinite memory.
In this last case the series is said to be non-stationary or containing an unit root which means that its mean and variance will change over time. Alternatively, a time series with an autocorrelation less than 1 is said to be stationary having a fixed mean and variance. The concept of stationary in time series is well described in a formal way by Stock and Watson (2003:447).
In essence, the degree of persistence impacts not only the variability but also the predictability. As explained by Stigler (2011:30) "series with a coefficient lower than 1 exhibit stable forecast intervals, while series with a coefficient of 1 show forecast intervals that expand over time. This means that they are impossible to predict." Moreover, "the question of a series' persistence is also relevant for modelling strategy, as non-stationary variables require non-standard statistical techniques".

The basic storage model in presence of an independent and identically distributed (i.i.d) supply and deterministic demand function, induces high price autocorrelation but still stationary. The model, also shows a skewed distribution of commodity prices even under symmetric supply and demand shocks. Moreover, time series of prices will show isolated spikes "a feature determined by the possibility of occurrence of stockouts that are periods in which stocks fall to zero. Storage, in fact, introduces a key nonlinearity in the market demand, implying two different regimes of price volatility, one in which abundant reserves can buffer the effects of negative shocks in supply, and another in which, at high prices, the low levels of stocks leave the market particularly vulnerable to shocks in supply or demand" (Cafiero et al. 2011b:302).

A clear consensus about the empirical validity of the standard storage model is still under debate,

Empirical tests of the storage model began with Deaton and Laroque (1992). In their influential article they investigate how the storage model is compatible with the relative high, but still stationary, auto-correlation found in annual price for a large number of commodities. They were quite sure about the stationary hypothesis concluding that random walk (non-stationary) in price series "seems very implausible, at least for commodities where the weather plays a major role in price fluctuations." (Deaton and Laroque, 1992:31). In order to achieve these results, the authors used a so called Generalized Method of Moments (GMM) estimator showing that the prices dynamic analyzed are consistent with a two regime autoregressive process in which price at the time *t* is correlated to the previous one only if the latter is below a given threshold due to the storage. This result was encouraging but was not a definite evidence in support of the validity of storage model given that other model of price behaviour could generate the two-regime auto-regression. As well observed by Cafiero et al. (2011b), Deaton and Laroque (1992) used a limited range of parameters values for the fundamental parameters of the model opening the question of whether there are other values for the fundamental parameters of the model that could generate high levels of serial correlation like those observed in the series of actual prices, A few years later, Deaton and Laroque (1995, 1996) challenged the storage model introducing the Pseudo Maximum Likelihood (PML) empirical estimation approach in order to estimate the parameters of the underlining demand and storage cost relation. In this case, they could not confirm the positive results obtained in 1992 with the GMM estimation, and found that, in order to replicate the observed levels of autocorrelation in their model, it was necessary to relax the assumption of i.i.d harvest. This conclusion is well summarized in Deaton and Laroque (2003:2): “The speculative model, although capable of introducing some autocorrelation into an otherwise i.i.d. process, appears to be incapable of generating the high degree of serial correlation of most commodity prices.” In particular, in Deaton and Laroque (1992) the price autocorrelation was far below the sample autocorrelation observed. Moreover, the specification of their model did not generate sufficient price variation in comparison to the values observed for most of commodities analysed.

However, according to Cafiero et al. (2011b), the negative results of the PML estimation should be attributed to the particular specification adopted by Deaton and Laroque (1992) model instead of the validity of the speculative storage model as a whole.

Cafiero et al. (2011a) found that after a small modification of Deaton and Laroque’s approach, the storage model was indeed able to replicate high-correlations re-establishing the empirical relevance of the standard storage model. In fact, the consumption demand function specified by Deaton and Laroque (1992) with price elasticity within the range -0.5 to 0.1, is more sensitive to price than are consumption demands in the major commodity markets. In order to increase the price variation in the model, Cafiero et al. (2011a) used a reduced and more reasonable price elasticity demand in the range between -0.2 to -0.067. Moreover, the same authors assumed no storage cost other than interst charges in order to favour high serial correlation. In this way, the authors demonstrate how to use the estimated model to generate distributions of the price next period, given the past history of prices and conditional on the amount of stocks implied by the current price. This estimations seem to be very useful in anticipating periods of high price volatility and in planning policies to avoid prices peak and crisis in food markets.

3. INTERNATIONAL WHEAT MARKET: A THEORETICAL FRAMEWORK

Price market determination for wheat has been deeply discussed by producers, consumers as well as policy makers since long time. A large strand of literature has been involved in attempting to understand the wheat price formation mechanism in world market. Wheat world trade has changed in a massive way since the 60's. According to Sarris (2000), world trade has become more liberalized thank to several international agreements and to the role of governments in cereal markets that have strongly reduced their interventions. Moreover, different major producing countries such as China and Russia are undergoing significant economic changes increasing their income pro capita and, in its turn, their eating habits. Technological changes in production and new communication tools have further changed the market framework increasing the integration of regional markets.

The purpose of this chapter is to explore the price formation mechanisms of world wheat market. Firstly, different theoretical models discussed since the 60's in order to provide a theoretical framework for analysing wheat price behaviour will be briefly introduced. Secondly, a recent annual model for United States wheat price firm used by USDA in short-term market analysis and long term base line projection will be deeply explained.

3.1 Price formation in world wheat market. A theoretical review

Wheat international market has been deeply analysed and several theoretical models have been proposed to formalize the price formation mechanisms. McCalla (1966) attempted with his pioneering paper to present a formal model about international wheat market during the 1950s and 60s. The author defined a cooperative duopoly model where Canada and the United States are the duopolists, with Canada the price leader and the United States the usually silent partner adjusting price within a zone of cooperation. All the other exporters and big producers such as Australia, Argentina and France create a large group constituting a "fringe of price follower" setting a price just below the price set by duopolists to clear their stocks. According to McCalla (1966), the duopoly approach was the better approach to describe the market structure at that time at least for two reasons. First of all, Canada and United States controlled 60% of the market. Second, market power shows a strong correlation with the ability to hold stocks. These two countries had adequate storage facilities to permit holding in comparison with the other exporters giving them a great market power.

Both countries had the objective to maximize exports subject to the implied duopoly relationship. The market structure results in a deterministic solution for price and exports. However, Canada and United States' demand function was the residual from the aggregate demand and supply function of the smaller exporters.

Furthermore, McCalla (1966) recognized the possibility that changes in international conditions may alter the structure of world wheat market underlining the inherently instability of international trade in wheat due to domestic agricultural policies. The author argued that rapid increases in Australian wheat production with a strong declining stock of the United States and Canada may bring a severe change in the market structure.

In line with these findings, ten years later, Alouze, Watson and Sturges (1978) postulated a triopoly model of world wheat market between United States, Canada and Australia with Canada as a revenue-maximizing price leader. This model was supported by three pieces of evidences well explained by Wilson (1986).

Firstly, Australia's wheat stocks were increased since the end of the 60's. In this way Australia reached a higher market power. Secondly, Australia domestic agricultural policy was completely changed in term of stocks supply. In fact, especially during the end of the 60's, Australia did not clear its stock in each marketing year. Finally, meetings organized by Canada and United States to define price and market shares started to include Australia too.

However, during the 1970's, the triopoly was no longer able to represent the market structure for a number of reasons. New conditions changed the framework. First of all, large purchase by Russia greatly reduced the large surplus of the previous decade. Since market power was strictly correlated with stockholding, the decreased level of stocks create a competition to set price and exports between the major exporters.

Moreover, the models described so far don't recognize the potential substitutability of wheat by class and origin but, for the sake of simplicity, assumed them to be homogenous. Conversely, Oleson (1979) has been the first to take into account the importance of wheat quality and the role of different classes and origin in maintenance of market power. In essence, he distinguished three historical periods to describe wheat trade framework. During the first one, from 1953 to 1962, Canada is the market leader because its dominance in the high protein wheat market. The United Stated had, in that period, a limited supply of higher protein wheat but larger supply of other classes. For this reasons, United Stated accepted Canada's price leadership for the high protein wheat market establishing export prices only for other classes. Fringe competitors, in line with McCalla's (1966) results, had limited storage for all wheat classes and followed a policy of minimizing stocks each market year.

From 1963 to 1972, the second period, the role of Canada as price leader was not so strong anymore. United States and Australia, in a lesser way, increased their production of higher protein wheat. Moreover, new technology in the baking industry resulted in reduced demand for higher protein wheat. All this factor lead to an eroded Canada market power.

After 1972, the last period, United State become the recognized price leader. According to Oleson (1979) several factors contributed to this transition. Firstly, there was a severe expansion in export demand especially form URSS. This strong demand was mostly covered by the US. Secondly, the strong interaction between US and Canada in defining prices and exports was suspended. In other words, US adopted an open-market pricing policy subject to the operation of government price interventions such as loan rates[5], target prices, supply control and storage payments. Finally, Canada exports, during this period, were influenced by logistics and transportation problems which served as a constrain and affected their storage policy. All these aspects led Canada to become a new member of the large group of smaller exporters that is called by McCalla (1966) "competitive fringe".

Considering this changed international wheat market framework, Wilson (1986) described wheat international market using a price leadership model with the US being the price leader. According to the author, "US farm programs, particularly the loan rate program, play a dominant role in the international price structure for wheat. It is the interaction between cash and futures markets with the loan program which determine international prices, which are effectively ceiling prices for the price taking competitive

[5] "The loan rate is the price at which farmers can borrow from the government against their crop. If crop prices rise, the farmers can redeem their crop and sell it to repay the loan. If prices do not rise, the crop is retained by the government as full payment of the loan. In many years, the US loan rate becomes a price floor, which supports the US market price and because of the size of US exports the world price as well". (Mitchell and Duncan 1987:20)

fringe. It is in this indirect way that the US has assumed the role of price leader, although it was probably not intentional.” (Wilson 1986:29).

In essence, the main features of Wilson’s dominant country price model can be summarized in this way: US is assumed to be the price leader and all the other exporters are included in a large group of competitive fringe. Obviously, they are considered price takers since they are individually too small to affect international price. Moreover they are thought to act independently each other.

The supply function for the competitive fringe taken as a whole has a great influence in demand function for the US. In particular, the elasticity of US demand function is affected by the elasticity of the supply function for the competitive fringe. “A more elastic competitive fringe supply implies a more elastic effective US demand” (Wilson 1986:30). For instance, the author suggests that technological improvements and increased exporting capacity by smaller exporters, result in lower export provided by US. In other words, with prices fixed by US, changes in aggregate demand are all absorbed by the US in terms of stock and supply adjustment. Wilson (1986) noted also that an appreciation of the US dollar negatively affects the effective demand function for US increasing exports from competitive fringe. Finally, this price leadership model was supported also by the export strategies adopted by the smaller exporters. The author noted that France, Argentina and Australia adopted policy to minimize the level of stocks cleaning the market each year with price that were in line with US price or even below US price. Canada is presented as a special case. This country was used to maintain high stock level during the 60’s reaching a great market power. Its stock level became less and less until the 80’s. This decreased level of stock in addition to increased exports represents a clear political choose that “reflect a recognition of reduction of market power.” (Wilson 1986:30)

In spite of Wilson’s model, Mitchell and Duncan (1987) proposed a model that is generally consistent with the dominant-firm oligopoly model for analysing the behaviour of the major grain exporters. Their results, however, showed that rice and coarse grain markets were very closely to the oligopoly model with the United States being the dominant firm. The same results for wheat market were a little bit different. In this case there was not a clear market leader. Wheat market can be better defined as a more complex oligopoly involving a shared dominance between the United States, Canada and Australia. Moreover, in line with the conclusions of Alouze et al. (1978), price leadership is provided by the United States through its wheat loan rate. In essence, as well described by Mitchell and Duncan (1987:3) United States with Canada and Australia represent the word's residual supplier for wheat. United States, because its loan rate, has established price floor for wheat and allows other small exporters to sell as much wheat as they choose at that price. For this reason, the behaviour of the United States in wheat market and, more generally, in grain market, has fundamental implication for all the small exporters. "As long as the United States, or any other country, behaves like the price leader, others can export at the price it sets." This opportunity has been used in a profitable way by Argentina for the wheat case.

According to the model, when world import demand decreases United States greatly reduces its export supply while other small exporters are only little affected. This is because the role of world residual supplier of the United States. The reduction in export is reflected in an increased stock level. This behaviour, well explained by the model, is in line with growing stock level of the United States and the remained low level of the other exporters during the years analysed by Mitchell and Duncan (1987). Moreover, when the United States dollar appreciated against other currencies it reflected immediately in United State export. In fact, when US dollar appreciates compared to other currencies, the price of wheat in international market is higher because it is usually expressed in US dollar. Considering that United States acts as a residual supplier in the model and because its price floor is not changed according to the US exchange rate, it should be clear that the import response to the dollar appreciation result only in a severe loss in export by the United States. Obviously, opposite results are reached in the case of US dollar devaluation.

Since mid-1980's market conditions and prices for wheat have been deeply changed. Agricultural sector has become more market oriented under agricultural policy changes of the last 30 years.

A useful and relatively recent price determination model for wheat implemented by Westcott and Hoffman of US Department of Agricultural (1999) provides a complete analytical framework for short term market analysis and long term baseline projections. In essence the model takes into account mainly to types of factors that influence prices such as market supply and demand aspects and government policy variables. The model is augmented by variables that reflect the changing role of agricultural policies, international market conditions and, finally, the role of wheat feeding and competition with corn for feed use. In the next paragraph USDA model price determination will be discussed more in detail.

3.2 USDA wheat price determination model

Because its simple structure and its small data requirement, USDA wheat price determination model is largely used in price forecasting and market analysis of supply and demand condition. The model simply uses four sources of information. Firstly, a stock to use ratio parameter to take into account the effects of market supply and demand factors on price determination. Secondly, Government agricultural policies that may directly affect price definition are included in the model. Then, international market conditions are also analysed since the market structure for wheat is considered much more competitive than in past decades. Finally, the role of wheat feeding and competition with corn for feed use is assumed affects the price determination mechanism. Westcott and Hoffman (1999:21) present model performances measures showing that the price model reflect actual prices very well and that "the statistical measures indicate good performance for the price model and suggest that price model provides an analytical framework that can be useful in price-forecasting application". The authors also state that "most differences between the model estimates and the actual prices are less than 20 cents per bushel of wheat." In next paragraphs each variables included in the model will be briefly described.

3.2.1 Supply and demand factors affecting wheat price

The effects of market supply and demand factors on price determination represent the main core of the model. The components of supply and demand will be briefly considered separately.

Wheat supply includes beginning stocks, imports and production. Wheat is produced annually and under modest conditions it is storable for long period of time. Carryover stocks from the previous year become the beginning stocks for the current year increasing the current production. We have already seen how large stocks can provide an additional source of supply in a low production year buffering prices spike. In order to improve wheat supply each country may acquire wheat from the international markets. Generally speaking, imports market is quite competitive involving a large number of countries which are not big enough in terms of purchases to affect the international price. In particular, focusing on US, wheat imports have been insignificant relative to the total supply. Finally, production can be defined the major component of supply at least for the countries that are taken into consideration in this thesis. Production depends on the amount of acreage harvested and the yield per surface unit. Acreage planted "reflects producer net returns per acre for a given commodity compared with returns for competing crops" (Westcott and Hoffman, 1999:3). Government policy such as subsidies and agronomic consideration can severely alter net returns per acre affecting planting programs. Yields is affected by a plethora of factors including climatic conditions, farm management and also wheat variety and soil quality. Unfortunately, because weather condition, in any year yields can be pushed above or below trends affecting in this way international price.

On the demand side, major components for wheat include food, seed and industrial use, feed and residual, exports and, finally, carryover stocks.

Generally; food, seed and industrial use is the largest component of wheat total domestic demand. Within this category, consumption for food usage is the greater component. Human consumption is close related to population growth and income level. Moreover, food uses are inelastic to farm-level prices since the farm value of wheat in consumer food stuff is relatively small.

Feed use for wheat is much less important than for corn that is the main feed crop. Feed use is more variable than food use because this kind of use is strictly related to wheat price compared to corn price and wheat quality. Usually, most feed use of wheat occurs in the summer, when wheat prices are seasonally low following the wheat harvest but before corn is harvested.

Export is an important component in wheat total demand for the countries included in this thesis. We have already introduced different models explaining demand exports for the main exporters countries. In those models, international trade in wheat has evolved from an oligopoly in which Canada was the price leader (McCalla, 1966) to a price leadership model in which the US is the price leader (Wilson, 1986). More recently, Westcott and Hoffman (1999:7) recognises that although the US is the largest world exporter of wheat its world market share is not enough to be considered a price leader having a less dominant role in international market with respect to earlier years.

Market conditions of supply and demand are summarized in the stock to use ratio. This measure is defined as “stocks of the commodity at the end of a particular time period divided by use of the commodity during the same period of time” (Westcott and Hoffman, 1999:11). Stock to use ratio has been largely used in many models to represents supply and demand characteristics in an annual framework (see for instance Van Meir, 1983; Baker and Menzie, 1988). In line with these previous models, Westcott and Hoffman (1999) used stock to use ratio measure but in a quarterly framework.

This measure, in line with previous findings and literature, is negatively related to prices and provides a downward sloping nonlinear curve of prices plotted against ending stocks to use ratios.

3.2.2 Agricultural policies affecting wheat price

Beyond supply and demand factors, Government programs are considered important in affecting price determination mechanisms for this reason government policies variables are included in the model. There is a plethora of agricultural policies that may affect supply, demand and pricing of wheat directly and indirectly. Generally, policies affecting supply and demand factors have an indirect effect on wheat prices such as acreage reduction and set aside programs on the supply side and export subsidies on the demand side. Price effects of these policies are usually already included in supply and demand data and for this reason do not need to be considered again.

Government price support and commodities storage programs affect in a more direct way wheat market price beyond the effects on supply and demand. These programs should be considered in a more serious way and included in the model.

More in detail, price support programs for wheat have been popular in US. The loan rate is the most popular instrument of price support in US. If market price is below the loan rate it would be better for the farmer, under the economic point of view, defaulting on the loan and keeping the higher loan rate. According to Westcott and Hoffman (1999), loan rates for wheat increased in the late 1970’s and remained relatively high until the mid-1980’s. In 1986’s price support program started to change reducing significantly the effect of price supports on the market price. In essence, the loan rate continued to be used but it no longer supported price being well below market price in most of the recent years. These changes are considered as a part of a general movement in US agricultural policy toward a more market orientation.

A similar evolution can be observed in commodities storage programs in which government programs led to a large build up of stocks in the early 1970's to the mid-1980's.

The major storage programs were the Farmer-Owned Reserve (FOR), the Commodity Credit Corporation (CCC) and finally, the Food Security Wheat Reserve (FSWR).

More in details, Commodity Credit Corporation (CCC) can be defined as public stocks owned by the Government acquired by loan defaults or market purchases. These stocks have severely affected market price because they have generally not been readily accessible to the marketplace.

The Food Security Wheat Reserve (FSWR) was created at the beginning of 1980's with the aim to provide a government wheat reserve of up to 4 million metric tons for emergency food in developing countries.

However, also for these programs, between 1985 and 1990, deeply changes in the legislation toward market oriented stockholding policies reduced wheat stocks level and the impact of these programs on wheat price.

In conclusion, policy changes since 1986 until recent have continued to reduce price effects of government price support and commodity storage programs. As a consequence, price for wheat has been mostly determined by market supply and demand factors with a reduced influence of government policies.

3.2.3 The pricing model

The pricing model described by Westcott and Hoffman (1999) relates wheat price to ending stocks. In particular, in its simplest form, stocks are a function of price. The equilibrium condition to clear the market determines the price at which supply equals demand plus stocks. In a more formal way, using Westcott and Hoffman (1999:12) notations we have:

$S=f(p_{t-1},z)$ (Supply_function) (1)

$D=g(p,p_{t-1},z)$ (Demand function) (2)

$K=h(p,z)$ (Stocks function) (3)

$S-D-K=0$ (Equilibrium condition) (4)

In which, *S* is supply, *D* is the demand, *K* is the ending stocks, *p* is the market price and *z* is a set of exogenous variables. Lagged prices are included in both supply and demand function. They are particular important for wheat used for feed since livestock production decisions made in previous periods in response to prices in those period affect feed demand over a number of years in advance. Export demand is also considered function of lagged prices to reflect international supply response. Supply is positively related to expected price while, on the other hand, demand and stocks are negatively related to price.

In equilibrium price can be derived from the inverse of the stocks function. In a more formal way it can be written as follow:

$p=h^{-1}(K,z)$ (Price equation, inverse stocks function) (5)

Equation (5) represents the basic pricing model. However, adjustments are needed to take into account other factors affecting prices. In particular, adjustments will be added to include Government programs that directly affect price determination such as Government loan program and stockholding policies. Other adjustments will introduce variables related to global wheat market factors and wheat feed use and related cross commodity pricing considerations. These adjustments result in upward or downward shifts of the basic functional relationship between ending stocks and prices expressed by equation (5).

Starting from the different effects that government programs have on price determination two additional terms are added in equation (5).

LR= the effect of Loan rate program;

CCC= the effect of Government programs.

In essence, there is a negative relationship between prices and total stocks as we have already seen. However, we should consider separately the effect of the total ending stocks from the effect of the government owned stocks on price determination mechanism. For the former, larger total stocks are generally associated with lower wheat price. For the latter, larger Government owned stocks lead to higher price. This is because Government stocks are much more isolated from the marketplace.

In order to keep into consideration the role of global wheat market in price determination, a variable reflecting the world wheat market structure should be added to the basic model. In fact, although the United States is the largest exporter, its role is not as dominant as in the corn market at least during the last decades. US wheat price (and, in its turn, world wheat price since it is strongly anchored to the US price) is affected by world market conditions. A variable representing stockholding in four major exporters beyond US is added to the pricing model to reflect this international market effect. Larger ending stocks in EU, Canada, Australia and Argentina lead to lower wheat price in US. In line with Westcott and Hoffman (1999) notation, a variable called C4K will be added to include competitors stocks effect in price determination mechanism.

The last two adjustment to the basic model reflect the effect of wheat used for feed purposes compared to total usage and cross commodity pricing considerations with respect to corn.

In particular, wheat competes with feed grains especially during the summer when wheat has been already harvested and all the other feed grains have not. Usually, if wheat is largely used for feed, this lower value usage is reflected in a lower price. Moreover, as well explained by Westcott and Hoffman (1999:13) “when low wheat prices lead to large wheat feeding, typically in summer, the wheat price tends to be influenced by price of competing feed grains such as corn.

To represent these two wheat pricing consideration, the two variables added to the basic model are briefly described below:

FS/U: summer quarter wheat feed use expressed as a share of total use. This variable should reflect the importance of wheat used as a feed in the season average price. In essence, larger summer quarter wheat feeding means lower season average price.

PCS: Summer quarter corn price provides a measure of the level of cross-commodity pricing influence provided from competing feed grains. In particular, “the higher the price of corn in the summer, the higher the price of wheat used for feed, and thus the higher the overall season average wheat price” (Westcott and Hoffman, 1999:13).

Adding these wheat price considerations to the general pricing model, the price equation (5) for wheat can be written as follow:

$$p = h^{-1}(K, CCC, LR, C4K, FS/U, PCS, z) \qquad (6)$$

The double log functional form is used to estimate equation (6). As we have already explained, the coefficient on the stock to use ratio is negative because the negative relationship between wheat price and stock to use ratio. Thus, this functional form provides a downward-sloping, convex-shaped relationship between the stock to use variable and wheat price. Most other explanatory variables used are also used in logarithm from. Only the government owned stocks variable is not transformed to logarithm.

USDA wheat price model specification is shown in equation (7) below:

$$Ln(p)=a + bLn(K/U) +c(CCC/U) + dLn(LR)Dum7885 + fLn(C4K/C4U) + gLn(FS/U) + hLn(PCS); \quad (7)$$

The variable *p* is the firm level price, *LR* is the wheat loan rate and *K* is the total stock. *U* represents annual utilization of the crop. A dummy variable *Dum7885* is added to represent the effects of the loan program on wheat price from the late 1970's to 1985. During this period, wheat loan program had a major effect on price level. For this reason, *Dum7885* variable equals to 1 in 1978-85 and equals to 0 in other years.

CCC represents government owned stocks; *C4K* and *C4U* represent stock and use in the main exporters (EU, Canada, Australia and Argentina); *FS* represents wheat feed use in the summer quarter and *PCS* is the price for corn in the summer quarter.

The terms *a*, *b*, *c*, *d*, *e* , *f*, *g* and *h* are parameters to be estimated using ordinary least squares regression.

The expected sign of the total stock to use ratio coefficient (*b*) is negative as we have already seen. In spite of this, the coefficient (*c*) for the government owned stock to use ratio is expected to be positive. This because larger government stocks at the end of the year indicate that a greater share of the total stocks are not accessible to the market place leading to higher price.

Price government programs summarized by the loan rate had a great positive influence on wheat market price up to the middle 1980's. The expected sign for the coefficient (*d*) is positive when the dummy variable values 1. Previous models for wheat price determination used a different specification for the loan rate. In particular, the dependant variable was defined as the farm price minus loan rate. This is particular useful when most part of the dataset is collected before 1985, when the effect of the loan rate was particularly significant for the price determination. In contrast, Westcott and Hoffman (1999:15) model uses a large number of data belonging to the period post 1985 when the effect of the loan rate in affecting wheat price is no so important anymore. Thus, according to the authors, "rather than including the loan rate in the dependent variable, it seems more appropriate now to include the loan rate as a separate independent variable for the years when high price supports affected prices, providing a policy shift effect on price determination in those years. With this specification for the loan rate, the dependent variable is the farm level price."

The stock to use ratio for the major exporters beyond US is added in the pricing model to account the effect on US wheat price of condition in international market. Obviously, a larger competitor stock to use ratio results in lower international price, exerting downward pressure on US price as well. Thus, the sign of the coefficient (*f*) is expected to be negative.

Finally, some considerations about the value of the coefficients representing feed wheat usage and cross grain pricing considerations.

The two variables used to represent the feed use effect on wheat prices are expected to have opposite effects on wheat prices. In particular, summer quarter wheat feed use as a share of total annual use is expected to have a negative effect on wheat farm price (coefficient *g* is expected to be negative). On the other hand, the variable representing the price for corn in the summer quarter is expected to have a positive effect on wheat price (coefficient *h* should be positive).

4. WORLD WHEAT MARKET IN TERMS OF PRODUCTION, CONSUMPTION AND TRADE

Price, consumption and stock in world wheat market have been a major concern for private producers, consumers and, most of all, governments. The reason is that a market failure leading to high price can lead, in its turn, to large income transfers between various market participants. Obviously the poor people is the most vulnerable in front of an increased wheat price and an augmented volatility of prices.

During the last decades, world wheat market has deeply changed under different point of views. First of all, the market has became more liberalized and, on the other hand, different governments have reduces their intervention in the in cereal market. Secondly, several major producing countries such as China and Russia, are deeply changing under the political and economic point of view. Finally, technological changes in production and improving in communication tools are also factors affecting the world wheat market (Sarris A.H. 2000).

At the present time, world wheat market is segmented into groups of countries with different productive capacities and level of use. A small number of countries strongly influence global wheat market producing and exporting a large portion of global wheat. As it will be seen later, also the ending stocks of wheat in global markets appears concentrated in few countries or regions. On the other hand, world wheat import market is not so concentrated. In essence, the global wheat market is characterized by a small number of wheat exporting and producing countries that sell to a relatively larger group of importers. China and India represent a particular case. They are two major wheat producing and usage countries but they are not so involved in trade focusing on the domestic market. Given the critically important role of wheat as human food, seed and industrial use, world wheat demand is projected to increase along with the world population that is expected to grow in the next years. Nevertheless, the major role played by some countries in definition of global wheat market supply-demand balance is unlikely to change appreciably in the coming future.

The purpose of this chapter is to is to briefly present a complete picture of world wheat market using data covering the last decades and introducing projection for the coming five years.

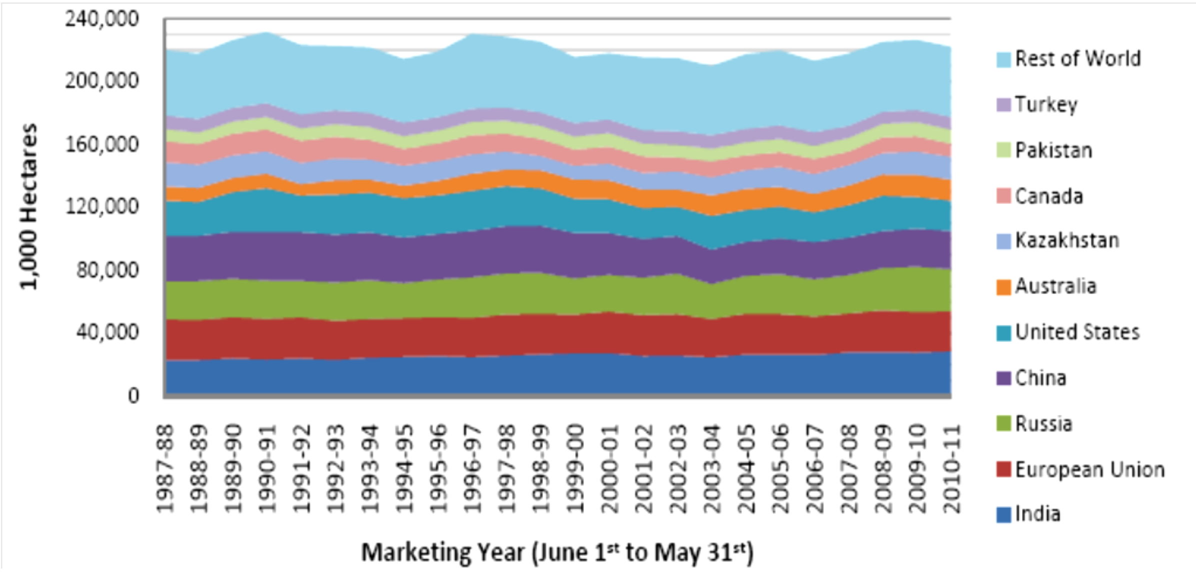
Generally speaking there are different factors affecting global wheat market such as supply of wheat in terms of production and stocks level, the demand of wheat in terms of consumption for human food, feed and industry uses and finally export. Other factors, that are less important but that should be keep in mind, are wheat quality, logistical costs and political instability. According to these factors, global wheat market will be discussed taking into account firstly the production side, than the consumption side and finally the trade. The information provided represents a general overview and should not be considered as a complete studies on world wheat market.

4.1 World wheat harvest Area

According to O'Brien (2011), the planted area of wheat in the world in the 2010/11 marketing year is estimated to be over 220 million hectares which is in line with the average planted area since 1987/88 (218 million hectares).

The 10 largest wheat producing countries provided an average of 79,9% of world wheat harvested acreage over the period 1987/88 to 2010/11 as showed in figure n. 4.1.

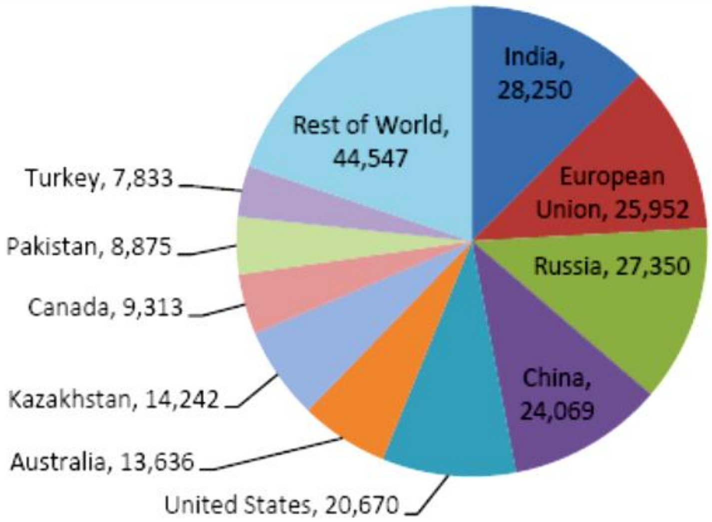
Figure 4.1: World wheat harvested Area



Source: O'Brien (2011), Agmanager.info article.

Considering the most recent period 2008/09 to 2010/11, the 5 more important countries in terms of average world wheat harvested acreage covered more than 50% of world planted area. In this period India is the country with the larger harvested acreage followed by Russia and European Union (figure n. 4.2).

Figure 4.2: World wheat harvested acreage by Country average of 2008/09 to 2010/11 (1000 ha)



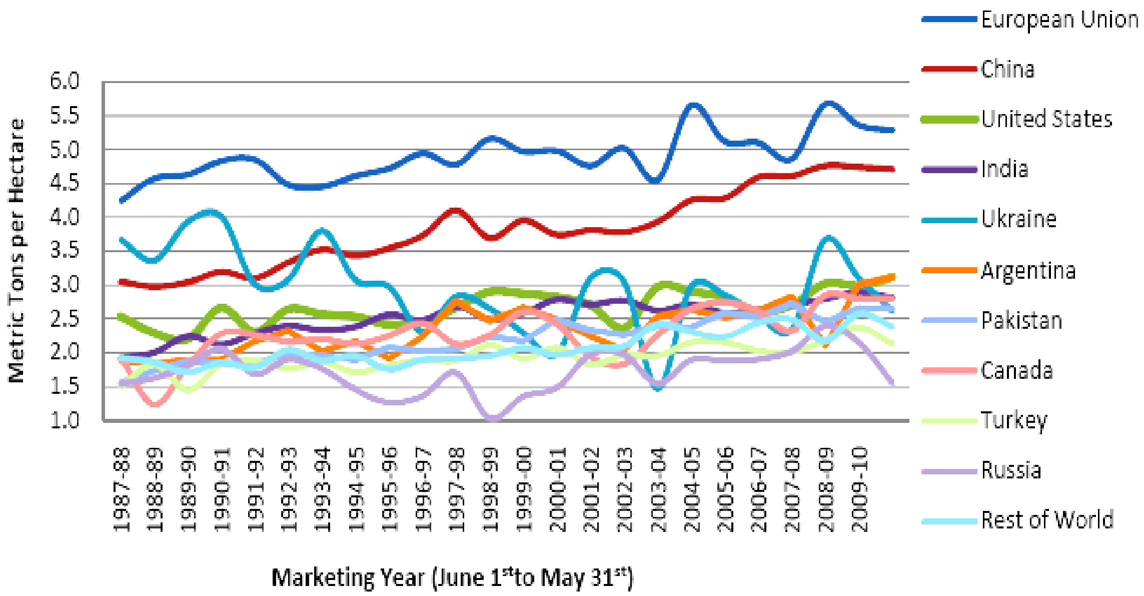
Source: O'Brien (2011), Agmanager.info article.

According to International Grain Council forecast, global harvested area are projected to expand by around 0.4% annually with a slightly increased average yields until to 2016/17.

4.2 World wheat Yields

According to O'Brien (2011), the marketing year 2010/2011 was characterised by an average world wheat yields of 2.90 metric tons per hectare. The same value calculated since the 1987/88 marketing year has been estimated to be 2.67 mt/hectare that means an average annual increase of 0.03 mt/ha over the last 24 year. Considering the wheat yields by countries in details it should be noted the huge difference between regions. In particular, the highest average yields over the last decade were registered in the European Union (5.14 mt/ha) followed by China with 4.35 mt/ha with an impressive yields trending upwards close to 0.12 mt/ha per year. Figure 4.3 summarizes the wheat yields over the 24 year period for the 10 largest producing countries.

Figure 4.3: world wheat yields by countries

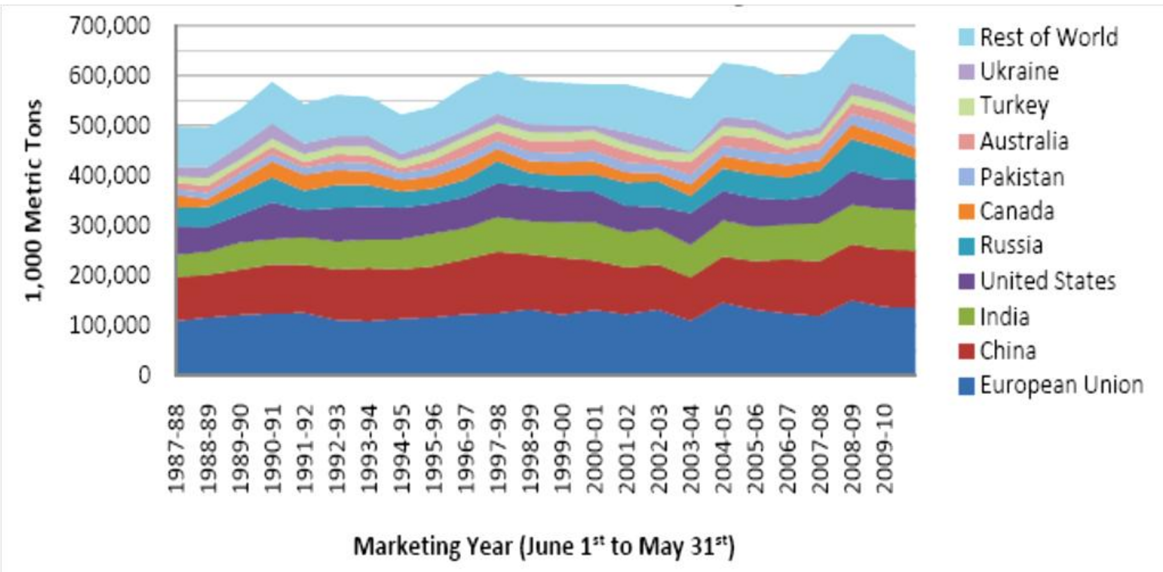


Source: O'Brien (2011), Agmanager.info article.

4.3 World wheat production

According to the International Grain Council, world wheat production in the 2010/11 marketing year is close to 649 million of tons in line with O'Brien (2011) estimation. Moreover, the same author provides an average world wheat production of 589 millions of tons since the 1987/88 year with average increase of 5 millions of tons per year over the 24 year period. The production of wheat is strongly concentrated in some countries. In fact, the 10 largest wheat producing countries produced an average of 84.3% of world wheat over the same 24 year period as showed in figure 4.4.

Figure 4.4: World wheat production by country

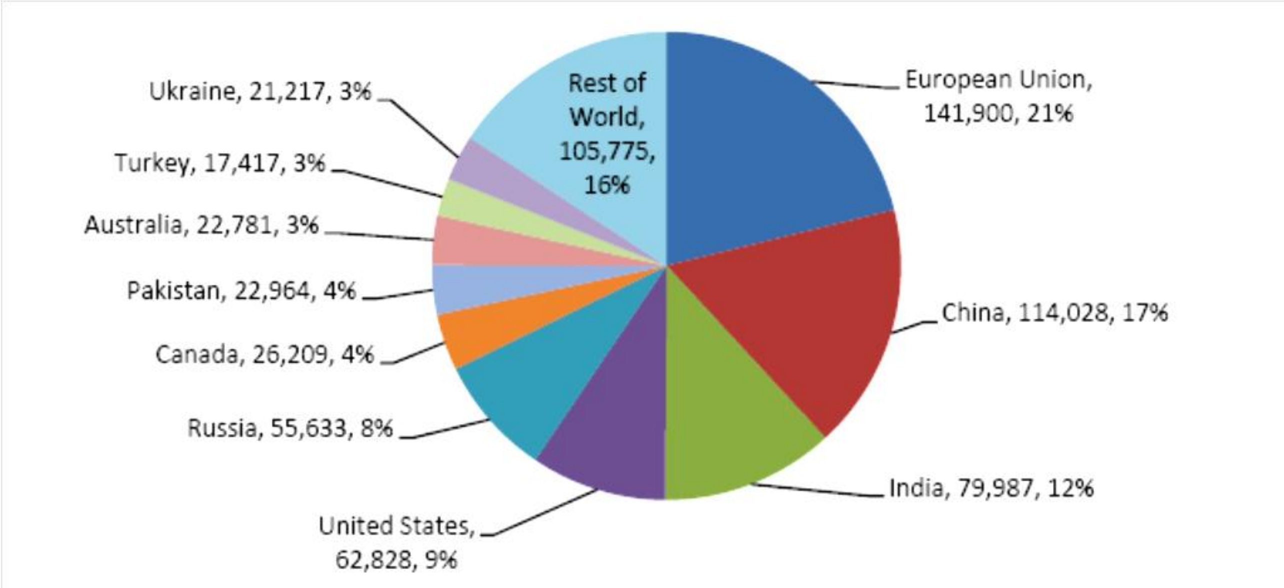


Source: O'Brien (2011), Agmanager.info article.

As showed in figure 4.4, some important countries such as Ukraine, Australia and Russia, have a larger variability in wheat production compared to other countries. This is in line with the value of the variability coefficient calculated by O'Brien (2011). The value of the coefficient measures the historical variability in wheat production relative to the average quantity produced since 1987/88. Ukraine, Australia and Russia have a coefficient variability of 0.33, 0.30 and 0.22 respectively. On the other side, the same coefficient for United States and European Union measures 0.12 and 0.09 respectively.

During the last 3 year period (2008/9 to 2010/11), the three largest countries in terms of average world wheat production were the European Union, China and India that together provided almost the 50% of the global wheat production followed by United States and Russia (figure 4.5).

Figure 4.5: World wheat production by country 2008/09 to 2010/11 in metric tons



Source: O'Brien (2011), Agmanager.info article.

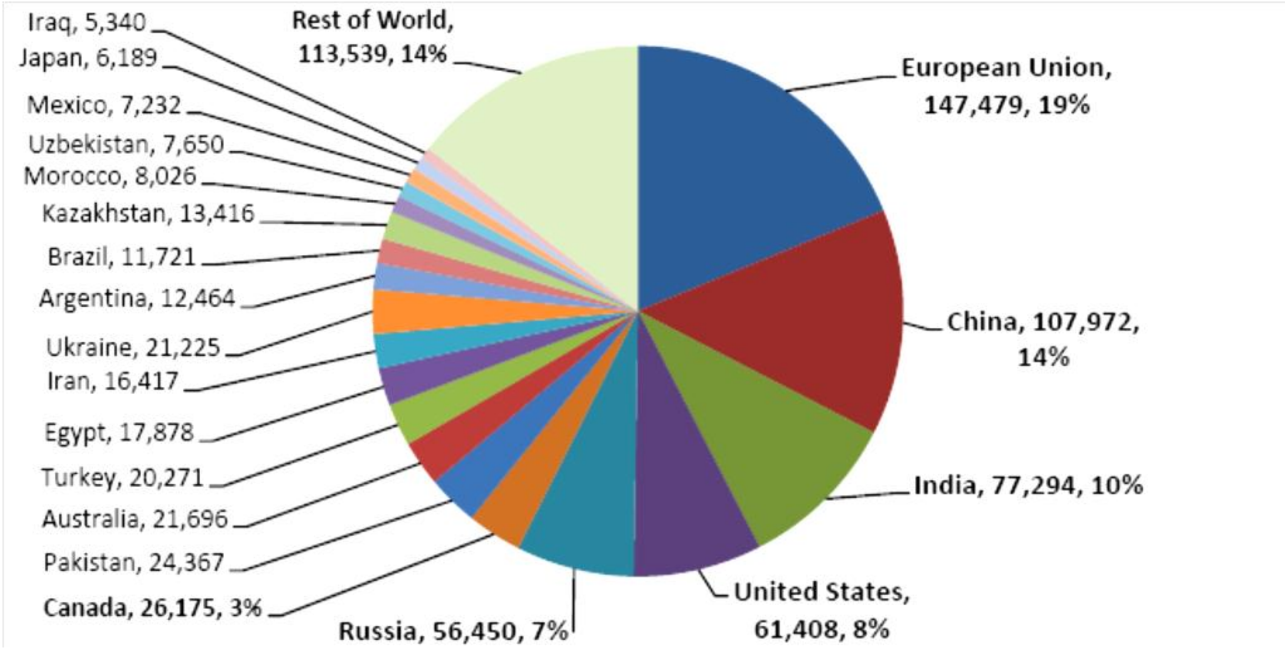
China is the second largest wheat producing countries after European Union. Nevertheless, China produces mostly low quality winter wheat. This fact, in addition to its increased demand, explain why they import mostly high quality wheat in order to improve the nutritional level of their domestic wheat.

Finally, International Grain Council outlook forecasts a production record for 2016/17 close to 714 million tons due to an expanded harvested area and a slightly increase in average yields.

4.4 World wheat utilization

World wheat total use in the 2010/11 marketing year is estimated by O'Brien (2011) to be 788,011,000 tons. This compares to average world wheat use of 735,475,000 tons since the 1987/88 marketing year, with average increases of 6,397,000 tons per year over the 24 year period. Over the half of average world wheat usage during the 3 most recent marketing years is concentrated in 4 regions; the European Union (19% of total usage), China (14%), India (10%) and the United States (8%)

Figure 4.6: World wheat total use by country average of 200/2009 to 2010/2011 (1.000 tons)



Source: O'Brien (2011), Agmanager.info article.

FAO food outlook (2011) provides different and lower data for world wheat total utilization estimating a total use over to 667 million tons for the 2010/11 marketing year, 20 million tons higher than the previous year. FAO forecasts an increase in total wheat utilization for the next years mostly in response to larger availability and larger use of wheat for animal feed because more competitive relative to maize. This is in line with the International Grain council outlook which estimates an annual increase of 1,1% in consumption reaching a total utilization close to 716 million tons in 2016/17.

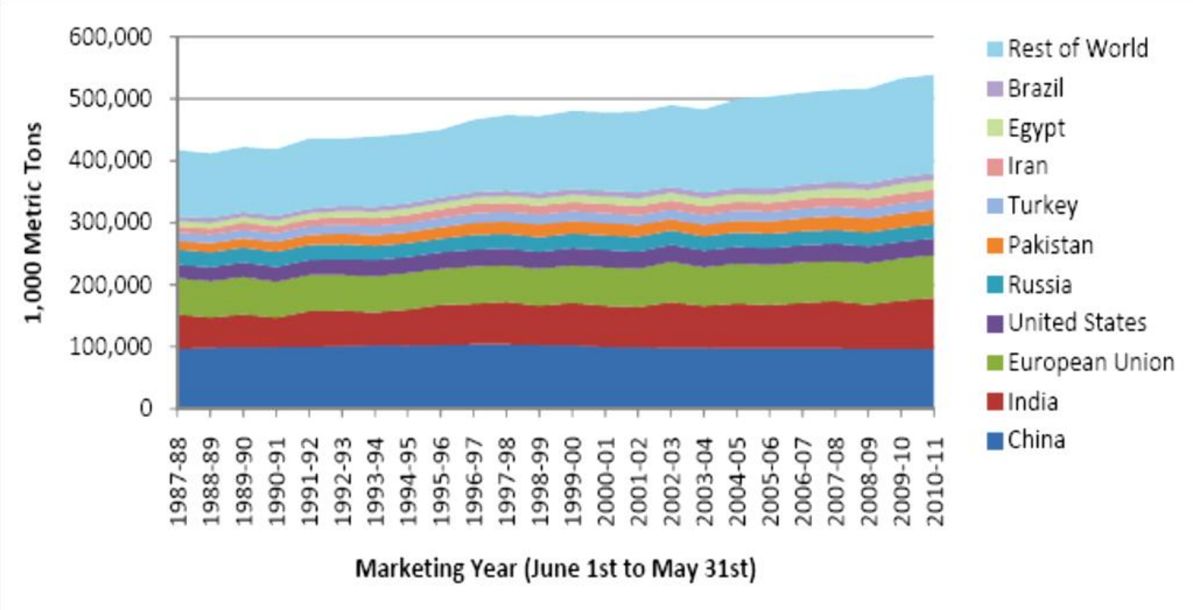
In the next paragraphs, total wheat utilization will be described in function of the specific usage of wheat for food, feed and other uses respectively.

In fact, FAO (2011) splits up the total utilization in food, feed and other usage estimating a human food use for more than 70% of total usage (468 million tons). Feed use and other use (including industrial use and seeds) accounting for 19% and 11% respectively.

4.4.1 World wheat food, seed and industrial use

According to O'Brien (2011), world wheat food, seed and industrial use in 2010/2011 marketing year is estimated to be 539 million tons. Since the period 1987/88, the average of wheat total utilization is measured close to 504 million tons. This means that the total utilization is increased with an average of 5 million tons for year over the 24 year period as clearly showed by the figure 4.7.

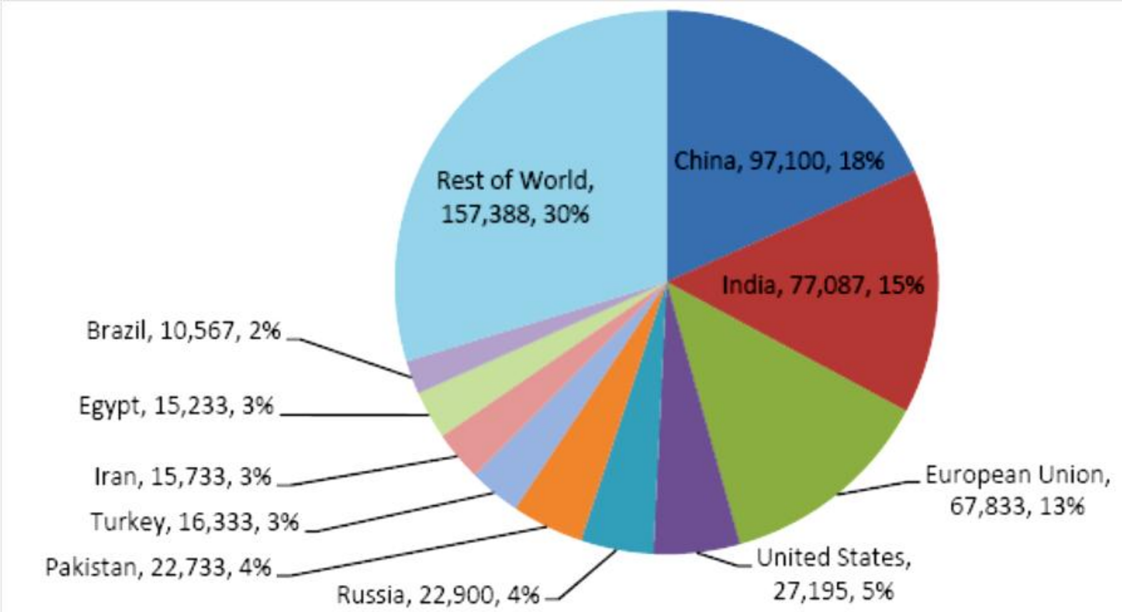
Figure 4.7: World wheat food, seed and industrial use by country



Source: O'Brien (2011), Agmanager.info article.

China is the most important region in terms of wheat total utilization during the period 2008/09 to 2010/11 followed by India and European Union. This three countries or regions use together an average of 50% of world wheat as well described by the figure below.

Figure 4.8:World Wheat Food, Seed and Industrial Use by Country, average of 2008/09 to 2010/2011



Source: O'Brien (2011), Agmanager.info article.

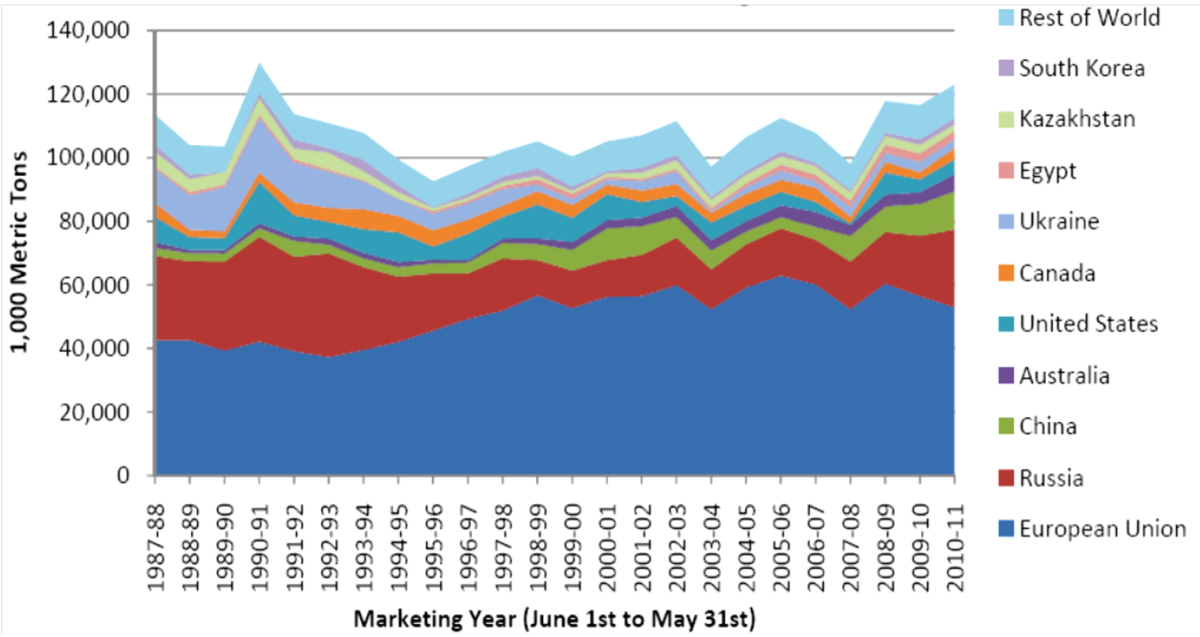
More in details, direct human consumption is forecast to slightly increase driven by expanding demand in developing countries. FAO (2011) estimates a 68 kg annual consumption per person, which is in line with the level of the most recent years. It means that the global food use of wheat is continuing to keep up with average world population growth. China, that is one of the major consumer country, is forecast to show a slow decline in per capita wheat consumption from the quantity of 73 kg at the beginning of the millennium to a level of just 64 kg. This decline is mainly due to larger consume of more value added food products in response to the income increase.

The combination of industrial use, seeds and losses in post harvest operations, account for 11% of world wheat production in 2010/11. The industrial use of wheat has slightly increased during the past decade driven by larger utilization of wheat as feedstock and, more recently, for biofuels production. According to the International Grain Council (2011), total wheat industrial usage could reach 21 million of tons in 2011/2012 with an increase in wheat used for biofuels production that will reach 7,3 million tons, 22% higher than in 2010/2011.

World wheat feed use in the 2010/11 marketing year has been estimated in 123 million tons that compared to an average world wheat feed use of 109 million tons since the

1987/88 marketing year with an increases of 128 million tons per year over the 24 year period. Over the most recent 3 year period (2008/09 to 2010/11) the 5 largest countries or regions in terms of average world wheat feed use were the European Union, Russia, China, United States and Australia.

Figure 4.9: World wheat feed use by country, 1987/88 to 2010/2011



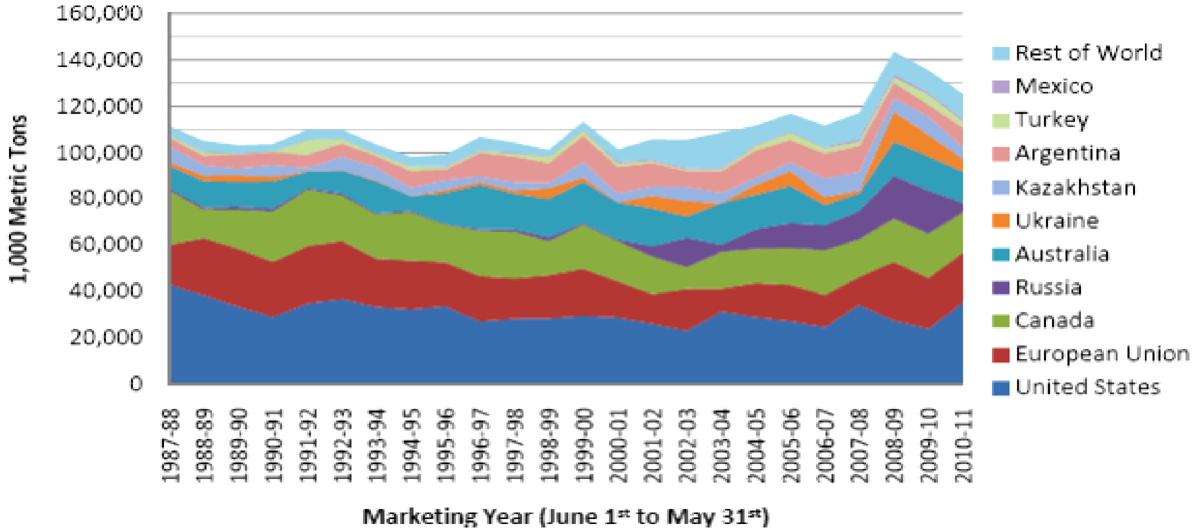
Source: O'Brien (2011), Agmanager.info article.

Feed usage as a share of total cereal utilization is relatively limited and, most important, concentrated in few countries or regions. European Union is the largest market for feed wheat. Nevertheless, FAO (2011) predicts an increase in the wheat usage for feed due to its competitiveness with respect to coarse grains and also because the tight maize availability. The fastest expansion is expected in China, the EU and the United States.

4.5 World wheat export

Average World wheat exports since the 1987/88 is estimated to be 116 million tons. However, world wheat exports in 2010/2011 are estimated by O'Brien (2011) to be more than 125 million tons with an average increase of 998,000 tons per year over the 24 year period. The most important aspect to keep in mind is the strong concentration of world wheat exports. During the 24 year period considered by O'Brien (2011), the 10 largest exporting countries or regions counted, in average, for more than 90% of world wheat exports as clearly showed in the figure below.

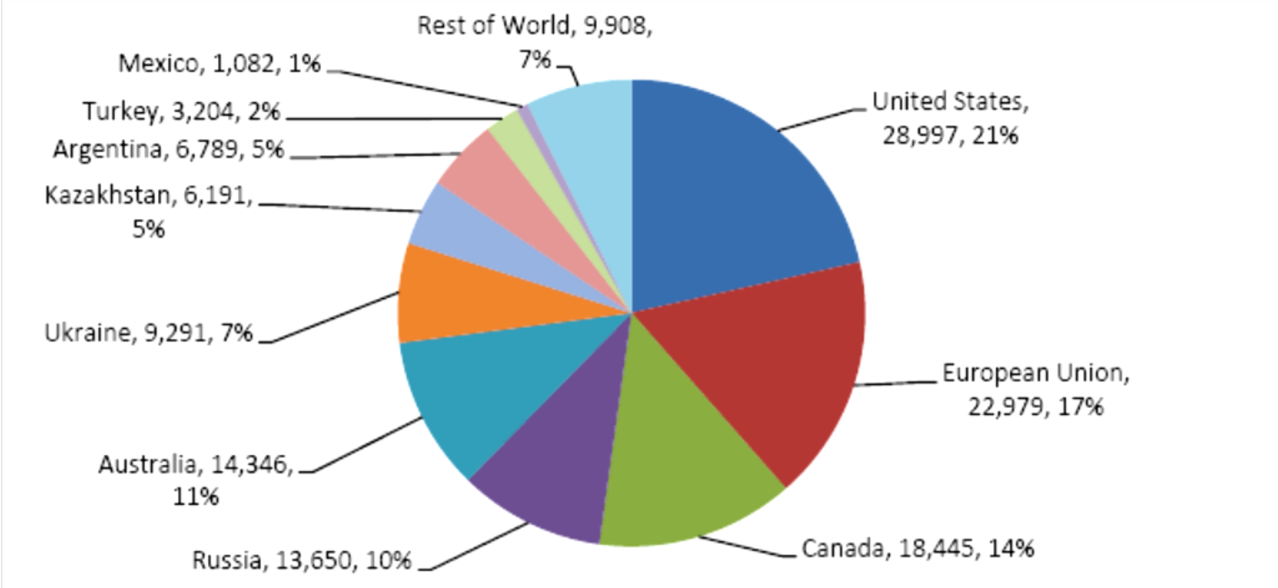
Figure 4.10: World wheat exports by country, 1987/88 to 2010/2011



Source: O'Brien (2011), Agmanager.info article.

Focusing on the most recent three years, the largest countries in terms of average world wheat exports are represented in the figure 4.11.

Figure 4.11: World wheat exports by country, 2008/09 to 2010/2011



Source: O'Brien (2011), Agmanager.info article.

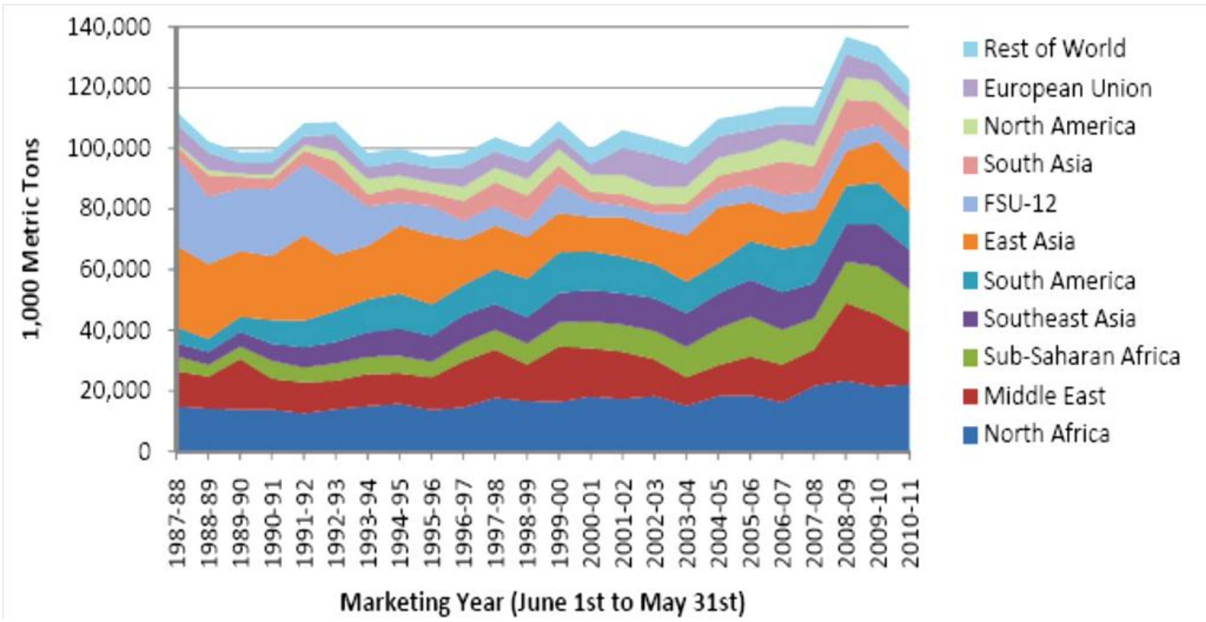
As clearly showed in figure 4.11, wheat international market does not show a leader but it may be better described as a more complex oligopoly characterized by a shared predominant position between the United States, European Union, Canada and also, but with a less importance, Russia and Australia (Mitchell, D.O, et al 1987). The largest exporting country is the United States with 21% of the world wheat exports during the 3 year average, followed by European Union (17%) and Canada (14%). Quite important is the area of black sea and Russia.

In United State, because its environmental and the huge availability of land, wheat is harvested during the whole year. In fact, wheat is divided in two major categories, winter and spring. Winter wheat is planted after the summer and is harvested during the following summer. Spring wheat is planted during the spring and is harvested during the fall. Moreover, within winter and spring wheat six types of wheat can be distinguished in function of colour, hardness and percentage of protein. Each class of wheat is adopted to a particular set of planting condition depending on the specific region. All together they allow United States to produce a supply covering different period of the year for different uses. The most important class of wheat is called hard red winter that is grown prevalently in great plains. This wheat accounts for 40% of the wheat exported by United States every year. Hard red spring wheat, grown in the north central states has the highest quality according to the high content of protein (13-14%) and covers over 20% of the wheat exported every year. The same percentage is estimated for the soft white wheat growing in the pacific northwest cost and exported prevalently to Asia and middle east. Less important, in terms of exports, are the class called Soft red winter wheat and the durum wheat used mainly for pasta. Finally, hard white wheat , grown in different regions, is mainly used on the domestic market demand.

4.6 World wheat imports.

World wheat import market is not so concentrate like world wheat production and export markets in term of predominant countries and regions. Another important aspect to keep in mind is that two major countries in producing and usage such as China and India focus on domestic usage of wheat without affecting in a massive way the trade. The 10 largest world wheat importing regions account for an average of 95% of world wheat imports over the last 24 years.

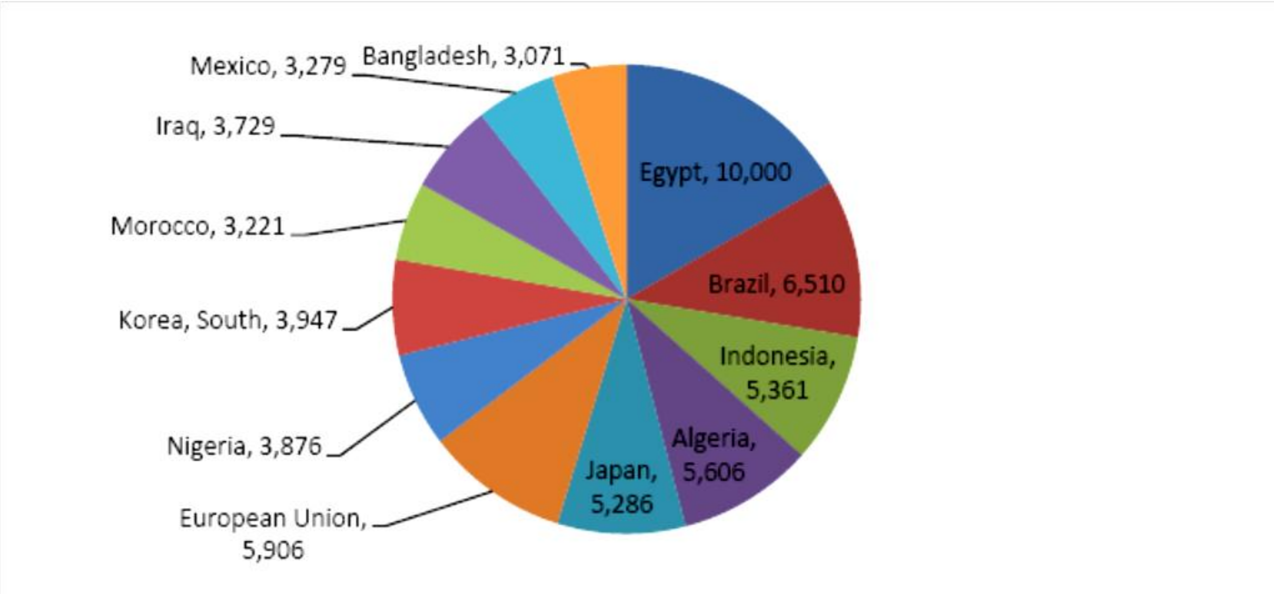
Figure 4.12: World wheat imports by region 1987/88 to 2010/11



Source: O’Brien (2011), Agmanager.info article.

More in detail, world wheat imports in the 2010/11 marketing year has been estimated by O’Brien (2011) to be over 122 million tons, that compared to the average world wheat imports of 107 million tons during the last 24 years, means an increases of about 1 million tons per year since 1987/88. Considering only the last three marketing years since 2008/09, the most important importing country has been Egypt with an average of 10 million tons during the period considered. Then Brazil and European union with 6,5 and 6 million tons respectively as showed in figure 4.13 below.

Figure 4.13: Top 12 wheat importing countries average of 2008/09 to 2010/11



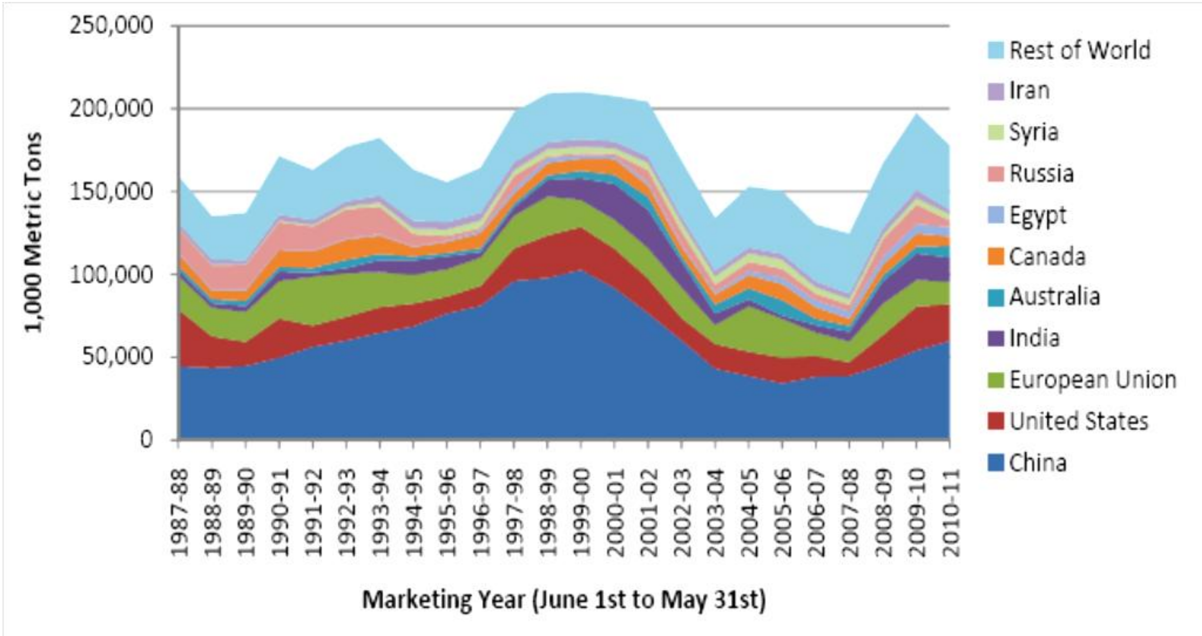
Source: O'Brien (2011), Agmanager.info article.

According to figure 4.13 , North Africa is the first wheat importing region over the 3 most recent marketing years.

4.7 World wheat Ending stocks and world wheat ending stock-to-use

Total world wheat ending stocks are estimated in different way according to the source. O'Brien (2011) estimates a total world wheat ending stock close to 177 million tons in the 2010/2011 marketing year. On the other hand, FAO (2011) suggests an ending stock close to 182 million tons for the same marketing year. Nevertheless, both the reports show how ending stocks of wheat in world markets tend to be concentrated in a limited number of countries or regions. Using O'Brien (2011) data, ending stocks has increased by 174.000 tons per year during the last 24 year since the amount of 168 million tons in the 1987/88 marketing year. The 10 largest world wheat countries or regions in terms of ending stocks had an average of 80,7% of total world wheat stocks over the 1987/88 to 2010/11 period of time.

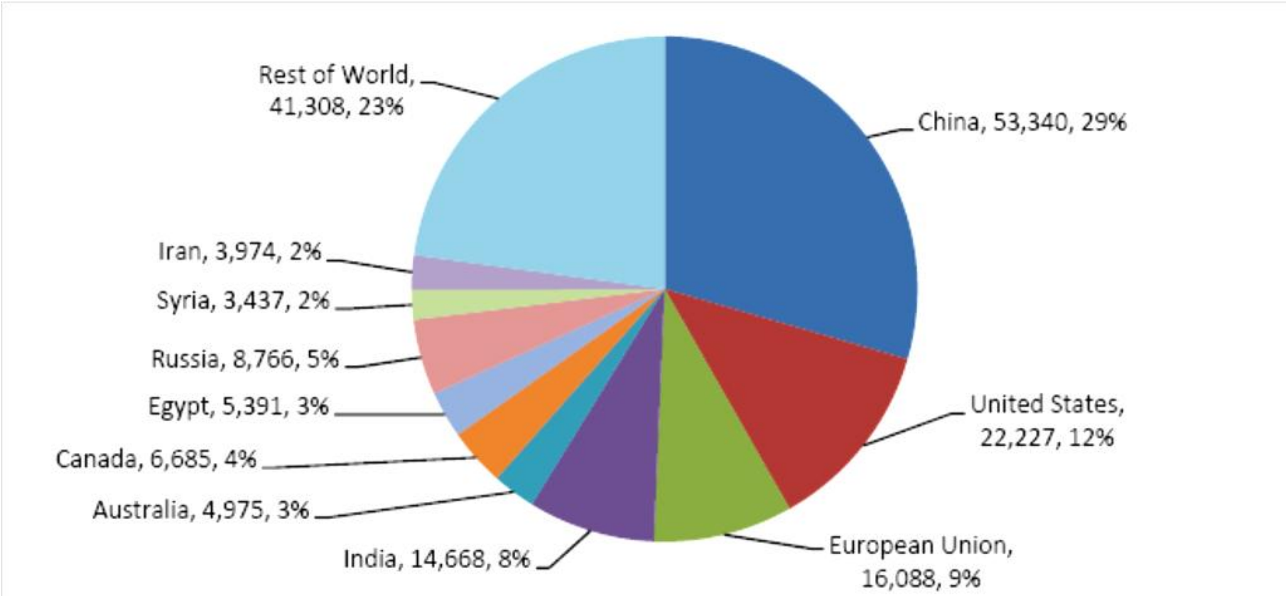
Figure 4.14: World wheat ending stocks by country



Source: O'Brien (2011), Agmanager.info article.

Focusing on the most recent three year, the three largest countries account for more than 50% in terms of average world wheat ending stocks. In details China accounts for 29%, United States and European Union hold 12% and 9% respectively. The leadership of China in world wheat ending stocks was much more sensible until 2000/01 marketing year. In fact China held 47% of world's ending wheat stocks during the period between 1997/98 and 2000/2001 that is much more higher than the level estimated during the most recent years.

Figure 4.15: World wheat ending stocks by country. Average of 2008/09 to 2010/11 (1000 tons)

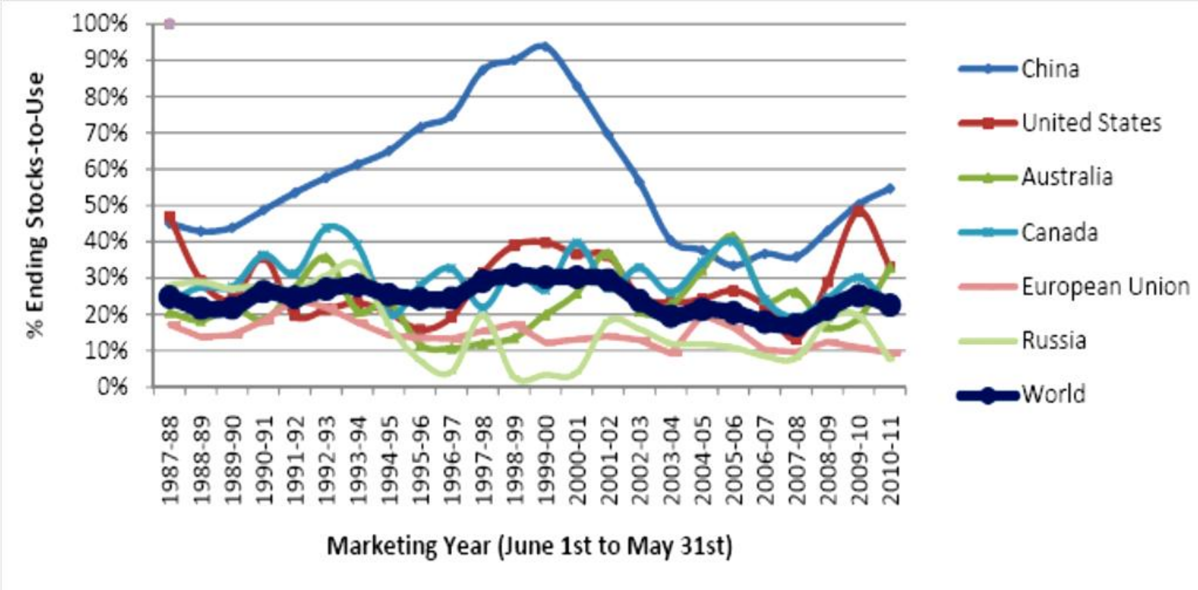


Source: O'Brien (2011), Agmanager.info article.

According to International Grain Council outlook, world wheat stocks are projected to stay relatively ample in the next five years. Those of the major exporters are projected to maintain the same level as currently at least until 2016/17.

Historical dynamic of world wheat ending stocks is better represented using the wheat ending stocks to use ratio. Since the 1987/88 marketing year, the average world wheat ending stocks to use ratio is estimated to be 24,5%, higher than the value estimated for the 2010/11 marketing year (22,6%). In details, since 2001/02, world ending stocks to use ratio have averaged 21,9%, with a decreasing trend of 0,4% per year. The figure below illustrates the annual value for the world ending stocks to use ratio since 1987/88 marketing year showing the negative trend during the previous decade and the recovery attempt during the 2008-10 years and the recent declining in the 2010/11 due to serious wheat production problem in various major producing regions.

Figure 4.16: Wheat % ending stocks to use since 1987/88



Source: O'Brien (2011), Agmanager.info article.

5. GLOBAL VECTOR AUTOREGRESSIVE MODEL (G_VAR)

In this piece of research we model the impact of the main factors behind the wheat export price dynamic. More in details the research consists in a worldwide dynamic model that provides short and long-run impulse responses of wheat prices to various real and exogenous shocks. Specifically, a Global Wheat Market Model (GLOWMM) to study the export wheat market dynamics will be proposed.

The model is specified by using a Global Vector Autoregressive (GVAR) modelling approach with exogenous variables in line with the pioneering work of Pesaran et al. (2004) and the more recent studies introduced by Dèes et al. (2007). The methodology allows to model the export countries, and to aggregate the single country models into a global model by using weighting matrices mainly based on the share of wheat international market (measured in term of export) of each country.

In other words, the GVAR model includes different models that are modelled individually as a Vector Autoregressive (VAR) model. In our case, each analysed country is modelled as VAR augmented by weakly exogenous variables (VARX). In its turn, each country model is linked to the others by including the weakly exogenous variables. After estimating the country models, their corresponding estimates are connected through link matrices and then piled up together to build the GVAR model.

The methodology allows to model EU and non-EU countries, and to aggregate the single regional VARX models into a global model by using weighting matrices mainly based on the share of wheat international market (measured in term of export) of each country.

In essence the model provides a general and practical modelling framework for quantitative analysis of the relative importance of different shocks on agro-food sectors. Specifically, using this strategy we analyze channels of transmission from external shocks but also integration properties of the series and the long-run relationships among the variables. Among the different sources of shock that can be analyzed by the model, we show that low level of stock may exert an important role in determining wheat prices during the period of analysis and the model allows to provides new evidence on the relevance of this factor in influencing food prices.

In order to analyze the results, the Generalized Impulse Response Functions (GIRFs) proposed in Koop, Pesaran and Potter (1996) will be employed. GIRFs present an advantage in the GVAR framework that make these tools more appealing compared to others. In fact, they are invariant to the ordering of the variables and of the countries as well explained by Galesi and Lombardi (2009). In our multi-country analysis it is preferable to use the GIRFs because does not exist any clear economical ordering reason of the countries.

5.1 A global model for the analysis of the wheat world market

We analyze the dynamics of wheat prices focusing on the six main export countries, USA, Argentina, Australia, Canada, Russia and EU. For each country we assume that the country-specific variables are related to the global economy variables measured as country-specific weighted average of foreign variables plus deterministic variables, such as constant and time trend, and global exogenous variables such as oil prices. To analyze the relationship between country-specific variables and global variables we use the Global Vector AutoRegression (GVAR) methodology proposed by Pesaran et al. (2004) and Dees et al. (2007) as it have been already specified.

The GVAR approach is particular appealing for the analysis of the worldwide wheat market for two reasons. First, it is specifically designed to model fluctuations and interactions between countries. This is a crucial asset given the features of world wheat market and the global dimension of the food prices crisis that cannot be downsized to one country, rather involves a large number of countries. Secondly, the GVAR allows to model the dynamic of wheat export prices as results of the effects exerted by the country-specific and by foreign-specific variables. The foreign-specific variables are defined as weighted average of wheat export prices, the stock to utilization ratio and the effective exchange rate fluctuations in all competitor countries. Thus both country-specific as foreign-specific effects can be jointly modelled. Finally the GVAR model combines a number of atheoretic relationships. Unlike structural models, as for example general equilibrium models, the approach does not attempt to make restrictions, for example on the basis of economic theory.

In our approach, in line with Pesaran et al. (2004), each country model is individually estimated by assuming weak exogeneity for both global foreign-specific variable and global variables: this accounts to assume the small economy hypothesis for each country. In other words, wheat export prices are worldwide determined and there is not a leader country. "The individual country models are then combined in a consistent and cohesive manner to generate forecast impulse response function for all the variables in the world economy simultaneously." (Pesaran et al. 2004:130).

The specification of the model proceeds in two stages. The first stage is the estimation stage of the following reduced form augmented vector autoregression, VARX(*p*,*q*), model for each country *i* in our sample, while in the second stage we stack all six individual country VARX models and link them using a weight matrix.

In the first step, we model each country as a VARX(*p*,*q*),

$$\phi_i(L, p_i)y_{it} = a_{i0} + \Lambda_i(L,q_i)y^*_{it} + \Psi_i(L,q_i)d_t + \varepsilon_{it} \text{ con } i=0,1...N \; t=1,..,T. \quad (1)$$

Where

a_{i0} is a $(K_i \times 1)$ coefficient vector of the deterministic intercept;

y_{it} is a $(K_i \times 1)$ vector of country specific (domestic) variables and corresponding $(k_i \times k_i)$ matrices of lagged coefficients, denoted by $\phi_i(L, p_i)y_{it} = I - \sum_{p=1}^{p_i} \phi_i L^i$, where L is the lag operator.

y^*_{it} is a $(k_i \times 1)$ vector of trade-weighted foreign variables and corresponding $(k_i \times k^*_i)$ matrix lag polynomial denoted by $\Lambda_i(L,q_i)$.

$\Psi_i(L,q_i)$ is a matrix lag polynomial associated to the global exogenous variables d_t. As observed by Pesaran et al. (2004) the distinction between foreign variables y_{it} and the global exogenous variable d_t is relevant for the analysis of the dynamic properties of the global model but it is not important for the estimation of the country specific variables. For this reason, d_t and y_{it} will be combined and considered both as weakly exogenous variables.

Finally ε_{it} is a $(k_i \times 1)$ vector of zero mean, idiosyncratic country-specific shocks, assumed to be serially uncorrelated with a time invariant covariance matrix $\sum_{ii}$, i.e. $\varepsilon_{it} \sim iid(0, \sum_{ii})$.

The GVAR model assumes, for inference and estimation purpose, the weak exogeneity assumption of y^*_{it}, rules out long run feedbacks from y_{it} to y^*_{it}. It means that the world price, exchange rate and stocks are exogenously given. As suggested by Pesaran et al. (2004:132) "whether such exogeneity assumption hold in practice depends on the relative sizes of the countries or regions in the global model and on the degree of cross-country dependence of the idiosyncratic shocks, ε_{it}, as captured by the cross-covariances Σ_{ij}."

Next, we determine the order of the dynamic specification according to the Akaike information criterion (AIC). We allow at maximum for a VARX (3,1) specification to reduce the number of estimated parameters and avoid degrees of freedom problems. In the second stage of the GVAR methodology, we cast the country-specific models into their global representation. All routines have been written using GAUSS 11.0.

To show how the global model is constructed let's consider a generic country *i* in (1) with p_i and q_i equal to 2.

$$y_{it} = a_{i0} + \Phi_{i1} y_{it-1} + \Phi_{i2} y_{it-2} + \Lambda_{i0} y_{it}^{*} + \Lambda_{i1} y_{it-1}^{*} + \Lambda_{i2} y_{it-2}^{*} + \varepsilon_{it}. \quad (2)$$

According to Pesaran's notation (2004):

Φ is a $k_i \times k_i$ matrix of lagged coefficients, $\Lambda_{i0,}\Lambda_{i1,}\Lambda_{i2}$ are $k_i \times k_i^{*}$ matrices of coefficients associated with the foreign specific variables constructed as weighted averages, with country/region specific weights. ε_{it} is a $(k_i \times 1)$ vector of zero mean, idiosyncratic country-specific shocks, assumed to be serially uncorrelated with mean = 0 and a time invariant covariance matrix $\sum_{ii}$, i.e. $\varepsilon_{it} \sim iid(0, \sum_{ii})$.

In particular, y_{it} will include the wheat export prices p_{it}^{e}, the wheat stock to utilization ratio z_{it}, the real exchange rate rer_{it} measured as the ratio of the local currency per unit of US dollars (e_{it}) deflated by the export price p_{it}^{e}, and finally the fertilizer price pf_{it} expressed in US dollar. In a formal way we have y_{it} =($p_{it}^{e}, z_{it}, rer_{it}$, pf_{it}) with k_i =4.

Let's note that the real exchange rate of the country *i* at time *t* in term of the currency of the country *j* that means in terms of US dollar. Note that in the case of US, e_{it} =0 and y_{it} =(p_{it}, z_{it}, pf_{it}) with k_i =3. Moreover, in the case of countries or regions that try to maintain a fixed effective or nominal rate by anchoring their currency to a basket of currency or to the US dollar exchange rate, there will be a close correlation between e_{it} and e_{it}^{*}. Under the econometric point of view, in order to avoid this correlation problem, it would be better to not include e_{it}^{*} as an exogenous variable in y_{it}^{*}. The inclusion of e_{it} in the model is considered sufficient to include any effects of exchange rate variations on the domestic economy.

The foreign variables denoted by y_{it}^*, is a $k_i^* \times 1$ vector, where k_i^*=4 or 3 in our model. As already said, foreign variables are constructed as weighted averages, with country or region specific weights:

$$y_{it}^* = (p_{it}^{e*} + z_{it}^* + rer_{it}^* + pf_{it}^*),$$

With Pesaran's notation (2004):

$$p_{it}^{e*} = \sum_1^N w_{ij}^p p_{jt}^e, \qquad z_{it}^* = \sum_1^N w_{ij}^z z_{jt},$$

$$rer_{it}^* = \sum_2^N w_{ij}^e e_{jt}, \qquad pf_{it}^* = \sum_1^N w_{ij}^{pf} pf_{jt},$$

The weight $w_{ij}^p, w_{ij}^z, w_{ij}^{rer}, w_{ij}^{pf}$ for *i*,*j*=1…N are based on trade shares, that means the share of country *j* in the total trade of country *i* measured in U.S. dollars. Glick and Rose (1999) cited by Pesaran et al. (2004:131) stressed the importance of trade links in the analysis of contagion. According to the authors it would have been better to vary the weights over time "to capture secular movements in the geographical patterns of trade and capital flows". However, in line with Pesaran et al (2004), in our research we used fixed trade weights in order to avoid "an undesirable degree of randomness into the analysis" but base their computation on the average of trade flows over the period 2008-2010 from International Grain Council data. Using Pesaran's definition (2004:131), w_{ij} "can be measured as the total trade between country *i* and country *j* divided by the total trade of country *i* with all its trading partners, where w_{ii}=0 for all *i*."

5.2 The solution of the GVAR model

As suggested by Pesaran et a. (2004:132) it should be clear now that the GVAR model allows for interactions among the different countries included in the model through three separate but interconnected channels. Firstly the contemporaneous dependence of the country specific variables on the foreign specific variables; secondly through the dependence of the country-specific variables on common global exogenous variable such as the oil prices; and finally, "nonzero contemporaneous dependence of shocks in country *i* on the shocks in country *j*, measured via the cross-country covariances, Σ_{ij}."

To define the GVAR model from the VARX country specific model, the first thing to do is to construct the $(k_i + k_i^*) \times 1$ vector grouping both the domestic and foreign variables for each country:

$$z_{it} = \begin{pmatrix} y_{it} \\ y_{it}^* \end{pmatrix}, \tag{3}$$

Therefore each country VARX model (2) becomes

$$A_i z_{it} = a_{i0} + B_{i1} z_{it-1} + B_{i2} z_{it-2} + \varepsilon_{it}, \tag{4}$$

Where

$$A_i = (I_{K_i}, -\Lambda_{i0}),\ \ B_{i1} = (\Phi_{i1}, \Lambda_{i1}),\ \ B_{i2} = (\Phi_{i2}, \Lambda_{i2}). \tag{5}$$

Note that A_i and B_i are both $k_i \times (k_i + k_i^*)$.

In the next step we create a vector of *global* variables, it means that the countries specific variables can be all written in terms of y_t;

$$y_t = \begin{pmatrix} y_{0t} \\ y_{1t} \\ \vdots \\ y_{Nt} \end{pmatrix}, \tag{6}$$

and using the weight matrix W_i constructed from the export weights of each country we obtain the following identity

$$z_{it} = W_i y_t \quad \forall i = 0,1,...,N. \tag{7}$$

It should be clear that W_i represents a $(k_i + k_i^*) \times k$ matrix of fixed constants defined in terms of the country specific weights $w_{ij}^p, w_{ij}^z, w_{ij}^e, w_{ij}^{pf}$. Using Pesaran et al.'s words (2004:132), "W_i can be viewed as the link matrix that allows the country specific models to be written in terms of the global variable vector , y_t.

The previous relationship allows each country model to be written in terms of the global vector y_{it}. This is the fundamental device through which each country wheat market is linked to the global GVAR model. Using now the identity (7) and (4) we obtain

$$A_i W_i z_{it} = a_{i0} + B_{i1} W_i z_{it-1} + B_{i2} W_i z_{it-2} + \varepsilon_{it}, \tag{8}$$

for *i* = 0,1…,N.

where $A_i W_i$ and $B_i W_i$ are both $k_i \times k$ -dimensional matrices.

Finally by stacking each country-specific model in (8), we end with the Global VAR for all endogenous variables in the system, y_{it} ,

$$Gy_{it} = a_{i0} + H_1 y_{it-1} + H_2 y_{it-2} + \varepsilon_t \quad (9)$$

where

$$G = \begin{pmatrix} A_0 W_0 \\ A_1 W_1 \\ \vdots \\ A_N W_N \end{pmatrix}, \; H_1 = \begin{pmatrix} B_{01} W_0 \\ B_{11} W_1 \\ \vdots \\ B_{N1} W_N \end{pmatrix}, \; H_2 = \begin{pmatrix} B_{02} W_0 \\ B_{12} W_1 \\ \vdots \\ B_{N1} W_N \end{pmatrix}, \; a_0 = \begin{pmatrix} a_{00} \\ a_{10} \\ \vdots \\ a_{N0} \end{pmatrix}, \; \varepsilon_t = \begin{pmatrix} \varepsilon_{0t} \\ \varepsilon_{1t} \\ \vdots \\ \varepsilon_{Nt} \end{pmatrix}.$$

The **G** matrix is a $k \times k$ -dimensional matrix, of full rank and, for these reasons, it is non singular. Hence, we can invert it obtaining the Global wheat VAR model in its reduced form

$$y_t = b_0 + F_1 y_{t-1} + F_2 y_{-2} + v_t \quad (10)$$

where

$$F_1 = G^{-1} H_{1,} \; F_2 = G^{-1} H_{2,} \; b_0 = G^{-1} a_0, \; v_t = G^{-1} \varepsilon_t.$$

5.3 The dataset and empirical results

In the application we employ data for the main six wheat export countries Argentina, Australia, Canada, Russia, EU and USA at monthly frequency for the period July 2000 to January 2012. During the last three years period (200/9-2011/12), according to O’Brien (2011), the three largest countries in terms of average world wheat production were the EU, China and India that together provided almost the 50% of the global wheat production followed by US (9%) and Russia (8%). Nevertheless, China and India represent two of the most important wheat producers, they have a little role in trade word market focusing mostly in domestic market. In fact, during the same interval of time the largest exporting countries are US (21%), EU (17%), Canada (14%), Russia (10%), Australia and Ukraine (11% and 7% respectively). These six countries counts, in average, for more than 80% of word wheat export.

The GVAR model includes five variables for each country-specific VARX model: the wheat export prices p_{it}^{e}, the wheat stock to utilization ratio z_{it}, the real exchange rate rer_{it} measured as the ratio of the local currency per unit of US dollars (e_{it}) deflated by the export price p_{it}^{e}, and finally the fertilizer price pf_{it} expressed in US dollar. We first build the indexes of all variables using the period (July/2000 June/2001)=100 as the base year. All variables, with the exception of the stock to utilization ratio, are logs transformed. In the appendix B we present the data sources and the key steps used for their analysis.

The foreign-specific variables are constructed as (geometric) average of the single country variables using as weights the export-country shares. The weights are presented in Table 5.1. The choice of weights based on exports is undertaken with the rationale that exogenous shocks, as a wheat stock reductions and exchange rate devaluation, could pass-through on export prices in all countries through the trade channel. We use fixed weights over time computed as average of the years 2008-2010. Data are from the International Grain Council.

Table 1: Trade Weights Based on Wheat Export Statistics

Variables	Argentina	Australia	Canada	Russia	EU	USA
Argentina	0.00000	0.12179	0.16149	0.32007	0.18444	0.21220
Australia	0.04941	0.00000	0.17480	0.34646	0.19965	0.22969
Canada	0.05163	0.13775	0.00000	0.36201	0.20861	0.24000
Russia	0.06291	0.16786	0.22257	0.00000	0.25420	0.29246
EU	0.05300	0.14142	0.18752	0.37166	0.00000	0.24640
USA	0.05477	0.14613	0.19376	0.38404	0.22130	0.00000

Notes: International Grain Council. Trade weight are computed as average of shares of exports over the period 2008-2010. They are displayed in row by country. Each row, but not column, sums to 1.

The trade share of each country is displayed in rows. This matrix play a fundamental role in the models linking together each country model and showing how each country depends on the remaining countries. For instance, looking at the matrix it should be clear how Canada is much more integrated with the US wheat market than the rest of the countries. On the other hand, the trade weights show that Italy is strongly integrated with the France wheat market than the rest of the countries.

Thus, both country-specific and foreign-specific variables will affect the system. For example, wheat export prices in a specific country will be influenced by domestic variables as the stock to utilization ratio, the real exchange rate, the dynamics of fertilizer input prices and by the foreign-specific variables given by the average wheat stocks to utilization ratio and the real effective exchange rate of its competitors. Wheat export prices will be also influenced by global variables, i.e. variables common to all countries, as the oil price p_t^o.

The first step in the analysis is to test the non-stationary properties of our series and to select appropriate transformations of the domestic and foreign variables for inclusion in the country specific cointegrating VAR models. The results are presented in Table 5.2.[6] Given that the majority of the series are $I(1)$, the cointegrating VARX country models are estimated subject to the reduced rank restriction (Johansen, 1992 and 1995).

Table 2: Augmented Dickey-Fuller unit root statistics for Domestic and Foreign Variables

Variables	Argentina	Australia	Canada	Russia	EU	USA
p_{it}^e	-1.610	-2.530	-1.735	-1.484	-1.339	-1.901
z_{it}	-1.100	-3.088	-2.959	-2.411	-1.489	-1.953
rer_{it}	-2.800	-1.669	-0.500	-0.500	-1.539	-
p_t^f	-1.190	-1.190	-1.190	-1.190	-1.190	-1.190
p_{it}^{e*}	-1.370	-1.324	-1.367	-1.386	-1.787	-1.510
z_{it}^*	-2.006	-2.363	-1.822	-2.243	-2.857	-2.827
rer_{it}^*	-1.574	-1.640	-1.380	-2.623	-1.323	-1.576
p_t^{o*}	-1.109	-1.109	-1.109	-1.109	-1.109	-1.109

Notes: The ADF statistics are based on univariate *AR(p)* models in the levels with *p* chosen according to the Ng and Perron (2001) procedure. The regressions for all variables include an intercept. The 95% critical value of the ADF statistics for regressions without trend is -2.59.

To this end we employ the trace and maximum eigenvalue statistics. Both tests are conducted at the 95% significance level when a restricted intercept is included in the model. The rank statistics are reported in Table 5.3, while the number of cointegrating relationships for each VARX country model and the VARX autoregressive orders *p, q* are reported in table 5.4. The VARX orders are estimated using the Akaike criterion. For all country models, with the exception of Australia, the rank tests suggest one cointegration

[6] All the procedures for the analysis of the GVAR model have been written using GAUSS 11.

relation. For Australia, both tests indicate the presence of two cointegrating relations. Thus, each country model has been estimated using its Vector Error Cointegration (VEC) form or, in other words, each country model is estimated subject to reduced rank restriction.

Table 5.3: Cointegration Rank Statistics

Country	Trace				Maximum Eigenvalue			
	H_0	H_1	Statistics	95% Cr. Values	H_0	H_1	Statistics	95% Cr. Values
Argentina	$r = 0$	$r > 1$	96.24	90.60	$r = 0$	$r = 1$	44.87	40.19
	$r < 1$	$r \geq 2$	51.37	63.10	$r < 1$	$r = 2$	28.01	34.15
	$r \leq 0$	$r \geq 3$	23.36	39.94	$r \leq 2$	$r = 3$	13.17	27.82
	$r \leq 0$	$r \geq 4$	10.20	20.63	$r \leq 3$	$r = 4$	10.20	20.63
Australia	$r = 0$	$r > 1$	127.91	90.60	$r = 0$	$r = 1$	51.39	40.19
	$r < 1$	$r \geq 2$	76.52	63.10	$r < 1$	$r = 2$	39.04	34.15
	$r \leq 0$	$r \geq 3$	37.48	39.94	$r \leq 2$	$r = 3$	20.14	27.82
	$r \leq 0$	$r \geq 4$	17.34	20.63	$r \leq 3$	$r = 4$	17.34	20.63
Canada	$r = 0$	$r > 1$	124.43	90.60	$r = 0$	$r = 1$	48.74	40.19
	$r < 1$	$r \geq 2$	75.59	63.10	$r < 1$	$r = 2$	33.18	34.15
	$r \leq 0$	$r \geq 3$	42.40	39.94	$r \leq 2$	$r = 3$	27.93	27.82
	$r \leq 0$	$r \geq 4$	14.47	20.63	$r \leq 3$	$r = 4$	14.47	20.63
Russia	$r = 0$	$r > 1$	99.37	90.60	$r = 0$	$r = 1$	45.04	40.19
	$r < 1$	$r \geq 2$	54.33	63.10	$r < 1$	$r = 2$	21.79	34.15
	$r \leq 0$	$r \geq 3$	32.54	39.94	$r \leq 2$	$r = 3$	20.89	27.82
	$r \leq 0$	$r \geq 4$	11.65	20.63	$r \leq 3$	$r = 4$	11.65	20.63
EU	$r = 0$	$r > 1$	102.52	90.60	$r = 0$	$r = 1$	40.53	40.19
	$r < 1$	$r \geq 2$	61.99	63.10	$r < 1$	$r = 2$	36.06	34.15
	$r \leq 0$	$r \geq 3$	25.93	39.94	$r \leq 2$	$r = 3$	15.28	27.82
	$r \leq 0$	$r \geq 4$	10.65	20.63	$r \leq 3$	$r = 4$	10.65	20.63
USA	$r = 0$	$r > 1$	64.15	90.60	$r = 0$	$r = 1$	37.41	40.19
	$r < 1$	$r \geq 2$	26.75	63.10	$r < 1$	$r = 2$	22.07	34.15
	$r \leq 0$	$r \geq 3$	4.67	39.94	$r \leq 2$	$r = 3$	4.67	27.82

Notes: the null Hypothesis *(H_0)* indicates *r* cointegration vectors against the alternative hypothesis *(H_1)* of (at most) *r+1* cointegration vectors for the maximum eigenvalue (trace) test. *R* is chosen as the first non significant statistics, undertaking sequentially the test starting from $r = 0$.

Table 5.4: VARX Order and Number of Cointegrating Relationship

Country	p_i	q_i	Cointegrating Relationship
Argentina	1	1	1
Australia	3	1	2
Canada	1	1	1
Russia	3	1	1
EU	1	1	1
USA	3	1	1

Notes: Rank orders are derived using Johansen's trace statistics at the 95% critical value level.

The estimation of the cointegrating VEC models gives the opportunity to analyze the effects of foreign variables on their domestic counterparts. Specifically, the model allows for the analysis of the impact on the domestic variables of a 1% change of the corresponding foreign-specific variables.

These impacts have been labelled as *impact elasticities* and permit the analysis of the co-movements among the domestic and foreign variables. In table 5.5, we present the impact elasticities and their *t*-statistics. Looking at wheat export prices, we find that all the estimates are positive and significant, with the exception of Russia estimate that is not significant at the 5% significance level. Moreover, USA, Canada and Australia show an impact elasticity close to one. Positive but mainly non significant co-movements are evidenced by the real exchange rate variable. EU is the only region that shows a positive an significant estimate. Finally the stock-to utilization ratio variable presents both positive and negative co-movements. Argentina reports a negative and significant correlation, the elasticity for Russia is negative but not significant. The elasticities are positive and significant for the remaining countries.

Table 5: Contemporaneous Effects of Foreign variables on Domestic-Specific Counterparts

Country	p_{it}^{e*}	z_{it}^{*}	rer_{it}^{*}
Argentina	0.323	-0.534	0.763
	(3.013)	(-8.369)	(0.109)
Australia	0.995	0.872	0.402
	(4.426)	(7.666)	(1.727)
Canada	1.191	0.629	-0.134
	(3.817)	(8.172)	(-0.368)
Russia	0.311	-0.119	0.672
	(0.647)	(-0.905)	(1.412)
EU	0.729	0.088	0.89
	(4.495)	(6.269)	(3.814)
USA	0.980	0.214	- -
	(7.754)	(2.928)	(- -)

Notes: in parentheses the p-values

The GVAR model requires to account for the hypothesis of weak exogeneity for both the foreign and global variables. We use the exogeneity test proposed by Johansen (1992). For each country-specific model, the following regression is performed

$$\Delta y_{it,l} = \mu_{il} + \sum_{j=1}^{r_i} \gamma_{ij,l} ECM_{i,t-1}^{j} + \sum_{k=1}^{p_i} \phi_{ik,l} \Delta y_{i,t-k} + \sum \theta_{ik,l} \Delta \tilde{y}_{i,t-m} + \varepsilon_{it,l} \quad (11)$$

where the $\Delta y_{i,t-k}$ is the group of domestic variables expressed in differences, with k = 1, ..., p_i and p_i is the lag order of the domestic component for each of i^{th} country model, $\Delta \tilde{y}_{i,t-m}$ is the set of foreign-specific and global variables in differences, with m = 1, ..., q and q is the lag order of the foreign-specific and global components for each of i^{th} country model, and finally $ECM_{i,t-1}^{j}$ is the estimated error correction term, with j = 1, ..., r_i, and r_i is the number of cointegrating relations, i.e. the rank found in the i^{th} country model. The procedure consists in testing by means of an F the joint hypothesis that $\gamma_{ij,l}$ = 0 for each j = 1, ..., r_i. Results of table 5.6 indicate that the hypothesis of weak exogeneity cannot be rejected.

Table 6: F Statistics for Testing the Weak Exogeneity of Country-specific Foreign and Global Variables

Country		p_{it}^{e*}	z_{it}^{*}	rer_{it}^{*}	p_{it}^{o}
Argentina	F (1,127)	1.673	0.657	2.684	0.682
		(0.194)	(0.419)	(0.104)	(0.410)
Australia	F (2,116)	0.729	1.248	1.016	0.756
		(0.485)	(0.291)	(0.365)	(0.472)
Canada	F (1,127)	0.222	0.203	0.628	1.558
		(0.638)	(0.653)	(0.429)	(0.214)
Russia	F (1,117)	0.195	0.257	0.359	0.007
		(0.660)	(0.613)	(0.550)	(0.728)
EU	F (1,127)	3.041	2.792	1.669	0.529
		(0.084)	(0.097)	(0.199)	(0.468)
USA	F (1,121)	1.101	0.154	- -	0.601
		(0.296)	(0.695)	(- -)	(0.440)

Notes: in parentheses the p-values

5.4 Impulse Response Analysis

In the absence of strong a *priori* information to identify the short-run dynamics of our system, we use the generalised impulse response function (GIRF) approach proposed in Koop, Pesaran and Potter (1996) and further developed in Pesaran and Shin (1996).

According to Pesaran et al. (2004:135), impulse response analysis "characterizes the possible response of the system at different future periods to the effects of shocking one of the variables in the model."In essence, using GIRF's properties it will be possible to depict the time profiles of the shock's effect on the global and endogenous variables of interest. Thanks to the GIRF, the effects of the shocks will be identified "as intercept shifts in the various equations using a historical variance-covariance matrix of the errors" (Pesaran et al., 2004:146). It should be highlighted that GIRFs results are invariant to the ordering of the countries in the GVAR model and this property makes it suitable for the analysis of dynamics of the transmission of shocks across countries. Hence, even if GIRF is not the right instrument to provide the formal economic interpretations about shock on fundamental elements such as demand, supply and policy shocks, GIRF provides "a historically consistent account for the interdependencies of the idiosyncratic shocks, particularly across different regions" (Pesaran et al., 2004:146).

To assess the dynamic properties of the GVAR model and the time profile of the effects of shocks to domestic foreign variables, we analyze the implications of five different external shocks:

- A one standard error negative shock to US stock to utilization ratio
- A one standard error negative shock to global stock to utilization ratio
- A one standard error positive shock to oil price
- A one standard error negative shock to real effective exchange rate
- A one standard error positive shock to fertilizer price

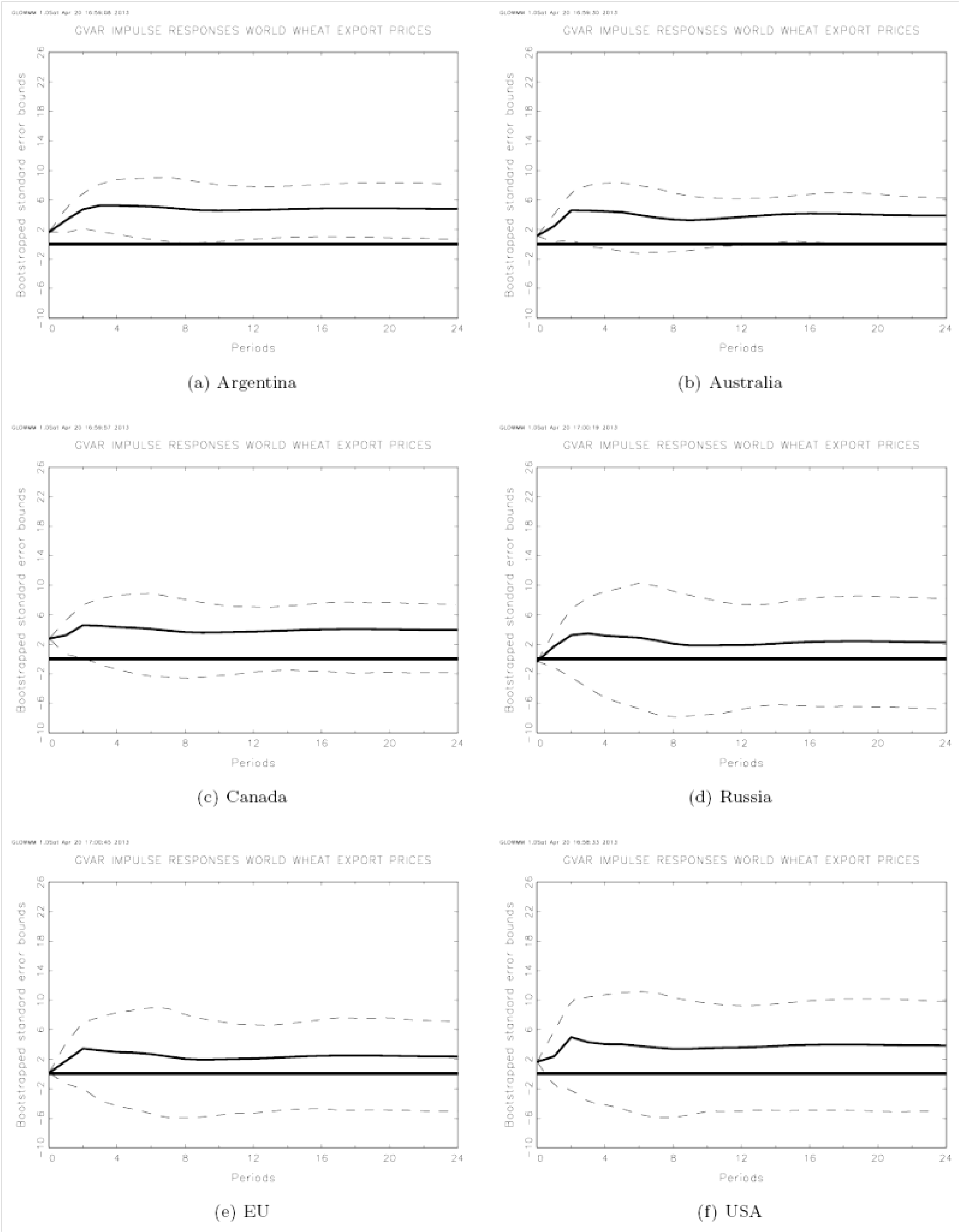
Due to space limitation we only present the GIRF impulse responses of the wheat export prices for the various countries analyzed and we focus on the first two years following the shock.

The first shock we consider is a negative shock to the USA stock to utilization ratio. In this case a one standard deviation shock corresponds to a decrease of 0.11% of the value of the variable.[7] In Figure 5.3, we show the effect of this shock on the wheat export prices with the solid line, while the 90% bootstrapped confidence intervals are represented by the thinner lines.[8] Unsurprisingly, a negative shock to US stock to utilization ratio raises the export prices in all countries. In US the response impact is +1.6%, after three months the wheat export price reaches the maximum of +4.9%. Similar shapes are evidenced by other countries. Argentina, Australia, Canada show similar impacts after the stock to utilization ratio shock, while Russia and EU present minor impact with long-run increase of wheat export prices close to +2.0%.

[7] During the period of analysis, the average value of the variable is 0.511

[8] The confidence interval is calculated using the sieve bootstrap method with 1000 replications.

Figure 5.3: GVAR Impulse Responses of Wheat Export Prices to a US Stock to Utilization Ratio Shock.

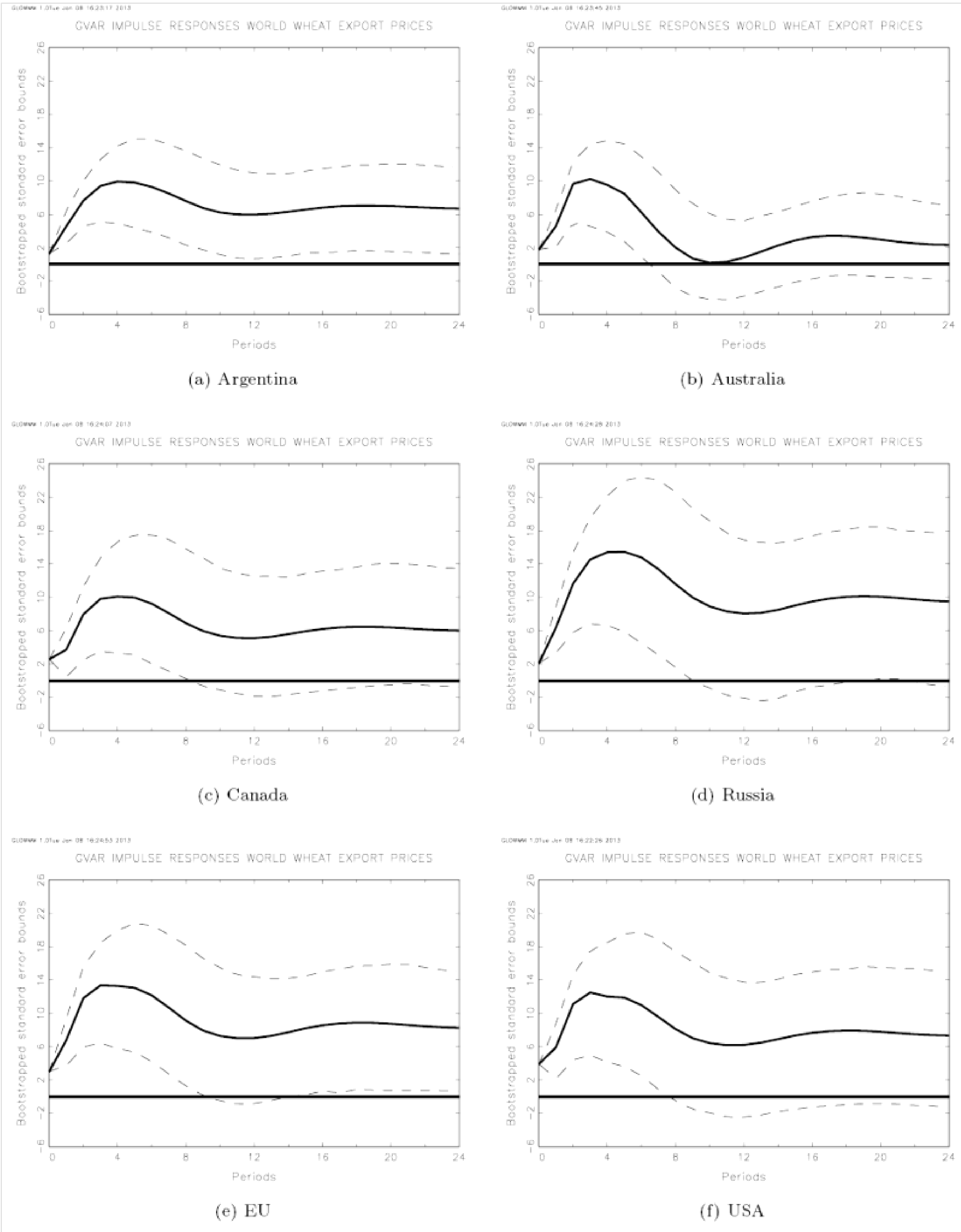


The second shock we analyze is what can be labelled *the perfect storm* of the stock to utilization ratio variable. We simulate a decrease of this variable in all countries, i.e. we assume a general reduction in stock detained by the main export countries.

The one-standard deviation shock corresponds in this case to an average decrease of 0.14%.[9] The impact on export prices is shown in Figure 5.4. As expected, the contemporaneous effect on wheat export prices is relevant. The export prices raise from the minimum value of +1.3% in Argentina to the maximum value of +3.0% in USA. Second-round effects are also relevant. Export prices in the first rapidly increase reaching values that ranges from +6.6% in Canada to +13.1% in Russia before reducing in the following months.

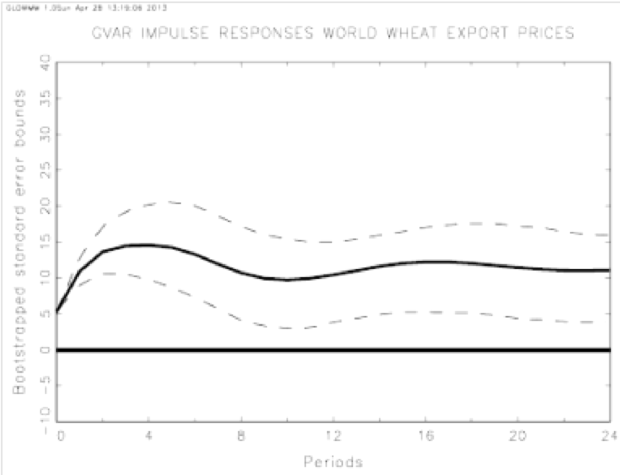
[9] This value has been obtained using single countries export shares

Figure 5.4: GVAR Impulse Responses of Wheat Export Prices to a Global Stock to Utilization Ratio Shock.

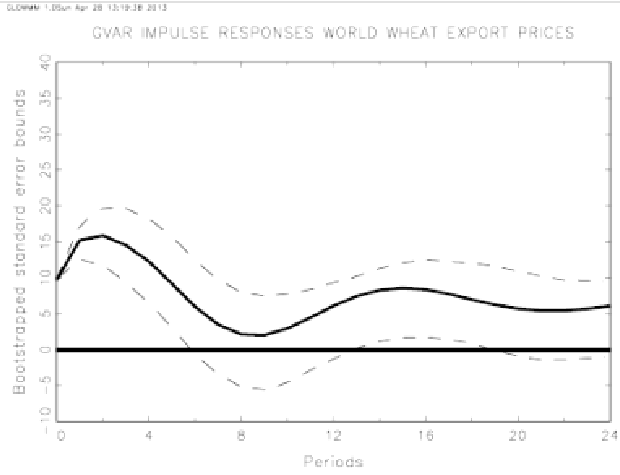


The devaluation of the US exchange rate has been ascribed as one of the main factors behind the commodity prices upsurge during the period 2007-2008. For this reason, we simulate the effect of devaluation of real exchange rate (RER) of US dollar. A one standard error shock in this case is equivalent to a fall of around 15% of the RER of US dollar against the competitors' currencies. Interestingly, the shock is accompanied by a raise of wheat export prices of the same entity. Thus, with the exception of Argentina and Australia that show a lower impact, on average we note an unitary elasticity of wheat export prices to a RER devaluation.

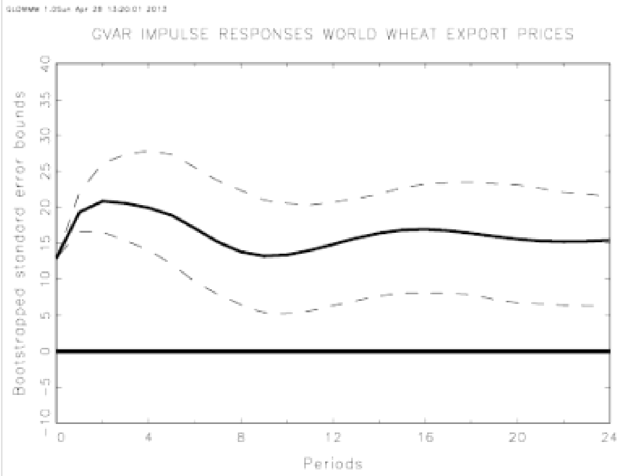
Figure 5.5: GVAR Impulse Responses of Wheat Export Prices to US dollar devaluation shock.



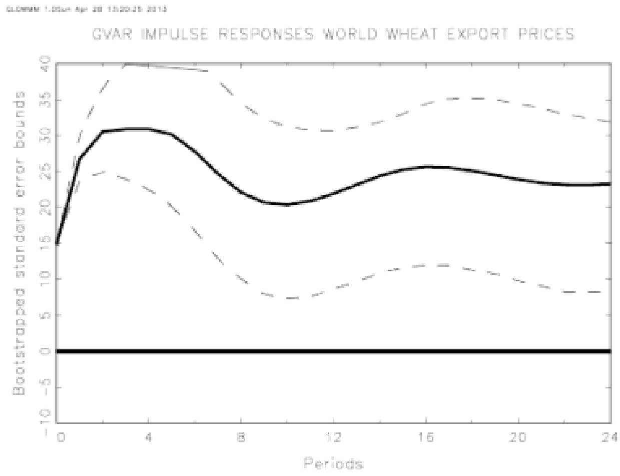
(a) Argentina



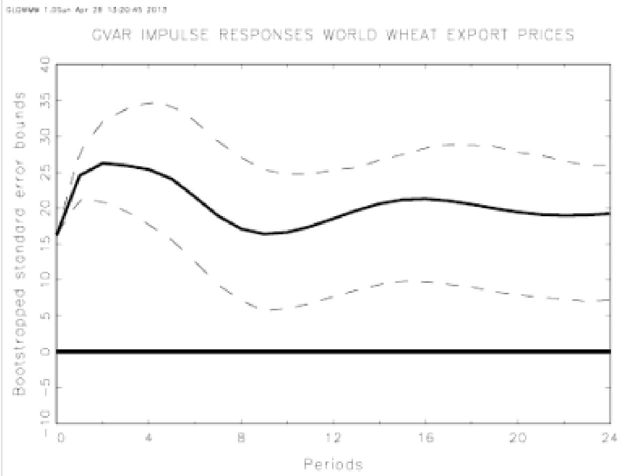
(b) Australia



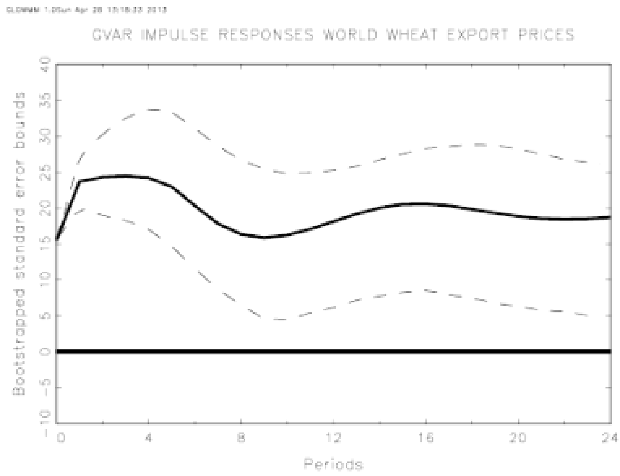
(c) Canada



(d) Russia



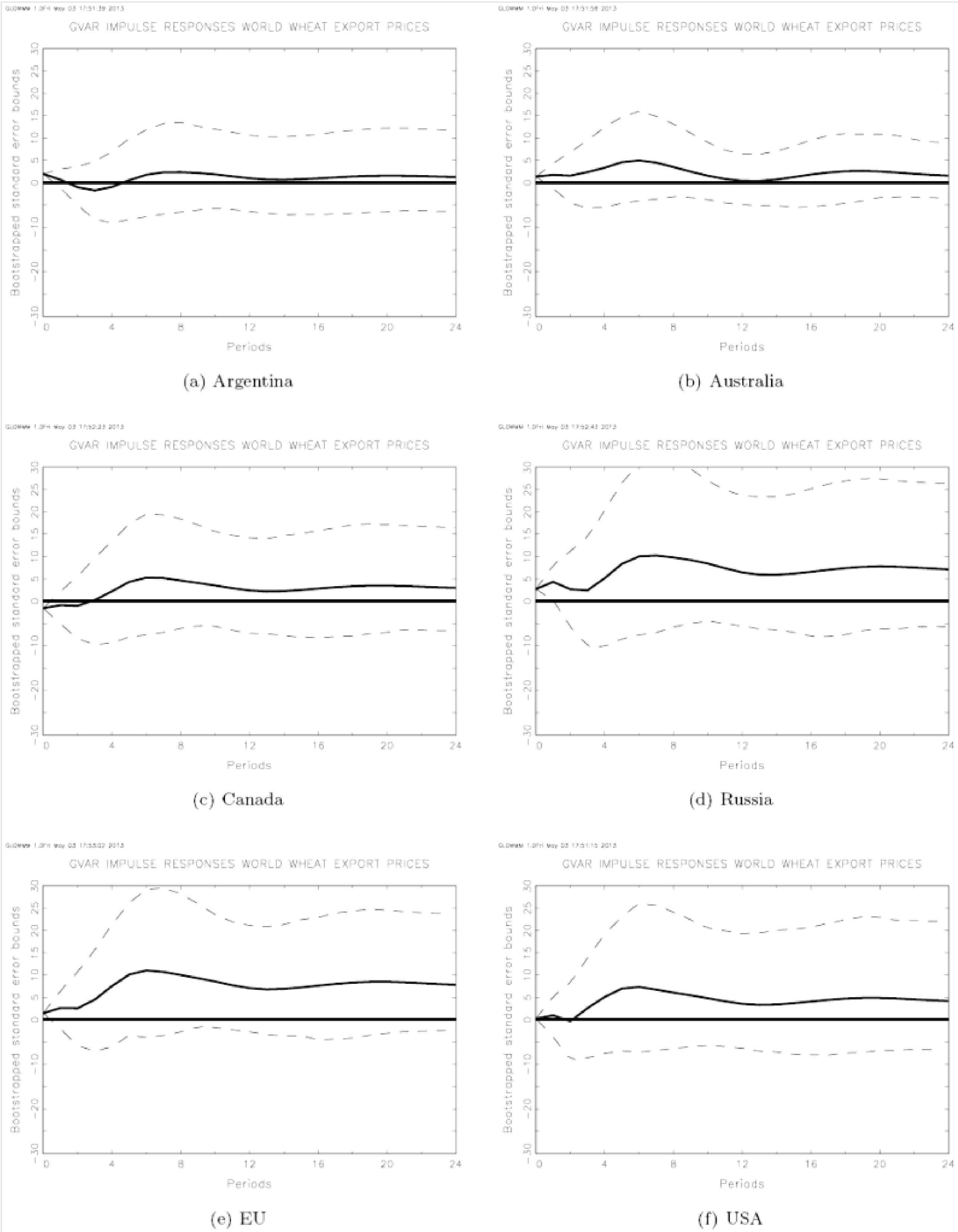
(e) EU



(f) USA

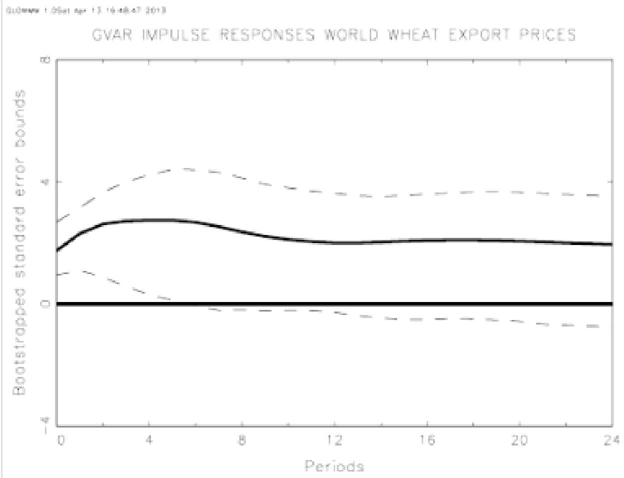
In Figure 5.6 are presented the impulse responses of a one standard error shock on the fertilizer price. In this case the one standard error shock means a raise of fertilizer price of 19.4%. This increase is associated with an increase in wheat export prices of 1.4%. The full effect after 24 months is differentiated. Russia and EU show the same long-run impact +7%, the long-run impact for USA remains at a baseline of 4% and for the other countries the magnitude of the rate of growth of wheat prices remains limited between 1% and 2%.

Figure 5.6: GVAR Impulse Responses of Wheat Export Prices to a Global fertilizer input price shock.

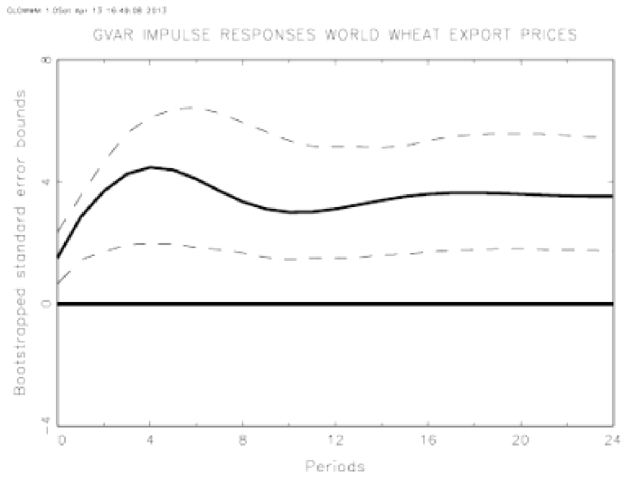


We finally analyze the effect of a global oil price shock to the dynamics of the export prices. The results are reported in Figure 5.7. A positive standard error unit shock to nominal oil prices corresponds to an increase of about 8.6 percent of the oil price index in one month. The impact of wheat export prices vary significantly among countries. For US and EU area the impact is quite similar and equal to 1.0%. Australia is the country that seems to suffer more for an oil shock with an impact on wheat export price close to 1.5%.

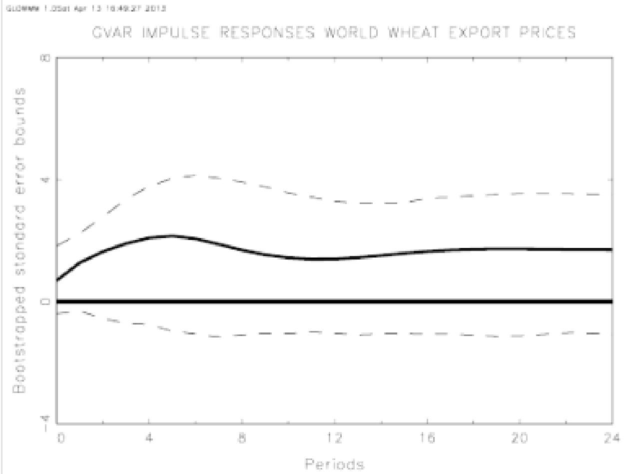
Figure 5.7: GVAR Impulse Responses of wheat Export Prices to an Oil price shock.



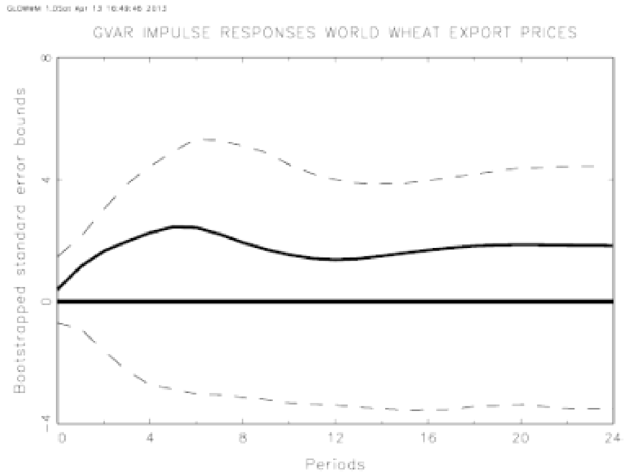
(a) Argentina



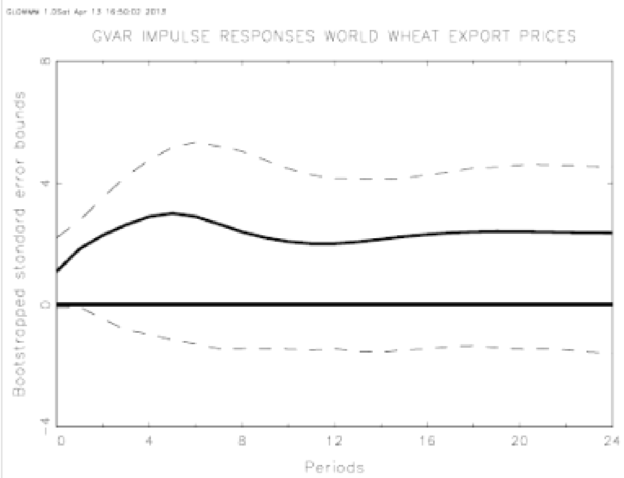
(b) Australia



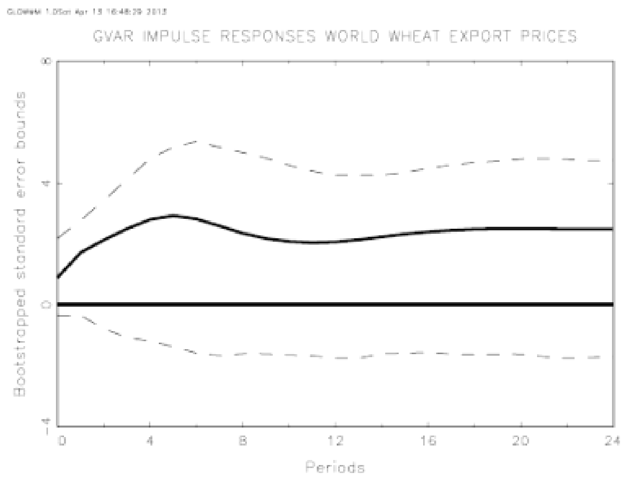
(c) Canada



(d) Russia



(e) EU



(f) USA

6. Concluding Remarks

In this thesis, we have developed an operational global model capable of generating forecasts for a set of macroeconomic factors. Our approach allows for the interdependencies that exist between national and international factors. More in details, we have employed the Global Vector Autoregressive (GVAR) methodology for the analysis of short and long-run response of wheat export prices to both different country-specific and common shocks.

The GVAR approach is particular appealing for the analysis of the worldwide wheat market for two reasons. First, it is specifically designed to model fluctuations and interactions between countries. This is a crucial asset given the features of world wheat market and the global dimension of the food prices crisis that cannot be downsized to one country, rather involves a large number of countries. Secondly, the GVAR allows to model the dynamic of wheat export prices as results of the effects exerted by country-specific and foreign-specific variables.

The GLObal Wheat Market Model (GLOWMM) allows the analysis of the wheat export prices for the six main export countries, USA, Argentina, Canada, UE, and Russia. Specifically, single country wheat export prices are individually modelled and estimated by region specific vector error-correcting models in which the domestic variables are related to corresponding foreign variables constructed exclusively to match the international trade pattern of the country under consideration plus the effect of global variables such as oil price.

In each model and for each country, we include five variables chosen in line with the most common literature about the food price crises in 2006-2010 and the most important theory about wheat price determination: the wheat export prices expressed in US dollar; the domestic stock to utilization ratio; the fertilizer price expressed in US dollar; the real exchange rate against US dollar and the oil price as exogenous variable. All data are collected at monthly frequency for the period July 2000 to January 2012.

These single country models are than aggregated into a global model by using export weighting matrices. All the procedures for the analysis of the GVAR model have been written using GAUSS 11.

We test the non-stationary properties of our series using the Augmented Dickey-Fuller unit root test showing how the majority of the series are I (1). Moreover, the GVAR model requires to account for the hypothesis of weak exogeneity for both the foreign and global variables. We use the exogeneity test proposed by Johansen (1992) and the results indicate that the hypothesis of weak exogeneity cannot be rejected.

Finally, for all country models, with the exception of Australia, the rank tests suggest one cointegration relation. For Australia, both tests, the trace and maximum eigenvalue statistics, indicate the presence of two cointegrating relations. Thus, each country model has been estimated using its Vector Error Cointegration (VEC) form or, in other words, each country model is estimated subject to reduced rank restriction.

The estimation of the cointegrating VEC models gives the opportunity to analyze the effects of foreign variables on their domestic counterparts. Specifically, the model allows for the analysis of the impact on the domestic variables of a 1% change of the corresponding foreign-specific variables. These impacts have been labelled as impact elasticities and they permit the analysis of the co-movements among the domestic and foreign variables. In table 5.6, we present the impact elasticities and their t-statistics. Looking at wheat export prices, we find that all the estimates are positive and significant, with the exception of Russia estimate that it is not significant at the 5% significance level. Moreover, USA, Canada and Australia show an impact elasticity close to one. Positive but mainly non significant co-movements are evidenced by the real exchange rate variable. EU is the only region that shows a positive an significant estimate. Finally the stock-to utilization ratio variable presents both positive and negative co-movements. Argentina reports a negative and significant correlation, the elasticity for Russia is negative but not significant. The elasticities are positive and significant for the remaining countries.

However, the main aim of the thesis is to investigate the degree of country interdependencies in wheat international market. In order to examine the propagation of real shocks across country and visualize how these shock may affect wheat international market we use the generalized impulse responses function approach proposed in Koop, Pesaran and Potter (1996) and further developed in Pesaran and Shin (1996) where the effects of shocks to a given variable in an given country on the rest of the word are provided.

The GIRF has the nice property of being invariant to the ordering of the variables and of the countries. This is of particular importance in our system where there is not a clear economic a priori knowledge which can establish a reasonable ordering. To assess the dynamic properties of the GVAR model and the time profile of the effects of shocks to domestic-foreign variables, we analyzed the implications of five different external shocks:

- A one standard error negative shock to US stock to utilization ratio
- A one standard error negative shock to global stock to utilization ratio
- A one standard error positive shock to oil price
- A one standard error negative shock to real effective exchange rate
- A one standard error positive shock to fertilizer price

We investigated the GIRF impulse responses of the wheat export prices for all the countries included in the model focusing on the first two years following the shock.

We first considered a negative shock to the USA stock to utilization ratio. In this case a one-standard deviation shock corresponds to a decrease of 0.11% of the value of the variable. The effect of this shock, showed in Figure 5.3, on the wheat export prices are quite unsurprisingly, perfectly in line with the results provided by the storage theoretical model and the main role of US in export wheat market. A negative shock to US stock to utilization ratio raises the export prices in all countries. In US the response impact is +1.6%, after three months the wheat export price reaches the maximum of +4.9%. Similar shapes are evidenced by other countries. Argentina, Australia, Canada show similar impacts after the stock to utilization ratio shock, while Russia and EU present minor impact with long-run increase of wheat export prices of +2.0%.

The second shock analyzed is what we labelled the perfect storm of the stock to utilization ratio variable. We simulate a decrease of this variable in all countries. In other words, we assume a general reduction in stock detained by the main export countries. The one-standard deviation shock corresponds in this case to an average decrease of 0.14%. The impact on export prices, showed in Figure 5.4, as expected, is relevant. The export prices raise from the minimum value of +1.3% in Argentina to the maximum value of +3.0% in USA. Second-round effects are also relevant. Export prices, after the shock, rapidly increase reaching values that ranges from +6.6% in Canada to +13.1% in Russia within the 6th month before reducing in the following months.

The devaluation of the US exchange rate has been ascribed as one of the main factors behind the commodity prices upsurge during the period 2007-2008. For this reason we simulate the effect of a real US dollar devaluation. A one standard error shock in this case is equivalent to a fall of around 15% of the US dollar against the competitors' currencies.

The shock, as suggested by the common literature, is accompanied by a raise of wheat export prices. Moreover, with the exception of Argentina and Australia that show a lower impact, on average we note an unitary elasticity of wheat export prices to devaluation (Figure 5.5).

The impulse responses of a one standard error shock on the fertilizer price, based on one standard error shock of 19.4%, means an increase in wheat export prices of 1.4%. The full effect after 24 months is differentiated with respect to the country considered. Russia and EU show the same long-run impact +7%, the long-run impact for USA remains at a baseline of 4% and for the other countries the magnitude of the rate of growth of wheat prices remains limited between 1% and 2% (figure 5.6).

We finally analyzed the effect of a global oil price shock to the dynamics of the export prices. A positive standard error unit shock to nominal oil prices corresponds to an increase of about 8.6 percent of the oil price index in one month. The impact of wheat export prices vary significantly among countries. For US and EU area the impact is quite similar and equal to 1.0%. Australia is the country that seems to suffer more for an oil shock with an impact on wheat export price close to 1.5% (Figure 5.7).

Summunig up our empirical findings, impulse response analysis reveals that a decrease of wheat stocks with respect to the level of consumption or an increase of oil prices and real exchange rate devaluation have all inflationary effects on wheat export prices although their impacts are different among the main export countries.

Focusing on the stock dynamics, low level of wheat stock can have serious economic such as social and political impacts with interesting consequences. From the economic point of view stock influencing wheat prices has an impact on the food chain. From a social and political point of view high wheat prices hit wheat importers countries hard. Increasing food prices affect certain population negatively, especially poorer people. Policy responses, at both national and international level, are usually less prepared for food price crisis and as consequence they are often ad hoc and uncoordinated (as for example the export constraint policies adopted by some exporting countries during the price-spike in 2007-2008 and 2010-2011 years). Moreover market interventions to reduce the high prices in domestic consumption such as bun and export restrictions may be either not successful or impose costs on other countries.

Because of the attention on modelling inter-linkages, our model can be readily used to shed light on the analysis of various transmission mechanisms caused by shock on specific factors and testing long-run theories.

However, a number of issues are left open for future research.

Unfortunately by construction the model is non-structural. Structural interpretations of VAR models

require additional assumptions that must be motivated mainly on institutional knowledge, economic theory, or other constraints on the model responses. Only after having identified the model we can assess the causal effects of all previous shocks on the model variables. However this work can be done using the approach proposed by Dees et al. (2007), and we leave this for future research.

Finally, it should be recalled that, in this thesis we employed data for the main six exporter countries. Noticeably absents are Cina and India. Although these two countries are not deeply involved in wheat international market they are invested by a strong development in economic and demographic trend. Moreover China has the biggest world wheat ending stock and, with India, they are the two most important countries in terms of world wheat total utilization. Enlarging the number of countries including China and India represents a further interesting possibility of developing the model presented.

APPENDIX_A

THE TECHNIQUE OF POLYNOMIAL APPROXIMATIONS

Current storage, namely $E[P_{t+1}|\ S_t]$, is stationary and self-replicating. The relationship $E[P_{t+1}|\ S_t]$ is true only in a specific S_t range. It does not include negative range of storage. Moreover, in order to avoid the case represented by a complete harvest failure and hence an infinite price, Salant (1983) introduced the concept of finite "choke price" as the maximum price a consumer would pay.

With these assumptions, the function $E[P_{t+1}|\ S_t]$ is used to solve the equilibrium storage in period t and hence to deduce P_t. In essence, if A_t is low, all the availability is consumed in the current period t without considering the expected price. By contrast, when A_t is high, the relationship $E[P_{t+1}|\ S_t]$, in conjunction with the arbitrage equation introduced in chapter 2, is used to deduce the equilibrium storage S_t and hence P_t. In fact, the relationship $E[P_{t+1}|\ S_t]$ includes all the information that we need to solve the storage rule with the advantages to be a much soother relationship and so easier to be deduced through numerical methods.

Williams and Wright (1991:63) represent the stationary relation between expected price and carryout stocks with an *n*th-order polynomial in S_t, $\psi(S_t)$. "Conceptually, at least, all one need do is find some function of S_t representing $E[P_{t+1}]$ that replicates itself. One could guess, hopefully non completely blindly, a function and see what the average price would be if storers used it as their expectations. The guess would not replicate itself, but the discrepancy would suggest an improved guess [..] throughout a refinement process."

Before analysing the computer routine and considering a specific example, it should be useful clarify why the expected price $E[P_{t+1}|\ S_t]$ is a function of current storage S_t or why the storage rule is not itself approximated. Regarding the first point, although P_{t+1} is directly determined by the quantity consumed in period $t+1$, in its turn, consumption in period $t+1$ is a function of the carryin S_t. Moreover, price in period $t+1$ has to be lower the larger is the carryin S_t no matter the weather in period $t+1$. Finally the relationship $E[P_{t+1}|\ S_t]$ should be a smooth relationship well represented by a polynomial. As regard the use of $E[P_{t+1}]$ instead of the storage rule the authors consider $E[P_{t+1}]$ a smoother function than the storage rule itself at least over the observed range of storage. This is because the storage rule, the relation between S_t and current availability A_t, has a sharp kink point as showed in chapter 2.

Williams and Wright (1991:82) summarize the computer routine in a sequence of steps strictly related each other and briefly described below. The aim of computer routine is to find a consistent set among $S^i_{t,}$ $E[P_{t+1}]$, h_{t+1} and P^r_{t+1}.

Firstly, the computer program should contain all the parameters for the system studied such as the value for elastic supply, the parameters of the consumption demand function, the marginal storage cost, the interest rate and the probability distribution of the harvest.

Then, the next step is to choose a first guess $\psi[S]$ for $E[P_{t+1}|\ S_t]$, where $\psi[St]$ is, as suggested by Williams and Wright (1991:82), a third order polynomial in S_t. The coefficients in ψ are selected so that $\partial\psi/\partial S<0$ and $\partial^2\psi/\partial S^2 \geq 0$. Secondly, let choose a value of current storage S_t. More in details, let choose a vector S_t of discrete values $S^i_t = 1,\dots, N$ where, as suggested by the authors, N should be at least 10 or 12.

For each component S^i_t of the vector S_t, let choose a guess for the equilibrium planned production $\hbar^i_{t+1}$ named χ in line with Williams and Wright' (1991) notation.

Then, let multiply χ by yield variability, $(1+v^j)$ to create a vector of realized next period production.

Now, adding S^i_t to the realized production generated in the previous step, total availability in period $t+1$ is obtained, A^{ij}_{t+1}, and in its turn the vector A^j_{t+1}.

At this point, let solve the implicit function below for S^{ij}_{t+1}:

$$P[A^{ij}_{t+1} - S^{ij}_{t+1}] + k - \psi[S^{ij}_{t+1}]/(1+r) = 0\ ;$$

(1A)

It should be clear that this implicit function represents the arbitrage equation already seen in chapter 2 with ψ used in place of $E_{t+1}[P_{t+2}]$. According to the non-negative constraint on storage, for any negative solution, S^{ij}_{t+1} should be equal to zero.

For each pair of A^{ij}_{t+1}, S^{ij}_{t+1} let calculate the associated price $P[q_{t+1}]$ from the inverse consumption demand function.

In the next step, using the vector of these prices, let calculate the expected price as below:

$$E_t[P_{t+1} \mid S^i_t] = \sum_{j=1}^{M} P[A^{ij}_{t+1} - S^{ij}_{t+1}]\, pro[v^j]$$

(2A)

Along with the calculation of expected price, let calculate also the rational producers' incentive price $P^r_{t+1}|\ S^i_t$ as below:

$$P^r_{t+1} \mid S^i_t] = \Sigma^M_{j=1}(1+v^j)P[A^{ij}_{t+1} - S^{ij}_{t+1}]pro(v^j)$$

(3A)

Note that the producer's incentive price is different from the expected price $E_t[P_{t+1}]$ because of the effect of the weighting factor $(1+v^j)$.

Finally, from the function of the planned production, substituting $P^r_{t+1}|S^i_t$ the value of planned production can be obtained. In a more formal way: $\hbar_{t+1} = \hbar[P^r_{t+1}]$.

Check whether the planned production is consistent with the guess χ. If there is internal inconsistency a new guess for χ should be done until an internally consistent value is found.

Iterating until ψ reproduced itself. The final self-replicating ψ contains the information necessary for plotting the stationary storage rule.

In the following paragraph an example is proposed in order to better understand the computer routine in action.

An example

Williams and Wright (1991:85) provide a useful example using the same specific set of parameters already used in chapter 2 and summarized below:

The system includes an elastic supply, specifically $h_{t+1} = 50+0.5P^r_{t+1}$; a linear consumption demand curve with an elasticity η^d= -0.2; an interest rate r=5%, a marginal physical storage costs equal to k=\$2 and a normal distribution of yields with a standard deviation of 0.10. Let suppose the initial guess for the polynomial is ψ = \$80-1.5S. Let ψ in subsequent interactions have four terms, namely a constant, S, S^2 and S^3.

From this initial guess for ψ, the routine requires ten interactions to find a ψ* effectively unchanged from the previous interaction. Obviously, for each of these interactions many other calculations must be performed.

The starting point consists in supposing $S_t=0$. The corresponding planned production for the period $t+1$ is 109 units. The storage in period $t+1$ follows the incentive \$80-1.5S_{t+1}.

First panel in table A.1. shows in the second column the nine possible harvests in period $t+1$, given planting of 109 units and their associated probabilities as expressed in the first column. For each of these harvests, the software solves numerically for S_{t+1} conditional on ψ (four column of the table). The weighted average of the resulting expected price is $E[P_{t+1}]$ = \$80.35 and the producer's incentive price P^r_{t+1} = \$77.78. Through this producer's incentive price P^r_{t+1}, given the supply function, the corresponding planned production is 88.89 units. Not the supposed 109 units. This discrepancy suggests to the routine to try a lower value for planned production.

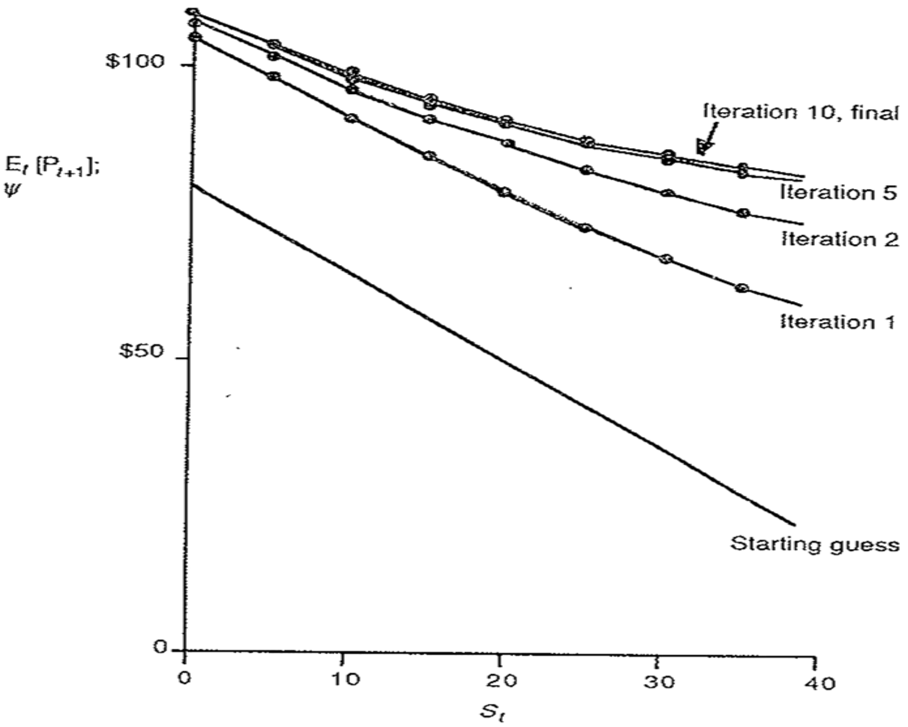
Eventually it finds that a planned production of 100.64 units, still supposing $S_t = 0$ and $\psi = \$80-1.5S$, leads to a P^r_{t+1} of \$101.28, which dictates the same 100.64 units for planned production. The calculations behind this first achievement of internal consistency are shown in the second panel of table A.1. But the expected price is \$104.88 if $S_t = 0$, not the supposed \$80. There is another internal inconsistency to be resolved. By the way, this point, 0 units of storage and an expected price equal to \$104.88, is the first fixed point for the refinement of ψ. The figure A.1. illustrates this first achievement with the first dot on the curve named "iteration 1". The other dots indicated on that curve are the result of calculations like those illustrated in the second panel of table A.1. for values of S_t that are respectively equal to 5.0, 10.0, 15.0 and so on. A third order polynomial describes these eight points well; ψ^* after the first interaction is $104.88-1.357S+0.0000623S^2+0.00013336S^3$. This polynomial is plotted in figure A.1. as the curve for the first interaction. This revised equation for ψ gives rise to the eight dots on the curve marked "interaction 2" in figure A.1. When fit by ordinary squares, they indicate a new polynomial $107.91-1.283S+0.0122S^2-0.00004834S^3$. By the tenth interaction the polynomial essentially duplicates itself. The remaining internal inconsistencies are negligible. The degree of the final internal consistency can be seen in the third panel of table A.1. For $S_t = 0$, if h_{t+1} equals 103.45 units and ψ equals $\$109.13-1.207S+0.01593S^2-0.00007118S^3$, the calculated P^r_{t+1} equals \$106.90 (equivalent to planned production of 103.45 units) and $E[P_{t+1}]$ equals \$109.12.

Table A.1. Examples of search for internal consistency

j	Prob[w^j]	$(1+w^j)$	A_{t+1}	$S_{t+1}\mid\psi$	$P[q_{t+1}]$	$(1+w^j)P_{t+1}$
1. First iteration, given initial guess for ψ and χ						
$\psi = 80 - 1.50\ S;\ S_t = 0.00,\ \chi = 109.00$						
1	.0401	0.80	87.20	0.00	$164.00	131.20
2	.0659	0.85	92.65	0.00	136.75	116.24
3	.1212	0.90	98.10	0.00	109.50	98.55
4	.1745	0.95	103.55	0.00	82.25	78.14
5	.1966	1.00	109.00	2.99	69.95	69.95
6	.1745	1.05	114.45	7.22	63.85	67.04
7	.1212	1.10	119.90	11.46	57.80	63.58
8	.0659	1.15	125.35	15.70	51.75	59.51
9	.0401	1.20	130.80	19.94	45.70	54.84
					$E_t[P_{t+1}] = 80.35$	$P^{r}_{t+1} = 77.78$
						$\bar{h}[77.78] = 88.89$
2. Consistency of $\bar{h}_{t+1}$ with latest guess for χ, for given guess for ψ						
$\psi = 80 - 1.50\ S;\ S_t = 0.00,\ \chi = 100.64$						
1	.0401	0.80	80.51	0.00	$197.44	157.95
2	.0659	0.85	85.54	0.00	172.28	146.44
3	.1212	0.90	90.58	0.00	147.12	132.41
4	.1745	0.95	95.61	0.00	121.96	115.86
5	.1966	1.00	100.64	0.00	96.80	96.80
6	.1745	1.05	105.67	0.40	73.64	77.32
7	.1212	1.10	110.70	4.31	68.03	74.83
8	.0659	1.15	115.73	8.23	62.47	71.84
9	.0401	1.20	120.77	12.14	56.85	68.22
					$E_t[P_{t+1}] = 104.88$	$P^{r}_{t+1} = 101.28$
						$\bar{h}[101.28] = 100.64$
3. Consistency of $E_t[P_{t+1}]$ with latest guess for ψ and $\bar{h}_{t+1}$ with χ						
$\psi = 109.13 - 1.207S + 0.01593S^2 - 0.00007118S^3;\ S_t = 0.00,\ \chi = 103.45$						
1	.0401	0.80	82.76	0.00	$186.20	148.96
2	.0659	0.85	87.93	0.00	160.34	136.29
3	.1212	0.90	93.10	0.00	134.48	121.03
4	.1745	0.95	98.28	0.00	108.60	103.17
5	.1966	1.00	103.45	3.15	98.50	98.50
6	.1745	1.05	108.62	7.46	94.19	98.90
7	.1212	1.10	113.80	11.87	90.38	99.41
8	.0659	1.15	118.97	16.35	86.91	99.94
9	.0401	1.20	124.14	20.93	83.95	100.74
					$E_t[P_{t+1}] = 109.12$	$P^{r}_{t+1} = 106.90$
						$\bar{h}[106.90] = 103.45$

Source: Williams and Wright (1991: 87)

Figure A.1. Iterations on polynomial approximation ψ



Source: Williams and Wright (1991:88)

APPENDIX_B

In this appendix we describe our data sources and key steps in the analysis of our data.

Wheat Export Prices:

- Source: International Grain Council. Index : 2000.7 - 2001.6 = 100.

Stock to utilization ratio

- Source: USDA, Grain World Markets and Trade

- Ratio of Predicted Ending Stocks on Predicted Consumption

Nominal Exchange rate

- Source : IMF Financial Statistics and Financial Statistics of the Federal Reserve Board.

- Real exchange rate : Ration of Nominal exchange rate of each country over wheat export prices of the same country. Index : 2000.7 - 2001.6 = 100.

Fertilizer prices

- Source: World Bank Commodity Price Data (Pink Sheet)

- DAP (Diammonium Phosphate) price. Nominal US dollar. Index : 2000.7 - 2001.6 = 100.

Oil price

- Source: World Bank Commodity Price Data (Pink Sheet)

- Crude oil price. Nominal US dollar. Index : 2000.7 - 2001.6 = 100.

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