M.Sc. Thesis in Business Economics Group

The impact of the increased volatility of commodity prices on the pig cycle in Europe

Author:	Andrea Kovács
Registration number:	851223-471-020
Date:	September 2009 – March 2010
University:	Wageningen University Business Economics Group
Company:	Rabobank International, Utrecht Food & Agribusiness Research Department
Examinator:	Prof. Dr. Ir. A.G.J.M Oude Lansink Business Economics Group, Wageningen University
Advisors:	Dr. M.P.M (Miranda) Meuwissen Business Economics Group, Wageningen University Dr. G. (Grigorios) Emvalomatis Business Economics Group, Wageningen University Albert Vernooij Senior Associate Farming, Commodities and Animal Protein Rabobank International, Food & Agribusiness Research Advisory Dr. István Szűcs University of Debrecen, AMTC, GVK Agro-business Management Department

Course code:	BEC-80433
ECTS:	33

Table of Content

List of Figures

List of Tables

Summary

Pork meat plays an important role in the daily food consumption in Europe. It has the highest share in the consumption basket in general and according to the OECD-FAO Agricultural outlook for 2009-2018, the pig meat sector will continue its long-term growth in Europe as well as in other parts of the World.

Background

Pork is characterised by cyclical price fluctuations which result in the pig cycle demonstrating the relationship between meat prices and pork supply. Besides pork prices and pork supply, commodity prices (feed prices) can also affect the cycle due to their high share (about 50%) within the overall cost structure. Until 2006 commodity prices for players within the pork supply chain were relatively stable therefore they did not appear to have a great impact on the pig cycle. However, they have become more volatile lately which may influence the shape of the cycle both in terms of length and amplitude in the future.

Objectives

In this context, the main objective of the research is to analyse whether (and how) the increased price volatility of commodities impacts the length and amplitude of the pig cycle in Europe. More specifically, this paper seeks to (1) identify the main determinants and drivers of the pig cycle in the past, present and future, (2) analyse the relationship between commodity prices, pork prices and pig supply in Europe between 1991 and 2009, (3) estimate the predictive power of pork price and commodity prices regarding the pork production, (4) predict how farmers form their expectations for future prices and (5) to evaluate the effect of increased price volatility on the length and amplitude of the cycle.

Methods

Correlations and simple linear regressions have turned out to be unable to reveal how pork production, pork price and commodity prices are actually related to each other, hence more complex models are implemented within this paper to explain the phenomenon of the pig cycle. The Cobweb model gives a theoretical background to comment on why prices might be subject to periodic price fluctuations in certain types of markets such as the pork market. It is assumed that cycles in agriculture are generated by the shape of the lagged output functions and new forces occurring in the market continuously. The model is based on time lags (time needed for farmers to respond to changes in prices) and static expectations which refer to one of the general assumptions of the model, namely that farmers tend to believe current prices will continue unchanged in the future. In reality, though, farmers are more likely to form their expectations by considering the direction of recent historical data and revise them based on the current observations and errors they previously made to predict future prices. It is called adaptive expectations assumption and one of the models which deals with it is Marc Nerlove`s so-called Adaptive Expectations Model.

Nerlove`s model is an elaboration of the Cobweb model and therefore consistent with it. He assumes farmers react not to last year`s price but rather to the price they *expect* and this expected price depends only to a limited extent on what last year`s price was. However expected prices cannot be observed, therefore there is a need for a good representative of

them. The final model is a multiple linear regression model which assuming that farmers react to relative prices (price of pork over price of commodities) within a certain time taking into consideration the previous production. Regarding the time needed farmers to make decisions on production and react to prices, two scenarios are considered; the first one assumes that farmers respond to changes in price after 12 months (at least 10-12 months are needed to produce a pig), the second one assumes that over the 10-12 months long production period farmers have some reaction time, therefore 18 months are taken. The estimable model gives information about how farmers form their expectations regarding future prices and how prices influence production. In addition, a so-called Chow-test for structural break is implemented to see whether there was a change in the farmers` expectation formation due to the increased price volatility which can be observed from 2006.

Data

The timeframe which is considered in this research stretches from 1991 to 2009. In this framework, the EU-15 is analysed since almost all the influential pork producers are within the EU-15. Monthly data are examined in the model. For pork prices, reference prices (spot prices) of pork in EU-15 are used because the pork market is a spot market. For pork production, the total of the countries` production in the EU-15 is taken. The website of Eurostat is used as a source for pork price and production data. For commodity prices, the futures prices of feed wheat, corn, soybean meal are examined taking the weighting average of them according to their share in the compound feed (feed wheat 20%, corn 35% and soybean meal 18%, respectively). The database of Bloomberg is used as a source.

Results

The results of the adaptive expectations models indicate that supply elasticity regarding the output-input price ratio is relatively small in both scenarios. For the model contains 12-month time-lag, it is 0.04 and for the model includes 18-month lag is 0.08. While the supply elasticity with respect to the *expected* ratio is a bit larger 0.26 in the case of 12-month lag and 0.14 in the case of the 18-month lag. It suggests that the volatility of commodity prices impacts the quantity supplied but may not cause such a great volatility in production. It is quite reasonable to say that producers may base their decisions on some reasonable assessment of the supply and demand conditions of pork meat rather than on rapidly changing prices.

As for how farmers form their expectations for future prices, the model indicates the following: with 12-month lag, farmers base in 14-15% on what they observe in the present when they form their expectations for future prices; with 18-month lag, the parameter of expectations indicates that farmers consider the current situation in 56% when they form their future price expectations. These values are occurred assuming that farmers revise their expectations each period, therefore they are considered to be short run estimations. If farmers have decided on producing in large scale, they will not react to these expectations very much.

Finally, the Chow-test for structural break indicates that after 2006 producers consider current prices less than they did before. That is, the increased price volatility impacts how farmers form their future expectations. Apparently, the point is whether they plan for short run or long run. If they make long run investments, they are not likely responding to current prices very much.

Conclusions

Based on the results, it can be concluded that the pig-cycle will not likely to change radically in the future because supply elasticity regarding to relative prices is small, that is, farmers seem to be unresponsive. In the pig cycle point of view it means that the length can be both increasing or decreasing. If farmers are not convinced about current prices will remain, they may wait to make decisions on quantity produced. This way the cycle is lengthening and becomes more pointed. On the other hand, if farmers may try to adopt these new circumstances in the market and tend to react faster, this behavior might lead to slight shortening and in the meantime flattening of the cycle. Though, it should be also considered that farmers would probably find themselves with lower incomes if they extensively revise their production plans in response to the wide swings that take place currently in the prices of commodities. Not to mention that the relatively long lifecycle of the pig (10-12 months) hampers the too much shortening.

All in all, the increased volatility of commodity prices are probably cause some additional noise and increase risk in the market but it seems farmers generally tend to react to their expectations and as Nerlove states these expectations depend only to a limited extent on what they have observed currently. Despite the increased volatility and risk, tendencies show that farmers continue to produce even if they cannot achieve positive profit margins in short run.

Recommendation

It is recommended to run these models with updated data after a couple of years, because it is assumed that the actual effect of the increased volatility on production has not been realized yet due to the fact that only four years elapsed since 2006 when the commodity boom occurred and prices became more volatile, and these four years stand against the trend of the examined period before 2006. Apparently this short period after 2006 was not enough to be able to know for sure what the increased volatility results in. It is also presumed that the impact of it could be observed in the profit margins of the pig farmers and not in the production yet.

1 Introduction

1.1 Background

Pork meat plays an important role in daily food consumption throughout Europe. It is the most consumed meat product based on consumer preferences (Wognum et al., 2008). The volume of pork produced in Europe in 2008 is 26.5 million tons (Best, 2009), which is 48.7% of the total meat production in Europe followed by poultry (23.6%) and bovine (23.3%) (Mataragas et al., 2008). The main reason of its popularity in Europe is that pork meat is used in 80% of the processed meat products, including convenience products, traditional dishes, and in addition, its price lies between beef and poultry. (Rabobank, 2008). Prognoses indicate that pork meat will likely keep this status of representing almost half of all meat eaten per person. The main producing countries in the EU are Germany, Spain, France and Poland. The Netherlands is one of the largest pork producers in Europe. In 2009, the output quoted is 1.26 million tons. The pig production in Europe in 2009 decreased by approximately 2.3% in comparison to 2008. For 2010, Rabobank expects some decline of pork production for the Netherlands as well as the rest of Europe.

The supply of pork is highly determined by the pork meat prices that have an inevitable impact on the so-called "pig cycle" (Boston et al., 2004). Pork is characterised by cyclical price fluctuations which result in the pig cycle demonstrating the relationship between the pork supply and meat prices. When the meat prices are below "normal" ("normal" level can be defined as the price and/or production level which tend to reach equilibrium in the supply-demand condition), there is no incentive for increasing the meat production and - due to death and culling - the sow population starts to decline which results in a fall in the meat production with a time lag as well. Since the meat production and therefore the meat supply also falls below the "normal" level, the prices start to rise and at this point there will be an incentive for farmers to increase the pork meat production. As the meat prices are rising, the farmers will start to increase the production. With a time lag the supply will also increase but in the meantime, parallel with the increasing supply, the prices start to fall again and the cycle starts from the beginning (Coase and Fowler, 1937). This circulation can be clearly seen in Figure 1.

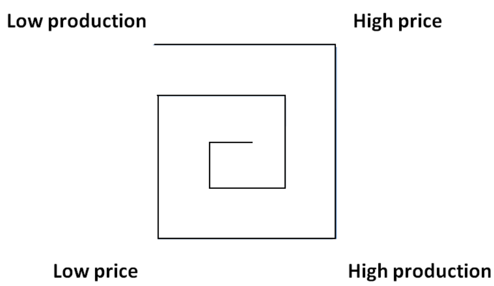


Figure 1: The pig cycle
Source: Own figure based on literature, 2009

The conventional pig cycle is stated to be one of six or seven years in Europe (Anonymous, 2009), however variability in the length of the cycle could be observed in the past and between countries. For instance between 1866 and 1914 in Great Britain a reduction in the length of the pig cycle from 6 to 3 years occurred. According to suggestions the reason could be the "more rapid circulation of market information" that led to a faster adaptation of production to price (Morgan, 1928). Of course there may be other explanations of this phenomenon. For instance, the shortening of the pig cycle could also appear due to "earlier maturity of pigs and increases in fecundity and fertility" stated by Dr. Keith Murray in his study on "The Future Development of the Pig Industry in Great Britain". As a result, sow population can be increased faster at any time in periods of high prices, consequently prices will fall faster and its effect will reduce the length of the pig cycle. Another explanation can derive from the fact that the cycle basically arises because of errors in forecasting on the part of farmers. In the case of a more accurate forecasting, the delayed reaction of farmers which is partly responsible for the length of the cycle can be reduced.

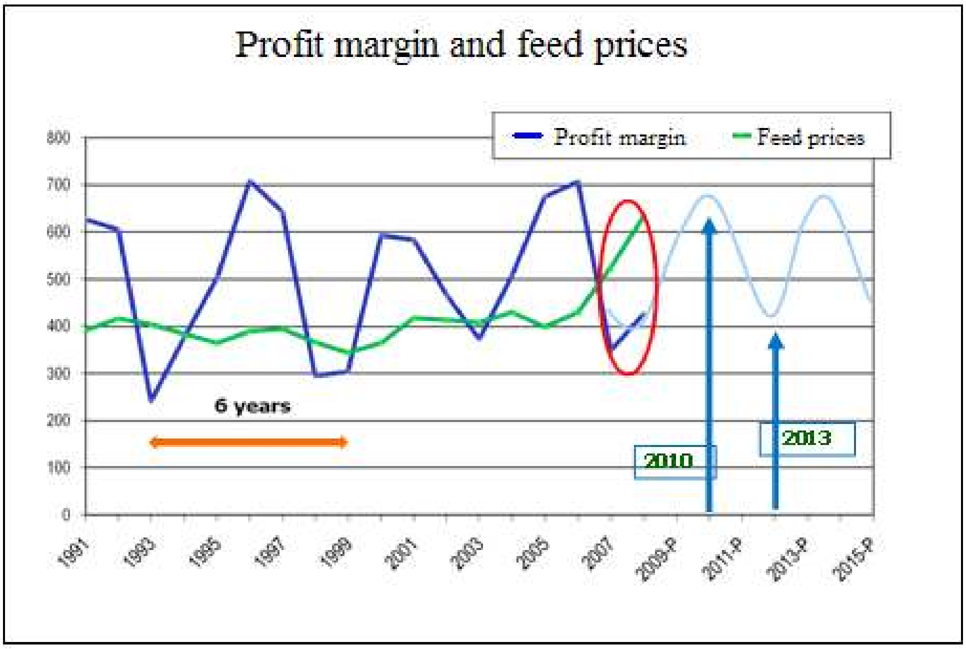


Figure 2: Profit margin and feed prices
Source: Rabobank, 2009

The pig cycle is normally determined by pork prices which are based on supply-demand conditions. Although, besides pork prices, commodity prices (feed prices) can also influence the cycle due to their high share, about 50 percent, within the overall cost structure. Until 2006 commodity prices for players within the pork supply chain were relatively stable, and therefore they did not have significant influence on the pig cycle. However, due to recent circumstances the commodity prices have become more volatile and the question arises what effect these increased price volatility of commodities have on the length and amplitude of the pig cycle. The pork industry faced relatively high feed prices in 2007 which hit seriously the pig production notably because of the incentive to sell the grains instead of feeding animals. In Figure 2 the profit margins of pig farms and the increased feed prices are presented for Dutch circumstances. It can be clearly seen that the feed prices have started to increase rapidly since 2006. The prices for corn, soybean, wheat and barley increased substantially throughout Europe (Beek, 2007) followed by a subsequent decline in 2008. In 2009 the prices of commodities have shown upwards movement again (Rabobank, 2009). High feed prices result in high input prices, while - among others due to the economic crisis - the pork meat demand has declined worldwide (Clark, 2009). As a consequence, oversupply of pork has occurred on the market causing low meat prices in many countries in the world. The increased volatility of commodity prices may have a remarkable effect on the pig cycle both in terms of length and amplitude of the cycle.

Regarding prognoses, commodity prices are expected to remain volatile in the coming decades. It is based on the increased crop demand deriving partly from the increased meat demand as a result of the growing welfare in the developing countries like South-America or China and partly from the increased demand for biofuels production which compete on grains and oilseeds. The increased price volatility of commodities indicates that the feed-to-food supply chain partners must cope with volatile input prices which cause more uncertainty and therefore increased risk for supply-chain partners in decision making.

1.2 Objectives of research

In this framework, the overall objective of the thesis is to analyse whether (and how) the increased volatility of commodity prices impacts the length and amplitude of the pig cycle in Europe. More specifically, objectives of the research are:

1. To identify the determinants and drivers of the pig cycle in the past/present and in the future.
2. To analyze the relationship between commodity prices, pork prices and pig supply in Europe in the past two decades.
3. To estimate the predictive power of the pork price and commodity price regarding the pork production.
4. To predict how farmers form their expectations for future prices.
5. To evaluate the effect of increased price volatility on the length and amplitude of the cycle.

The timeframe which is going to be considered within the thesis stretches from 1991 to 2009 because it is considered to be enough to draw a relevant picture on the pig cycle. Monthly data will be examined to get more accurate results. The research tends to analyze the countries of the EU-15 since almost all the influential pork producers are included in the EU-15.

1.3 Outline of thesis

Chapter 1 includes the introduction of the pork industry in general, the description of the pig cycle, the problem statement and the objectives of the research.

Chapter 2 gives an explanation of the pig cycle in detail using the cobweb theorem as a theoretical framework and then continues with the main determinants and drivers of the cycle in the past, present and the future.

Chapter 3 deals with materials and methods consisting of three main parts. In the first part data (production, pork price, commodity prices) are described using descriptive statistics followed by the analysis of the relationships among the three above mentioned variables, and finally Nerlove's model and its elaboration are presented.

Chapter 4 presents the results of the model, describes how farmers form their expectations for future, how quantity supplied is influenced by the prices of pork and commodities.

Chapter 5 contains the conclusions and discussions.

Chapter 6 includes the recommendation which highlights the possibilities and worthiness of further research.

2 Explanation of the pig cycle

The phenomenon of cycles can be regularly observed in the economic life under the combination of the following three conditions; (1) existence of a time lag between investment and final product, (2) numerous producers who are acting at least semi-independent in the market, and (3) having an ambiguous knowledge about the future. Cycles in the non-farm sector of the economy, in such areas as housing or textiles, are well known and clearly demonstrated, while cyclicality in agricultural finds several ways of expression. The pig cycle, also known as pork cycle, hog cycle or cattle cycle, is a classic example of the cyclical patterns occurring in the agriculture (Breimyer, 1959).

The pig cycle was first observed in pig markets in the USA by an American agrarian economist, Mordecai Ezekiel and in Europe by a German scholar, Arthur Hanau in the 1920s. It describes the phenomenon of cyclical fluctuations of supply and prices in livestock markets. The model which explains the mechanism of the pig cycle has come to be known as the "Cobweb Theorem" coined by Nicholas Kaldor, British economist, who analyzed the model in 1934 (Anonymus II, 2008). The model itself was worked out in 1930 by three economists, namely Jan Tinbergen from the Netherlands, Umberto Ricci from Italy and Henry Schultz from America, who developed it independently from each other. However the classic paper on the "Cobweb Theorem" was published by Ezekiel in 1938. His theory was realistic and operational and based on the flood of statistical findings in the 1920s, following the pioneering work of Henry Moore. It has been considered to be a landmark in the theory of the self-perpetuating pig cycle ever since (Waugh, 1964).

2.1 The theorem

The cobweb theorem is an economic model which serves as a theoretical framework for explaining why prices might be subject to periodic fluctuations in certain types of markets such as the pork market. The model is based on time lags and static expectations. According to the cobweb model, when prices are high, more investments are made due to producers´ static expectations. Static expectations refer to producers' expectations about future prices which are assumed to be based on observations of previous prices. In other words, producers tend to believe that "present prices will continue unchanged in the future" (Coase and Fowler, 1937). Therefore when prices are high, the producers will start to increase production since they expect prices to be high in the future. However effects of the investments are delayed mainly due to the breeding time which results in a time lag. This time lag leads the following situation: when the prices are high, the production starts to increase but at a point, apparently before the production achieves a peak, the market becomes saturated which results in a fall in prices while the production is still increasing. As a consequence the production will be reduced but the effects of the reduction will take time to be noticed due to the time lag. After a while the production will be so low that the supply cannot cover the demand which leads to increasing prices again. This procedure repeats itself cyclically. The resulting supply-demand graph resembles a cobweb.

The cobweb model can have three main types of outcomes due to the slope of the demand and supply curves: (1) continuous fluctuation, (2) divergent fluctuation, (3) convergent fluctuation. The following figures will show the relation between supply and demand where any change in price in one period does not have an effect on the production until the next period due to the time lag necessary for the market to react to the change in price. In the figures the demand curve represents prices in the initial period (period 1), where prices are based on the supply available in period 1. The supply curve shows quantities available in the following period (period 2), where quantities are called forth by the prices of the preceding period (period 1) (Breimyer, 1959).

1. Continuous fluctuation

If the slope of the supply curve is equal to the slope of the demand curve (in absolute value), which means that the elasticity of the two curves is equivalent, we are talking about continuous fluctuation. In Figure 3 the initial quantity is represented by Q_1. Since it is relatively high and the supply is larger than the demand the price is declining (P_1). If farmers expect this low price to continue, then in the following period, they will reduce their production (Q_2). With a time lag the production starts to fall. After a time the supply cannot satisfy the increased demand and the price starts to increase (P_2). At this point farmers will start to raise the production expecting the high price to continue in the future, and with a time lag the supply will increase (Q_3). As long as the price (P_1) is entirely determined by the current supply (Q_1), and the supply in the next period (Q_2) is entirely determined by the preceding price (P_1), this process will repeat itself indefinitely, fluctuating between periods of low supply with high prices and then high supply with low prices without achieving an equilibrium in the supply-demand condition. The equilibrium price and quantity are located in the intersection of the curves.

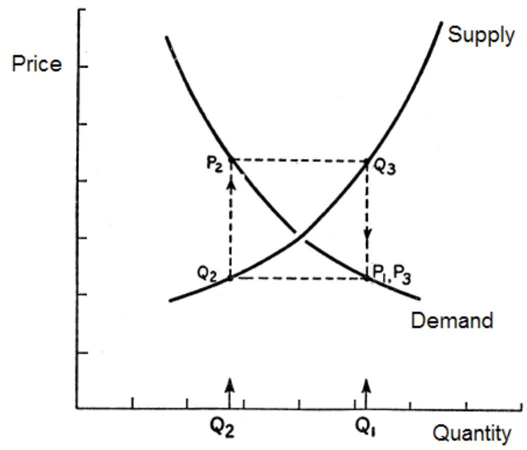


Figure 3: Continuous fluctuation
Source: Ezekiel, 1938

2. divergent fluctuation

If the slope of the supply curve is less than the slope of the demand curve (in absolute value), the fluctuations increase in magnitude with each cycle, so that prices and quantities spiral outwards. It is called the unstable or divergent case. It can be seen in Figure 4. Under this condition, the supply-demand situation is getting more and more unstable which leads to either zero prices or abandoned production in the end.

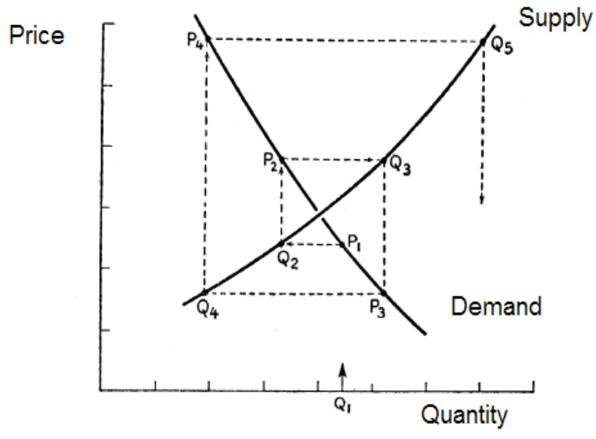


Figure 4: Divergent fluctuation
Source: Ezekiel, 1938

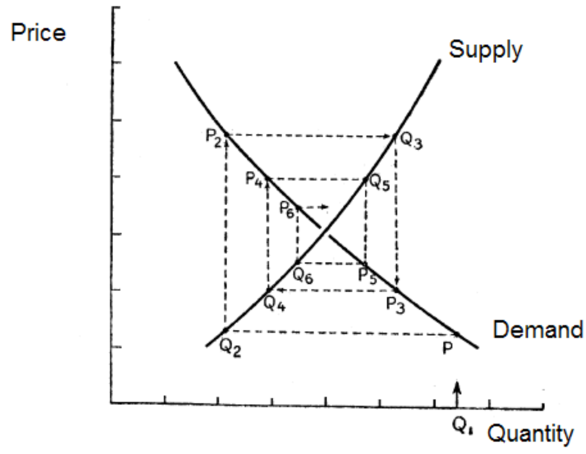


Figure 5: Convergent fluctuation
Source: Ezekiel, 1938

3. *convergent fluctuation*

If the slope of the supply curve is greater than the slope of the demand curve (in absolute value), the fluctuations decrease in magnitude with each cycle, therefore a plot of the prices and quantities over time would look like an inward spiral, as shown in Figure 5. It is called the stable or convergent case. Among the three, above mentioned fluctuations, only this one behaves in the manner which is assumed and expected by an equilibrium theory since the prices and quantities are convergating to the equilibrium price and quantity (Ezekiel, 1938).

Note that the above mentioned supply and demand curves are not equal to the supply and demand curves Alfred Marshall was discussing in his most important book, *Principles of Economics*, published in 1890. They are different concepts and must be considered on their own merits. Marshall´s concept deals with simultaneous supply and demand curves, while Ezekiel´s curves in the cobweb model are not simultaneous at all due to the time lag. Even if they are usually drawn on the same diagram, the two curves exist in different time dimensions and that must be the key distinction between the cobweb model and Marshall´s model (Waugh, 1964).

There are three assumptions which have to be fulfilled for applying the cobweb theorem. (1) Static expectations, meaning the plans for the following output are based on the present prices since they are expected to continue in the future, (2) the production plans cannot be changed until the next period, and (3) prices are determined by the current supply (Ezekiel, 1938). The production of pork suits to these conditions. Research indicate that current prices have important role in the decision making on the future production plans of the pork industry, moreover it is quite evident that once the sows are bred the production is basically fixed for the coming year, at least on the upward side. The discussion about whether the cobweb theorem is an applicable theoretical tool for explaining the mechanism of the pig cycle has centered around the length of the cycle. The question arises if the predicted length of the cycle is equal to the real, observed length. It is well known that the time needed to produce a pig, from breeding to slaughter, is 10-12 months: the gestation period takes 3.5-4 months, piglets are weaned in about 2 months, and 4-6 months are normally required for feeding the livestock to achieve market weights. Using this lag, we may declare that the fastest possible response of the market to change in prices takes approximately one year. It would mean that the cobweb produces a two-year cycle. Although in practice the pig cycle is longer than two years which derives from the fact that the time lag involved in the cobweb theorem is not solely the breeding time but the lag between price and its effects on supply. This actual lag can be split into two components, a "technical lag", which is required to produce an average pig and "another lag" needed for the producers' respond to the price. The time lag highly depends on the producers' expectations. If the producers expect the prices to continue in the future, they will respond to it as soon as they can. However if prices are expected to be temporary, they will not response to it, at least not immediately. All in all, the length of the pig cycle is determined by the lag required for a change in price to affect supply (Harlow, 1960).

Besides the length, the shape and amplitude of the cycle needs to be mentioned. We could see that various types of cycles (continuous, divergent and convergent) can be produced by applying different supply and demand curves. In addition to the slope of the demand and supply curves, the initial positions of the three measures of the hog cycle have to be taken into consideration. The hog cycle can be described in terms of price and production, where production may be measured at the initial stage (pig crop) or the final stage (slaughter). Therefore the three measures of the pig cycle are price, pig "crop" (pig herd) and slaughter (Harlow, 1960). The price in one period affects the size of sow population in the following period which determines the number of pig slaughtered. The volume of pig slaughtered will impact the price which will influence the pig herd in the next period and the cycle starts again. Let us assume that the price is high. It indicates that the slaughter levels on a relatively low stage and the pig herd is of, let us say, normal size. As a result of the high price, the producers will introduce new gilts, in other words, they will increase the production. As a consequence the pig crop will increase to a high level and the slaughter will achieve normal size while the price will decrease to normal. The slaughter is increasing further and about to achieve a high level, however the price is falling and the production declines to a normal level. Since the price is low the producers will stop increasing the production and the pork population will start to decline due to death and culling. The slaughter will start to decline and in the meantime the price starts to increase until it reaches a peak again.

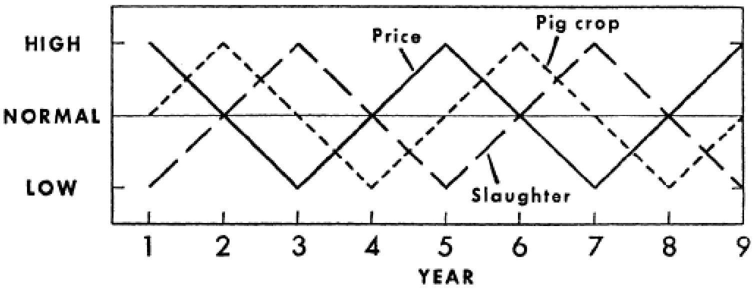


Figure 6: Interrelationships among price, pig crop and slaughter
Source: Harlow, 1960

The interrelationships among the three measures are demonstrated in Figure 6 which was developed by Arthur A. Harlow in 1960. In the figure the vertical axis shows the levels of price and production and the horizontal axis presents the years. A four-year cycle is modeled which can be obtained if we assume one year lag between price and pig "crop" and between pig "crop" and slaughter. However, this four-year cycle does not reflect the pig cycle can be observed currently. Nowadays the pig cycle is known to be one of about six years in Europe as it was also indicated before. This difference in length, of course, has an explanation. In the first part of the twentieth century a surprisingly regular four-year cycle became apparent in Europe. At this time one farmer was dealing with not only pork but beef and/or poultry production as well as crop farming which means that his income derived from more agricultural activities. Therefore a bad year for pork production could be compensated by a large crop yield of the same year for instance. Since the 1950s, the agricultural production has become regionally more and more specialized and farmers have become specialists in one activity, e.g. pork production or poultry production. The areas to where the industrial population moved were probably those which best endowed for specialized and intensive agricultural activities and due to the improvement of transport facilities they could be easily reached. In addition, the improvement of transportation has increased feed availability due to the rising possibility of importing commodities from the USA and Brazil. As a result, the agricultural production has become more effective (Chisholm, 1962). The shift from the mixed farms to the specialized, intensive agricultural activities resulted in changes in the length of the pig cycle. The cycle became longer. The reason of the increased length is that the specialized pig producers have incomes exclusively from the pig production. In theory, when the price is low producers stop increasing the production because there is no point introducing new gilts. In practice, however, when the price is low producers keep buying pigs and fattening them up to market weight, because if they do not act like that, they will not have income at all, and cannot cover their expenses like fixed costs. Therefore they will not stop producing pigs when the price is low which will lengthen the cycle. Regarding to what was previously said, we can conclude that the years of rising prices and the years of falling prices are not equal in reality unlikely to the theory where two years rising prices are followed by two years falling prices. In practice, the periods of falling prices are longer than the periods of rising prices within one cycle (Coase and Fowler, 1937). This statement is reinforced by Figure 7 which shows among others the monthly hog-corn price ratios dating back to 1983. The ratio can be interpreted as the number of bushels of corn that can be bought with the price of 100 pounds of hogs. Therefore high ratio indicates that hogs are relatively higher in price and/or the corn is cheap (Breimyer, 1959), while a low ratio has opposite meaning. This ratio has generally followed the pig cycle in past years and if we consider the period of 2002-2008, we can conclude that the years of rising prices are approximately two, from 2002 to 2004 while the years of falling prices are about four, from 2004/05 to 2008 (Meyer and Steiner, 2009).

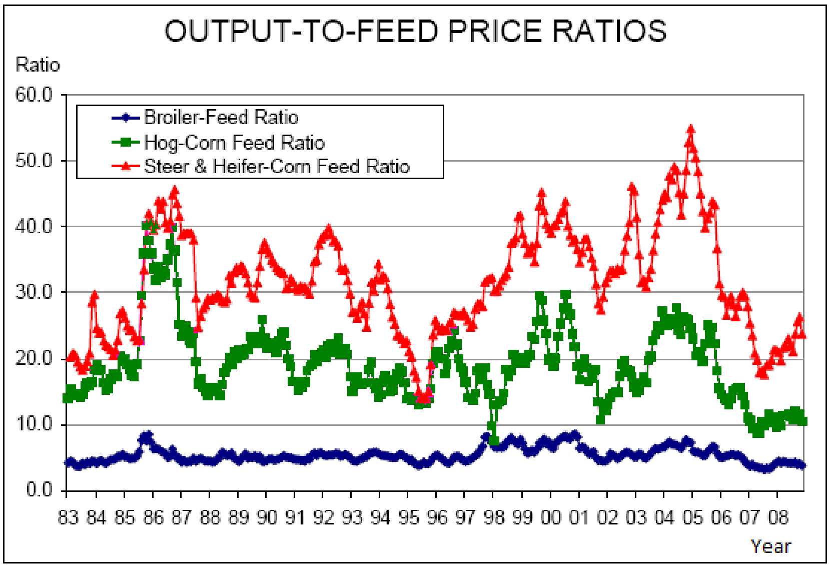


Figure 7: Output-to-feed price ratios
Source: Meyer and Steiner, 2009

The shape and amplitude of the cycle can be easily altered if different initial positions are set. For instance, peaks would not be so pointed in the case when pig crop and slaughter are both of normal level.

Regarding to the question whether the cobweb theorem is a proper theoretical explanation of the pig cycle, it can be said that it has sufficient flexibility to be a theoretical basis for the pig cycle because the model includes both the time lag which determines the length of the cycle and the supply and demand functions for the pork industry which determine the amplitude of the cycle. However there is one reason to be skeptical about: the cobweb model is based on static expectations, in other words it assumes producers base plans for future production on current prices which are expected to continue unchanged in the future (Holt and Willamil, 1986). This assumption was proved to be incorrect by Cohen and Barker in their study of *The Pig Cycle: A Reply* published in 1935. In fact, considering the behavior of producers in the market, it is more likely that producers form their expectations about what will happen in the future based on what has happened in the past and if these expectations turn out to be wrong, people will revise their estimates accordingly. This theory is called adaptive expectations.

2.2 Determinants of the pig cycle

It could be previously seen what factors are responsible for the formation of the length and amplitude of the cycle in general. In this part the determinants of the pig cycle will be presented in more detail. Firstly, the determinants which have stipulated the pig cycle so far will be discussed followed by a prediction on what other determinants will likely to appear in the future and affect the length and amplitude of the pig cycle.

2.2.1 Determinants in the past and present

The main determinants of the pig cycle are the pork prices and the pork supply-demand. Of course, there can be other factors which also influence the pig cycle. One of those factors which may play the most important role in impacting the pig cycle is the commodity prices (feed prices or feed costs).

It is evident that the production cost and the pork price have a great impact on supply i.e. the volume of pig produced and slaughtered. The number of pig slaughtered influences the price of pork and other animal proteins which compete on the pork meat in the market which, in turn, will influence the pork production in the following year. Feed costs have a remarkable share of the production cost, approximately 50 percent, therefore changes in commodity prices (prices for grain and oilseeds) may have essential effects on the production of the pork industry. Until 2006 the pig cycle was basically determined by pork meat prices which were dependent on the supply-demand situation. EU commodity prices were following a particularly stable long-term trend from 1998 to 2006 which indicates that they did not affect notably the pig cycle (ADHB Meat Services et. al., 2009). However the commodity prices have become more volatile recently which may contribute to changes in the pig cycle both in terms of length and amplitude. The core question which needs to be answered is the following: Will the increased price volatility of commodities impact the length and amplitude of the cycle?

Prices of the internationally traded commodities have increased since 2002 and especially since 2006 they have started a steady upward movement and reached peak levels in the first half of 2008. From January 2002 to June 2008 prices for commodities rose by 130 percent respectively (see Figure 8).

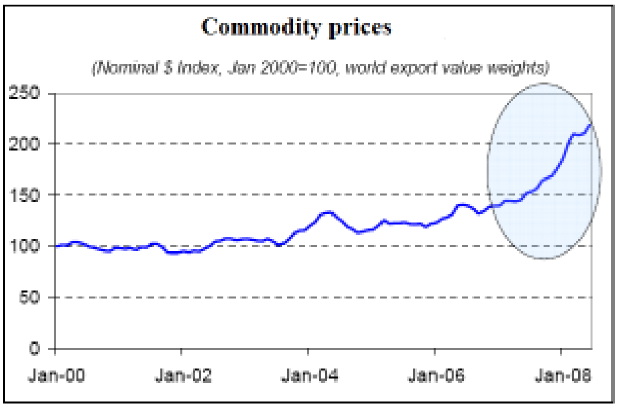


Figure 8: Commodity prices
Source: Mitchell, 2008

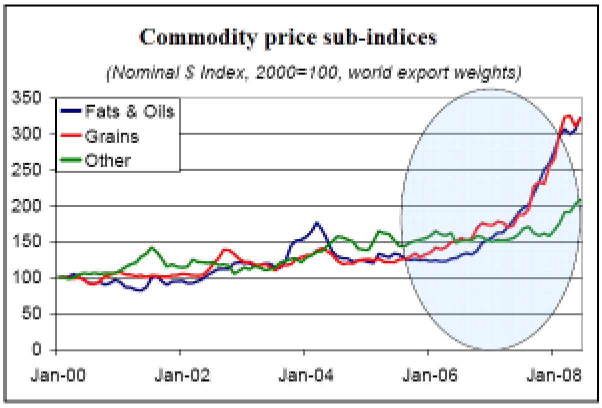


Figure 9: Commodity price sub indices
Source: Mitchell, 2008

The largest increase has been occurred in the prices of grains which started to rise unambiguously in 2005 (see Figure 9) despite the record global crop which was 10.2 percent larger than the average of the three preceding years (Mitchell, 2008). Global stocks of grain increased in 2004/05 but decreased in 2005/06 due to increased demand. Maize prices almost tripled between January 2005 and June 2008, wheat prices rose by 127 percent, rice prices increased 170 percent. Fats and oil prices have shown similar increases to grains. Soybean oil prices increased 192 percent while palm oil prices rose by 200 percent between January 2005 and June 2008. Other food prices (sugar, citrus, meat) increased 48 percent during this period (Rabobank, 2009). However it has to be highlighted that the increase in prices has not been continuous. A downward inflexion was observed after prices of commodities achieved peak levels in January 2008 followed by another increase in the market in 2009. As a consequence, one must deal with not only increased commodity prices but, what is more important, also increased volatility. The increased price volatility of commodities indicates that the feed-to-food supply chain partners must cope with volatile feed prices which cause more uncertainty and therefore increased risk for supply-chain partners in decision making.

As for prices of pork, they are playing a decisive role in determining the hog cycle. Unlike grains, fats and oils, meat prices did not show a spectacular development in 2008. (OECD-FAO, 2009). It can be partly explained by the fact that producers are not able to give a fast response to a sudden change in feed costs since production decisions have already made at the beginning of the production. Pork prices were EUR 1.35 per kilogram Carcass Weight Equivalent (CWE) in the EU in 2007, just below the long-term average of EUR 1.36 per kilogram since 1991. In 2008 pork prices increased to an average EUR 1.64 per kilogram CWE. Comparing to the average pork price in 2007, the pork prices rose by 21 percent. Approximately two-third of the rise in pork prices in the EU can be due to the higher feed costs. The increasing costs of commodities affect all pork producers globally. Due to negative profit margins a decline of sow herd could be observed in May 2008. It resulted in a fall in the volume of pigs ready for slaughter. (Rabobank, 2009) Consequently, it can be stated that the fluctuation can be noticed in the pork prices as well. In 2009 the price of pork decreased again to an average EUR 1.45 per kg CWE. The development of pork meat prices comparing to the prices of beef and poultry and the fluctuation in the meat prices can be seen in Figure 10.

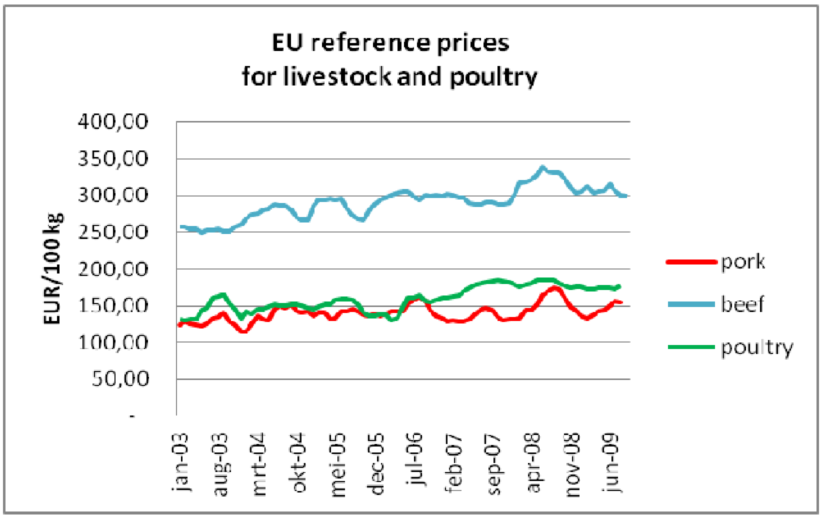


Figure 10: EU reference prices for livestock and poultry
Source: CIRCA, 2009

Pork supply is highly determined by pork meat prices theoretically. When meat prices are high, producers tend to increase the production which results in rise in pork supply. On the contrary, when prices are declining, producers stop increasing the production although the effect of that will be observed later on. In 2008 and 2009 high feed prices combined with moderate pork prices represented a great challenge to producers in Europe. Several farmers submitted evidence about their struggle to continue pig farming during this period. While numbers of pig farmers have given up farming completely, others have either relied on their arable farming to support the pig side of the business or relied on the poultry side of their business to support pig production (Environment, Food and Rural Affairs Committee, 2009).

2.2.2 Determinants in the future

This project is seeking to find information about what other determinants, if there are any, can influence the shape of pig cycle in the future. Is it possible that the key determinant of the pig cycle is solely the prices of commodities? Can it happen that the commodity prices influence exclusively the length and amplitude of the pig cycle through having a great impact on the pork prices and pork supply? If it was true, it would mean that everything in the pork market is dependent on the commodity prices.

2.3 Drivers of fluctuation in the pig cycle

Previously we have got acquainted with the main determinants of the pig cycle. In this session, the factors which impact the determinants and so the pig cycle will be examined. These factors are called the drivers of the pig cycle. First and foremost, the drivers of the pig cycle in the past and present will be presented followed by a prognosis on the possible future drivers.

2.3.1 Drivers of fluctuation in the past and present

It has already been mentioned that agricultural commodities (grains and oilseeds) can be important determinants of the pig cycle, in addition, they are one of the main cost components in the pork production. Feed, in general, accounts about half of the cost price of 1 kilogram of pork, therefore the price increase in the grain and oilseed markets followed by an inevitable sudden decline in the commodity prices may have great impact on the feed-to-meat value chain. The increased volatility in the prices of commodities i.e. the sudden and steep price increase and then the subsequent fast decline cannot be ascribed to any single factor. A rather complex combination of structural (long-term) and temporary (short-term) factors are responsible for the current price movements. Structural factors account for gradual shifts in the market equilibrium, while temporary factors affirm the speed and direction of changes (Rabobank, 2009).

2.3.1.1 Structural factors

Among the structural factors the effects of increasing global demand, changing government policies, altering research policies and changes in real income can be mentioned. The phenomenon of growing global demand is mainly due to the population growth, urbanization and changing dietary patterns i.e. consumers are shifting from the grain-based diet to a protein-based one, in other words they prefer high value-added products, especially meat. These factors raise per capita meat consumption and induce an expansion in world trade. Regarding to the changing government policy, during the 1990s the Common Agricultural Policy (CAP) of the EU put the direct income support forward against production-driven support and as a result the intervention stocks were reduced (Rabobank, 2009). On top of that, after many years of declining real-term food prices, governments dared to reduce the stock levels due to public sector budgetary concerns that led evidently to a decrease in the stock-to-use ratio. In addition, the focus from the solely yield-enhancing technologies has shifted to the cost-reducing technologies which means that the aim has become to reduce the cost as much as possible and it could normally be achieved by a moderate yield. Besides all these mentioned above, changes in real income can also affect the demand for agricultural commodities and hence cause increase volatility in agricultural product prices. In general, these effects are likely to be more moderate in developed, high-income countries where the elasticity of demand with respect to changes in income is lower for most of the agricultural commodities than in developing, low-income countries. These impacts, of course, may also show great difference among agricultural sectors and commodities. For instance, income changes are assumed to be more important for livestock sector because the demand for livestock products tends to be more responsive and reactive to changes in income than the demand for grains and oilseeds. It is partly due to the higher income elasticity and longer production processes of livestock products. A decline in the real income will decrease the demand for meat products, including pork as well, and results in decrease in price.

A more recent phenomenon is the positive correlation between increase in energy prices and feed prices. Energy prices affect prices of commodities both directly and indirectly. Since oil is a cost component of the grain and oilseed production – according to economists oil represents around 25 percent of the cost price of grains and oilseeds (Mitchell, 2008) - the increase in energy prices has a huge and direct impact on prices of commodities. In the meantime, as a result of the high energy prices, increased demand for biofuels (biodiesel and bioethanol) has appeared in the market. The biofuels production is based on grains especially maize and sugarcane in the case of bioethanol production, and oilseeds particularly rapeseed oil, soybean oil and sunflower oil in the case of biodiesel production which also put an upward pressure on prices of commodities. Generally speaking, higher oil prices lead to higher commodity prices because, on the one hand higher oil prices result in higher production costs which call forth lower crop production thus the prices of commodities will increase, and on the other hand higher oil prices induce increased demand for biofuels which trigger the reallocation from food to fuel production. It is now evident that commodity prices show high sensitivity to oil price changes as it is also represented in Figure 11. For 2009, the prices of oilseeds and maize have increased by about 25 percent compared to the mid-term economic projections made by OECD and World Bank which date to the end of 2008. Another result that becomes clear from Figure 11 is that the changes in oil prices are larger at the beginning than towards the end of the projection period to 2018 and as a consequence price effects are larger in short term (+13% - +28% for cereals and oilseeds) than in long term (+10% - +18% for cereals and oilseeds). The opposite can be observed in the case of sugar where a 10-11 percent increase in price is expected over the simulation period to 2018. This study also reveals that the impact of higher oil prices on the livestock sector is much smaller than for crops. Oil prices impact livestock markets through both higher cost of energy use and their effects on feed ingredient costs, yet despite the increased costs the decrease of meat production is not exceeding 3.5 percent globally in any of the years in the projection period (OECD-FAO, 2009).

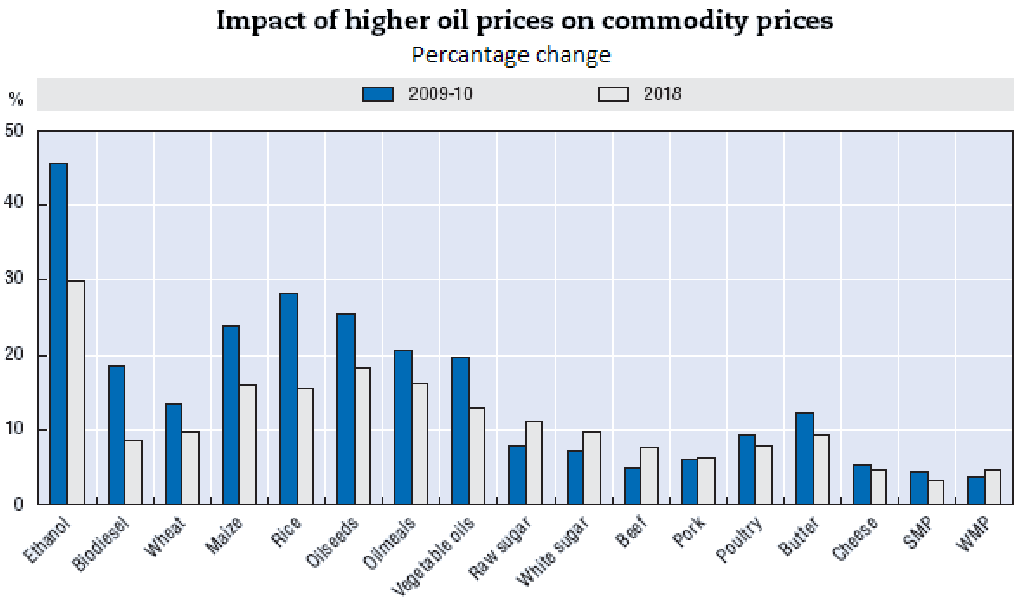


Figure 11: Impact of higher oil prices on commodity prices
Source: OECD-FAO, 2009

Many research indicate - despite the fact that there are several factors influencing the commodity prices - that the key driver is the increased production of biofuels from grain and oilseed in EU and in the USA which was driven by high oil prices increased sharply in 2007/08 (Mitchell, 2008). The International Monetary Fund (IMF) estimated that the increased demand for biofuels accounted for 70 percent of increase in maize prices and 40 percent of increase in soybean prices globally. The contribution of biofuels to the rise in feed and food prices raises an important policy issue. Much of these increase were due to EU and US government policies that provided incentives to biofuels production. The EU began to expand its biofuels production after the EU directive on biofuels (2003/03/EC) came into forth in October 2001 stipulating that national measures must be taken by EU member states that aimed at replacing 5.75 percent of all transport fossil fuels. Due to this legislation, the biodiesel production increased from 0.28 billion gallons in 2001 to 1.78 billion gallons in 2008 in EU. The US expanded their biodiesel production after the legislation passed in 2004 and took effect in January 2005 which provided an excise tax credit of $ 1.00 per gallon of biodiesel made from agricultural products. It led to an increase in biodiesel production from 0.03 billion gallons in 2001 to 0.44 billion gallons in 2007 in the USA (Mitchell, 2008).
The consumption of biodiesel as well as bioethanol is expected to grow in the coming decade in Europe as Figure A1 and Figure A2 also indicate (see Appendix). However, the increase in biofuels production has not only increased the demand for commodities but it has induced large land use changes which reduced supply of crops that compete with commodities used for biofuels production. The reduced supply of crops also pushed the prices of commodities up.

2.3.1.2 Temporary factors

Temporary factors which are considered to contribute to the increased volatility include among others the adverse weather conditions which often lead to supply disruptions in the grain and oilseed market. In 2007 the poor crop yield also led to increased commodity prices. Demand can be heavily impacted by diseases. In April 2009 the misconception about H1N1 influenza virus resulted in a decline in the pork meat demand worldwide (Clark, 2009). Many other potential drivers could be mentioned including declining dollar (see Figure A3 in Appendix) which heavily affects the export of EU in terms of commodities or the food price inflation which was higher than the overall inflation in the EU over the last two years (see Figure A4 in Appendix). In addition, increased financial speculation in the grain and oilseed markets appeared, more generally, increased investments in commodities have been made by institutional investors to hedge against inflation in commodity prices. Questions arise frequently as to whether or not it can affect market prices. Excess speculation might lead to further volatility in commodity prices (Mitchell, 2008).

Due to the global economic crises agricultural producers generally expect worsening future sales and prices over the following years. The players for feed-to-meat value-chain are experiencing both demand and credit effects of the crises worldwide. Demand has been reported to slow down somewhat meanwhile credit conditions are assumed to be deteriorating. Restricted access to credit has been observed by many firms especially from the downstream part of the value chain. The limited credit availability cause remarkable problems for chain partners since it has set blockages along the chain and limited the ability to source raw materials or to get the products from one stage to another. Since credit allocation by banks is based on the evaluation of the firms` ability on paying back the loan, the small and medium sized firms are facing with difficulties to get credit due to their limited equity and liquidity. It can cause further supply disruptions which impacts prices. According to farm/co-operative associations, in Western-Europe it seems that there is little or no impact of the economic and financial crises on the credit availability due to relatively low debt situation. It is especially true for the agriculture sector where credit conditions are said to be very robust comparing to other sectors of economy. However it is assumed that access to credit is becoming tighter. Moreover trade financing constraints have appeared which has been signaled by most firms involved in trade regardless of their position in the supply chain. These constraints are limiting the trading opportunities even among the EU countries charging huge transaction costs for trading partners. The trade credit constraints derive from the lack of confidence in the market and the credit providers` increased caution. For firms gaining most of their earnings from export of commodities the so called "trade credit issue" is considered critical (OECD-FAO, 2009).

2.3.2 Drivers of fluctuation in the future

As noted before, standards for allocating credit have tightened significantly since the beginning of 2009. Some bankers stated that greater emphases would be placed on the repayment capacity and the extent to which firms are leveraged as well as the market risk of their operations. An increased level of collateral will be required for loans which effect substantially the operation of firms. For instance, due to the structural change in bank landing and the tight credit conditions agro co-operators tend to stop investing in additional processing or storage facilities and according to prognoses the effects of changes in decision making will be substantial on the supply of agricultural products. Results of surveys indicate firms may see further sales fall in certain markets in the future due to tightening credit availability. Import firms are postponing or cancelling orders to deal with credit limitation whenever this is feasible which has an unquestionable impact on future supply of products including commodities as well. According to a recent survey conducted by FAO in 2009, 58 percent of Australian and 29 percent of New Zealand respondents suggested that the worsening of overseas markets and economies would have serious effects on future sales and incomes due to lower prices, price volatility and declining demand (OECD-FAO, 2009). As a result of lower incomes the demand for meat products such as pork meat is likely to dampen which influences the meat prices.

The trade credit issue is another upcoming topic of which impact on export and import of commodities can be severe in the future. On the export side, one co-operative from Denmark expressed strong concern about the current blockage in pork exports which stems from the lack of trade finance in importing countries due to the countries' exchange rate and institutional risks. On the import side, importers reported that "existing credit line guarantees have increased to an extent that it is literally impossible to import goods" (OECD-FAO, 2009). As a consequence, firms which cannot get some ingredients are forced to stop their activities either temporarily or even permanently. It may cause further supply disruptions. However financing of transactions between firms can raise problems not only in export-import relationships but even within a country. This was noted in the UK, where a firm's production can be held up due to inability to obtain inputs – raw or processed – due to credit constraints. Several firms in other countries in Europe, such as Belgium, Italy and Spain, reported similar difficulties in 2009. In global supply chains and distribution systems including the pork chain such constraints may be a determining factor.

Prices and therefore the pig cycle can be also influenced by changes in the supply of competing products, changes in the welfare or income of consumers or changes in institutional factors impacting the pork market such as freight rates, tariff quotas appearing in the future. Besides these, future outbreaks of diseases have to be also considered which can severely impact the prices of pork. The FAO has recently attracted attention to a growing African swine fever outbreak which threatens the Russian pork markets and observers believe that the disease can also spread to the EU that would have serious consequences.

Agricultural policies and governmental actions are also important drivers shaping the national and international meat markets. In the EU and in the USA as well, policy reforms are expected to take place.

Table 1 gives a summary on the determinants and drivers of the pig cycle discussed in this chapter.

Table 1
Determinants and drivers of the pig cycle

		Past and Present	Future
Determinants		• Pork prices • Pork supply-demand conditions	• Pork prices • Pork supply-demand conditions • Commodity prices (?)
Drivers	***Structural***	• Increasing global demand • Changing government policies • Altering research policies • Changing in real income • Increased energy prices	• Increasing global demand • Agricultural policies • Freight rates • Tariff quotes • Increasing energy prices
	Temporary	• Adverse weather conditions • Diseases (e.g. H1N1, BSE, FMD) • Increased financial speculations • Global economic crises • Tightening credit availability • Trade credit issue	• Changes in supply of competing products • Changes in welfare • Changes in income • Diseases • Trade credit issue • Financial speculations

Source: Own table based on used literature available in Rabobank, 2009

3 Materials and methods

Prior to this chapter a qualitative analysis on the past and possible future determinants and drivers of the pig cycle was made. We have become more familiar with the theoretical basis of the determinants and drivers influencing the cycle and now it is high time to examine how these determinants impact the pig cycle in practice. In chapter 3 the focus is on quantitative data analysis. First and foremost, data on the main determinants i.e. pork prices and pork supply of the pig cycle will be analyzed in Europe from 1991 to 2009. Analysing data on pork prices and pork supply is important to understand the developments in the pork market and to reveal the relationship between these factors in order to be able to explain the pig cycle in the past. Secondly, data on commodity prices will be collected and analyzed to find out how important role they play in affecting the pig cycle. It is already known that prices of commodities showed a standard development until 2006 therefore their effects (if there are any) have not revealed themselves. Although, as noted before, they have become more volatile recently and the question is that: Does the increased volatility of commodity prices influence the pork prices and the pork supply and therefore have any effect on the length and amplitude of the pig cycle? And in the case if it has effects on the pig cycle, how and to what extent? Is it possible that commodity prices are the real, absolute and dedicated determinants of the pig cycle? In order to answer these questions regression models will be established to examine the relationship among the variables.

3.1 Describing data

In order to analyse the pig cycle quantitatively first data collection on pork prices, pork supply and commodity prices is carried out. For data collection the database of Rabobank, Bloomberg[1] and among others the website of Eurostat, FAO, USDA, Statistics Denmark serve as a basis. For doing an accurate analysis monthly data are used. The examined time frame is stretching from 1991 to 2009 considering Rabobank`s interests. The goal is to gain information about the pig cycle in Europe within the above mentioned period and in particular the member states of EU-15 are analysed because all the countries which are significant regarding the pork industry both in terms of production and export are in EU-15, of course, the pork production and trade of other countries in Europe cannot be ignored either but they play relatively little part in the European pork market.

3.1.1 Data on the determinants of the pig cycle in the past

In this section, a descriptive statistical analysis on pork prices and pork production is made followed by the examination of the development of these factors in EU-15 for the period of 1991-2009. For examining the pork prices in EU-15 between 1991 and 2009 EU reference prices (spot prices) are used in monthly basis. As for pork production in EU-15 for the same period, the production of Austria, Sweden and Finland is considered from 1995 since they joined to the European Union that year.

[1] The Bloomberg Professional service, the core product of Bloomberg L.P founded by Mike Bloomberg in 1981, is the fastest-growing real-time financial information network in the world. It is the source real-time and historical financial news and data.

3.1.1.1 *Data analysis on pork prices*

Data on pork prices are analysed from January 1991 to December 2009 in a monthly basis. Therefore we have 228 data (N=228) as it can be seen in Table 2. During this period the lowest monthly price occurred was € 88.78/ 100 kg CWE in November 1998 and the highest was € 201.56/ 100 kg CWE in May 1997. The range of the set of measurements is the difference between the lowest and the highest value which is, in this case, € 112.78/ 100 kg CWE. The mean is € 137.54/ 100 kg CWE that can be defined as a model which summarize our data set, and can be calculated as the sum of the measurements divided by the total number of measurements. The standard deviation shows how well the mean represents the data. Since the std. deviation is 20.76 which is relatively small to the value of mean, the mean is an accurate representation of the data set.

Table 2
Measures for central tendency and variability regarding pork price in EU-15, 1991-2009

Descriptive Statistics

EU-15	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
pork price (EUR/100kg)	228	112.78	88.78	201.56	137.54	20.76	430.56
Valid N (listwise)	228						

Source: Own calculation based on Bloomberg database, 2009

In order to check the normality of the observations a histogram is drawn (see Figure 12). It represents the frequency of the data and it can be stated that prices for pork ranged the most often between € 140-145/100 kg CWE within the examined time period. This figure also demonstrates that the sample distribution is a bit skewed to the right but the deviation from normal is not remarkable.

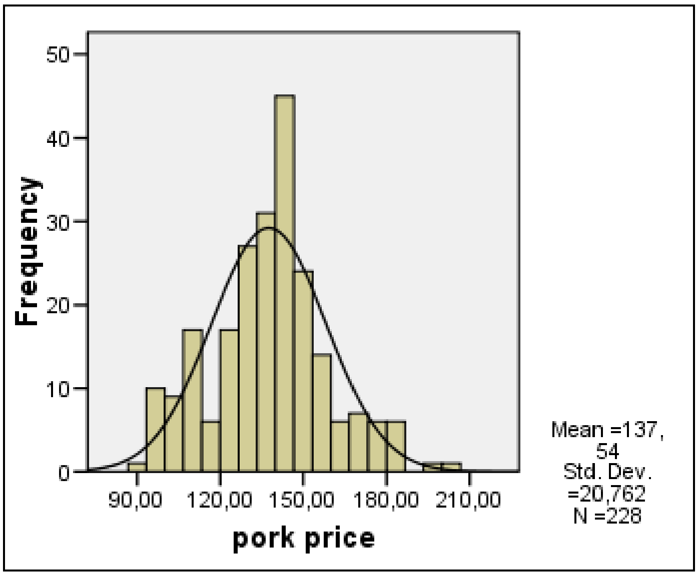


Figure 12: Examination of the normality of pork prices between 1991 and 2009 in EU-15
Source: Own figure based on Bloomberg database, 2009

3.1.1.2 Data analysis on pork production

The data on pork production in EU-15 are also analysed from January 1991 to December 2009. So the number of observations is 228 again. Table 3 indicates that the lowest production realized was 1.082 million metric tons in May 1992 (the table contains the production in thousand tons). While the largest production during the observed period was achieved in January 2008 and it was 1.765 million metric tons. The standard deviation is 144.94 which is considered to be relatively small comparing to the value of the mean that is 1421.62 and as a consequence the mean is an accurate representation of the data set.

Table 3
Measures for central tendency and variability regarding pork production in EU-15, 1991-2009

Descriptive Statistics

EU-15	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
pork production (1000T)	228	682.52	1081.98	1764.50	1421.62	144.94	20990.12
Valid N (listwise)	228						

Source: Own calculation based on Bloomberg database, 2009

The histogram presented in Figure 13 indicates that the most frequent volume of pork production was approximately 1.450 million metric tons. The distribution is slightly skewed to the right but the deviation from normal is not much.

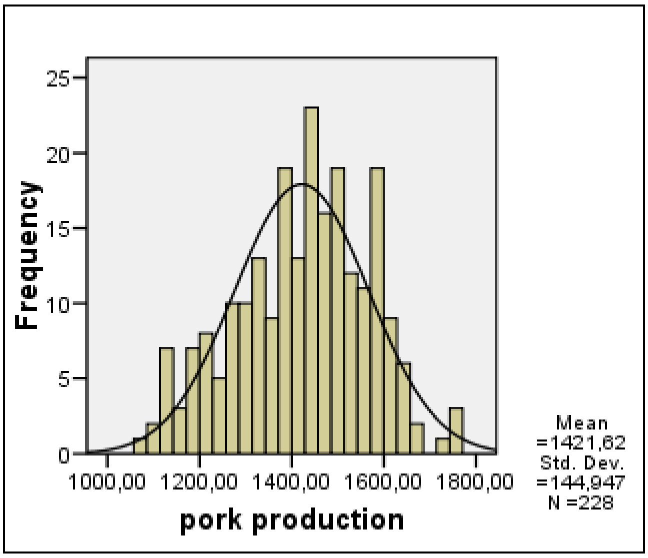


Figure 13: Examination of the normality of pork production between 1991 and 2009 in EU-15
Source: Own figure based on Bloomberg database, 2009

3.1.1.3 Development of pork prices and pork supply between 1991 and 2009

The following figure is representing the development of pork prices (see Figure 14) in EU-15 from 1991 to 2009. Considering the monthly pork prices we can see the price volatility over the examined period. Two peaks can be observed, one in the year of 1997 when the price for pork was about EUR 200/100 kg CWE. It was mainly due to a decline in pork production and export resulting from the swine fever outbreak in the Netherlands in 1997. At this time, beside Denmark, the Netherlands was a powerful pork producer in Europe. In addition there was a switch from beef to pork at that time as a result of the boviene spongiforme encefalopathie (BSE) scare all over in Europe. These two events made the pork price rise. The other price increase was in 2001 with EUR 180/100 kg CWE pork price due to BSE and foot-and-mouth disease (FMD) scares which lowered prices for beef and increased prices for pork. After declining pork prices in the second half of 2008, in the beginning of 2009 they have started to increase slightly again achieving EUR 150/100 kg CWE although according to projections pork prices are expected to remain weak throughout 2009 and 2010 and keep cycling in the coming decade (Quanbeck and Johnson, 2009).

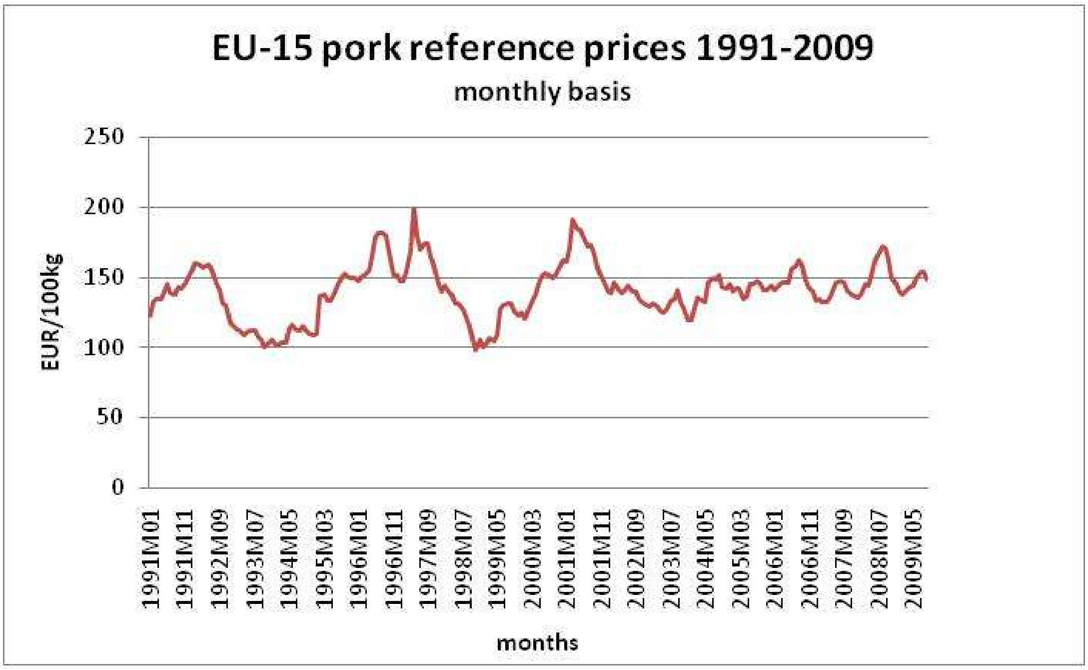


Figure 14: EU-15 pork reference prices 1991-2009
Source: Own figure based on Eurostat database, 2009

On the production size (see Figure 15), EU-15 increased its output from approximately 14 million tonnes in 1991 to 18 million tonnes in 2000, for an increase of 30.5%. The EU-15 pork sector maintained its size roughly unchanged between 2000 and 2006, then the production increased further in 2007 achieving 19 million metric tonnes as a result of growing global demand especially from the developing countries and international price increases all over Europe. It is approximately 85 percent of the total pork production of EU-27 which was 22.5 million metric tons in 2008. At the beginning of 2008 the production declined due to high feed prices. In 2009 the production was 18.5 million metric tons. Despite of the increased feed costs, the pork meat consumption still has the highest share in the consumption basket in general. According to FAPRI research, rising meat demand will increase the pork production over the next decade (FAPRI, 2009). Both the annual and the monthly pork production can be found in Appendix. Table A2 in Appendix represents the annual pork production in the Member States of EU-15 separately and in EU-15 altogether for period of 1991-2009. Figure A5 in Appendix demonstrates the volatility of pork production in EU-15 between 1991 and 2009 in a monthly basis.

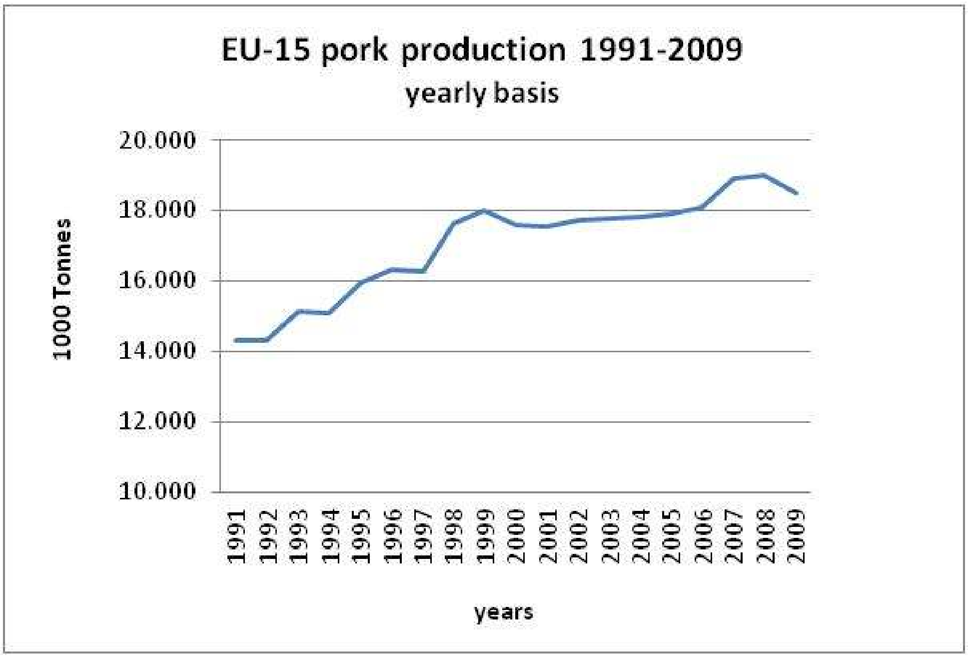


Figure 15: EU-15 pork meat production 1991-2009
Source: Own figure based on Eurostat database, 2009

3.1.2 Data on commodity prices

After the data analysis on pork prices and pork supply was done, the focus is on commodity prices. Data available in Rabobank are used for analyzing the commodity prices. Prices of three commodities assumed to be the most relevant to the pork sector are examined, namely feed wheat, corn and soybean meal since they are the major feed components for pork production (AgMRC, 2009). The prices used between 1991 and 1999 are listed on the London International Financial Futures and Options Exchange (LIFFE) in the case of feed wheat, and on the Chicago Board of Trade (CBOT) in the case of corn and soybean meal. These prices are in USD due to the fact that the EUR currency was first introduced in Europe in 1999. In order to get all the prices in EUR, they are converted from USD to EUR using the conversion ratio between USD and ECU within this period. The prices applied between 1999 and 2009 are listed in both USD and EUR currencies and a conversion was also needed from USD to EUR in the case of soybean meal because it is listed on CBOT while the prices for feed wheat and corn are listed on European stock exchange.

In this part, first, a descriptive analysis is implemented and then the development of the commodity prices are analysed. Secondly, it is intended to examine the relationship between pork prices, pork supply and commodity prices. It is wished to reveal the impact of the change in commodity prices on pork prices and pork supply. The experimental hypothesis (H_1) is that there is a relationship between the change in the commodity prices and the main determinants of the pig cycle. More general, it is assumed that changes in commodity prices have influence on the pork prices and pork supply. In order to prove it, a regression analysis has to be realized (see later).

3.1.2.1 Data analysis on commodity prices

Data on commodity prices are analysed between January 1991 and November 2009 in a monthly basis. Table 4 indicates the number of observations, the minimum and maximum values of prices during these two decades for each commodity and how well the mean represents the data. For feed wheat the lowest price was EUR 89.08/ metric ton achieved in September 2004 while the highest price was EUR 258.80/ metric ton occurred in August 2007. The standard deviation is relatively low comparing to the mean which is EUR 133.92/ metric ton and as a consequence the mean is a good representation of the data set. This statement is also true for the rest of the commodities. For corn and soybean meal the minimum and maximum prices can be read the same way as it was done with the prices of the feed wheat.

Table 4
Measures for central tendency and variability regarding commodity prices in EU-15, 1991-2009

Descriptive Statistics

EU-15	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Feed Wheat (EUR/MT)	227	169.73	89.08	258.80	133.92	31.89	1017.54
Corn (EUR/MT)	227	184.00	61.00	245.00	116.90	37.28	1390.06
Soybean meal (EUR/MT)	227	166.16	100.07	266.22	161.65	34.57	1195.26
Valid N (listwise)	227						

Source: Own calculation based on Bloomberg database, 2009

Histograms (see Figure 16, 17 and 18) are drawn for demonstrating the frequencies of the commodity prices. Prices for feed wheat range most often EUR 110-120/ metric ton during the examined period, for corn EUR 120-130/ metric ton and for soybean meal EUR 160-170/ metric ton. Taking a closer look at the frequency of corn, it can be seen that unlikely to the other two commodities it has two salient frequency points which are quite far from each other. Beside the highest frequency which ranges EUR 120-130/ metric ton, the second most frequent price of corn is EUR 70-80/ metric tons during the examined two decades. It can be explained by the introduction of EUR currency in 1999. Considering Figure 20, which represents the development of the commodity prices over the examined period, it can be observed that EUR 70-80/ metric ton was frequently observed before 1999. In that year there was a sharp rise in corn price achieving EUR 125/ metric ton probably due to the change in exchange rate as a result of the shift from ECU to EUR currency. This conception is confirmed by Figure A6 (see in Appendix), where the price of corn is given in USD/ metric ton. The slope of the corn price (USD/ metric ton) is quite flat in the year of 1999 which also indicates that the steep rise in corn price in Europe was due to the introduction of the EUR currency.

Taking a look at the figures below it can be stated that the distribution in the case of the feed wheat and soybean meal is slightly skewed to the left, while in the case of the corn is skewed to the right.

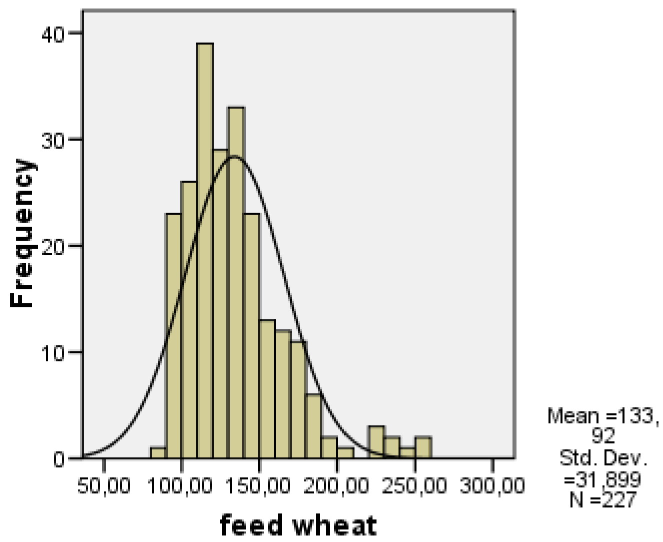


Figure 16: Frequency of prices for feed wheat
Source: Own figure based on Bloomberg

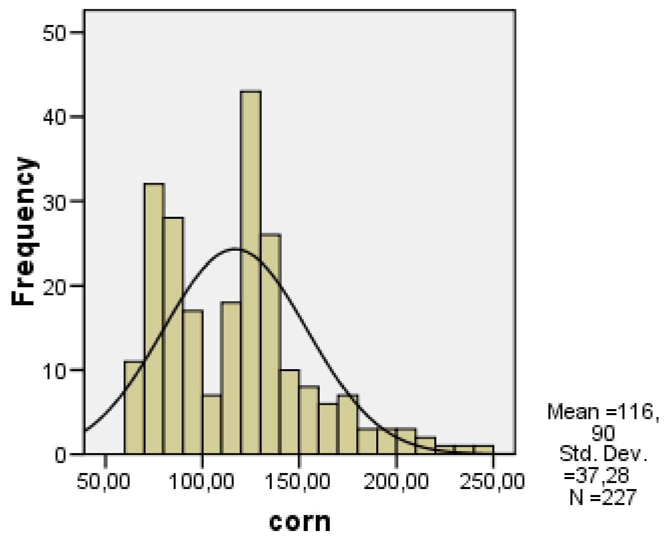


Figure 17: Frequency of prices for corn
Source: Own figure based on Bloomberg

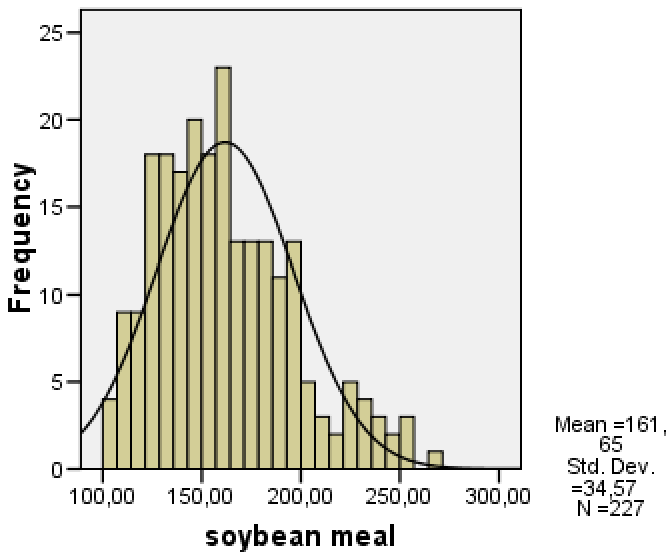


Figure 18: Frequency of prices for soybean meal
Source: Own figure based on Bloomberg

3.1.2.2 Development of commodity prices between 1991 and 2001

Prices for feed wheat showed a relatively standard development until the commodity boom occurred in 2006. Prices of feed wheat were around EUR 110-130/ metric ton until 2006. However prices for corn and soybean meal were fluctuating over this period of 1991 and 2009 and they showed similar movements (see Figure 19). In 1991 the price for corn was EUR 70/ metric ton and for soybean meal it was around EUR 120/ metric ton. By the beginning of 1997 both prices increased significantly. The price for corn increased with 50.2 percent to EUR 107.36/ metric ton by March 1997 while the price for soybean meal reached a peak in April 1997 with approximately EUR 250/ metric ton. The latter increased with 114 percent. The second peak of the prices of corn and soybean meal could be observed in the first half of 2004. The price of corn increased to EUR 177/ metric ton followed by the huge increase in the price of the soybean meal a couple of months later in April when it achieved EUR 241/ metric ton. The price increases in 1997 and 2004 might due to global changes in supply and demand. In 1997 the total domestic consumption of soybean increased by 3.0 percent in the world and in the meantime the year-on-year production growth slowed down achieving 1.5 percent (see Table 5 and Table 6 in Appendix).

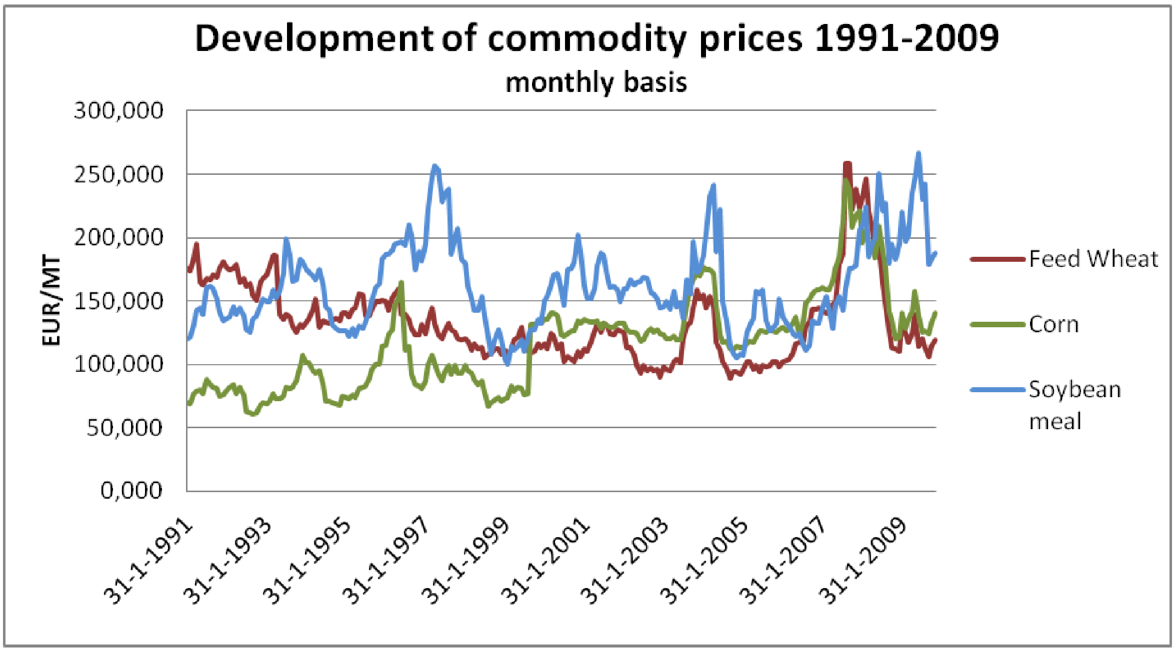


Figure 19: Development of feed wheat, corn and soybean meal prices between 1991 and 2009
Source: Own figure based on Bloomberg database, 2009

Since 2006 the prices of all three commodities have become much more volatile than they were before. The increased volatility stems from a rather complex combination of several factors (see Table 1 in Chapter 2).

3.2 Analysis of the relationship among pork price, pork supply and commodity prices

So far a descriptive analysis has been given on the pork price, pork supply and commodity prices followed by an assessment on the development of the three previously mentioned variables in EU-15 between 1991 and 2009. In this part, the relationship among pork price, pork supply and commodity prices is going to be analysed. Figure 20 gives a visual representation of these relationships. It includes the production, pork prices and commodity prices. In order to demonstrate the movement of the three commodities (feed wheat, corn, soybean meal) together, the weighted average price of them was taken. The weights are based on the commodities share in the compound feed that is wheat 20%, corn 35% and soybean meal 18%. Prices are deflated in order to clear both variables from the autonomous effect of time and avoid the spurious relationship[2]. This way we can get a more clear picture on the relationships. For deflation, the Consumer Price Index (CPI) was used in Europe from 1991 to 2009 in monthly basis.

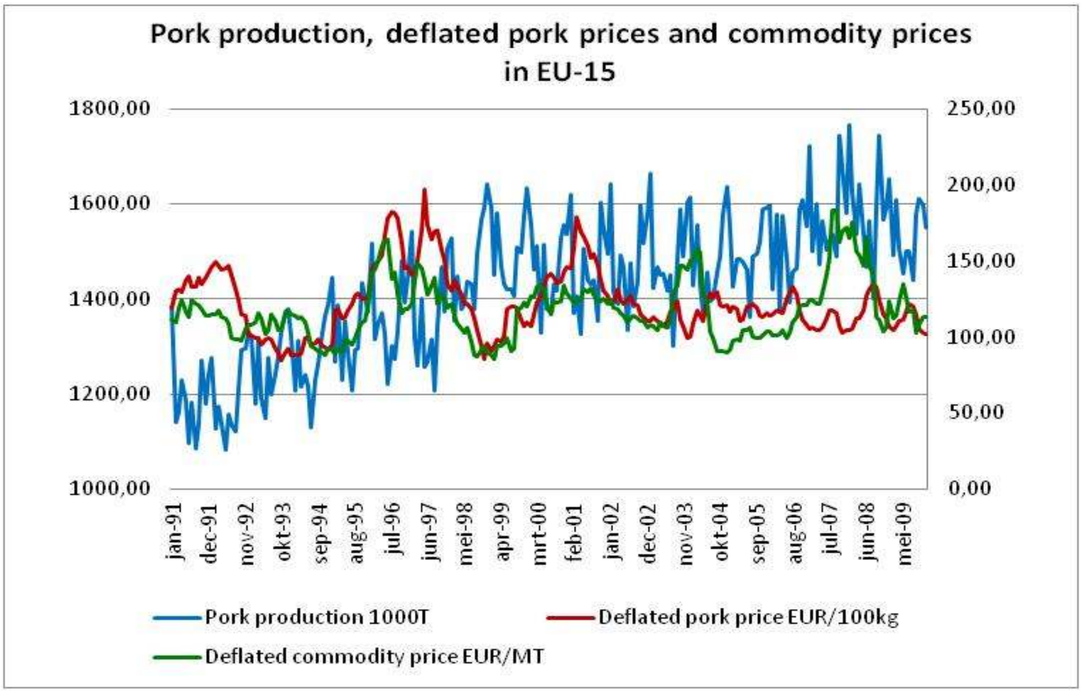


Figure 20: Relationship among pork production, pork price and commodity price
Source: Own figure based on Bloomberg database, 2010

The 6-7-year cycle can be clearly seen if we are taking a look at the line of the pork price. For instance, a peak can be observed around October 1991 which was followed by the next peak around January 1997. This figure also shows how the pork price follows the movement of the commodity prices with a certain time-lag. It is well-known that when commodity prices and thus feed prices increase, the output is assumed to decrease within a time-lag. It can be explained by the fact that due to higher input costs, there is lower incentive for producers to increase production. As a consequence, the supply will decrease and, the pork price will rise. It is hard to determine how much time passes away until the pork price reacts to the change in the commodity price. Based on the figure, the time-lag may be 10-12 months though it needs to be highlighted that the relation is indirect which makes the evaluation of the relationship even more difficult. The following table (see Table 5) statistically confirms that the 12-month time-lag is reasonable. It shows a simple correlation between pork price and commodity price.

[2] Spurious relation (or correlation) also called "illusory correlation" is a situation in which measures of two or more variables are statistically related but are not in fact causally linked, in other words the statistical relation is caused by a third variable (Field, 2000).

The "L12" represents the 12 months which elapse until the pork price reacts to the change in commodity price. In this context, the relationship between pork price in t time (any time within the period of 1991-2009) and commodity price 12 months before (t-12) is examined. The correlation is significant since P-value (= 0.00) is smaller than $\alpha = 0.05$ (the correlation is examined by taking a 95% confidence interval). The correlation shows a weak medium and positive effect ($r = 0.26$) between the variables.

Table 5
Correlation between deflated pork price and 12-month lagged deflated commodity price

Correlations

		deflated pork price	L12 deflated commodity price
deflated pork price	Pearson Correlation	1.000	**0.26***
	Sig. (2-tailed)		0.00
	N	216	216
L12 deflated commodity price	Pearson Correlation	**0.26***	1.000
	Sig. (2-tailed)	0.00	
	N	216	216

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Own calculation based on Bloomberg database, 2010

In the meantime, the reverse movement of the pork price and the pork production can also be observed. Theoretically, when the pork production is high, the pork price is low and when the pork production is low, the pork price is high. This statement seems to be proved by the figure. In January 1994, for example, there is a peak in the production, and the price that belongs to this production level is relatively low. The opposite occurs around March 1997 when the price of pork is high while the level of production is low. The reverse movement is also affirmed by Table 6.

Table 6
Correlation between pork production and deflated pork price

Correlations

		production	deflated pork price
production	Pearson Correlation	1.000	**-0.24****
	Sig. (2-tailed)		0.00
	N	223	223
deflated pork price	Pearson Correlation	**-0.24****	1.000
	Sig. (2-tailed)	0.00	
	N	223	223

**. Correlation is significant at the 0.05 level (2-tailed).

Source: Own calculation based on Bloomberg database, 2010

Table 6 represents the correlation between pork production and pork price in *t* time. The correlation coefficient clearly shows this negative relation between production and pork price (*r* = -0.24). It represents a weak medium effect between the variables. The results are significant at a 95% confidence interval: P-value is less than 0.05.

As already discussed, high pork prices induce high production which will realize later on. In this case, regarding to the time-lag, it is suggested to be approximately 18 months, if we take into consideration the lifecycle of the pig (10-12 months) plus the time needed for producers for decision making. Table 7 demonstrates the results of the correlation. The correlation coefficient indicates a weak and positive relationship between the variables though the results are not significant, P-value = 0.14 > 0.05. The correlation was repeated using 12- month time-lag and 24-month time-lag as well to find out how much time should pass until positive and significant results appear between the variables. In both case, the correlation coefficient were negative and for 12-month time-lag it was significant apparently due to the fact that in that phase of the cycle the reverse movement of the production and the pork price occurred, while for 24-month time-lag it was insignificant and it may stem from that this time-period was too long to detect the relationship.

Table 7
Correlation between pork production and 18-month lagged deflated pork price

Correlations

		production	L18 deflated pork price
production	Pearson Correlation	1.000	**0.10****
	Sig. (2-tailed)		0.14
	N	205	205
L18 deflated pork price	Pearson Correlation	**0.10****	1.000
	Sig. (2-tailed)	0.14	
	N	205	205

**. Correlation is significant at the 0.05 level (2-tailed).

Source: Own calculation based on Bloomberg database, 2010

Evaluation of the relationship between pork production and commodity price is an important part of this study since the more one knows about the relationship between them, the more accurate conclusions can be drawn regarding the impact of the increased price volatility of commodities. As it has been mentioned above, the increased commodity prices will be likely to drive the output down. But where is the point where feed price will decrease to perpetuate the cycle? One could argue that if production decreases and output goes down then there will be less demand for feed and therefore the prices of commodities will drop. However, commodities have so many alternative uses that a strong relationship here cannot be expected. That is probably one of the reasons why correlations between production and commodity prices have led to insignificant results, P-value larger than 0.05 (see Table 8) and it can be concluded that the effect might be too small to detect. Another reason might be that, given the theoretical background of the pig cycle and the cobweb theorem, the variation in output is mainly due to the variation in pork price and the price of feed is just introducing some additional noise in the model. If it is true, then why did the correlations between production and lagged deflated pork prices not show significant results? On the one hand, the reason may derives from that the phenomenon of the pig cycle is so complex that these simple correlation models cannot reflect what is happening in the reality and how these variables are actually related in the market. On the other hand, these correlations represent static expectations and it was discussed in the end of Chapter 2 that using adaptive expectations might be more reasonable if one wants to model the reality and captures the actual relationships.

Table 8
Correlation between pork production and 18-month lagged deflated commodity prices

Correlations

		production	L18 deflated commodity price
production	Pearson Correlation	1.000	**0.12****
	Sig. (2-tailed)		0.09
	N	205	205
L18 deflated pork price	Pearson Correlation	**0.12****	1.000
	Sig. (2-tailed)	0.09	
	N	205	205

**. Correlation is significant at the 0.05 level (2-tailed).

Source: Own calculation based on Bloomberg database, 2010

3.3 Adaptive expectations model

In the previous part it has turned out that static expectations models are not able to explain the relationships among pork production, pork price and commodity prices. A more advanced model is needed to reveal how the price movements impact the production in order to be able to make predictions about the impact of the increased price volatility of commodities. The following part introduces an adaptive expectations model which reveals how the changes in expected prices influence the production plan and how producers form their price expectations for future.

3.3.1 Introduction of Nerlove's model

All kinds of economic planning requires some sort of recursive analysis in which people try to make estimations for the future partly based on what they observe in the present. This is particularly essential in agriculture where programs, policies, supports are changing constantly. The cobweb model is the simplest recursive model in economics which is not only a realistic economic theory but can give practical forecasting and help establishing economic projections (Waugh, 1964). Despite all this, it has one weak point that cannot be ignored: the static expectations of the model. Static expectations assumption states that producers expect the price of next period to be the same as it is today:

$$p_t^* = p_{t-1}$$

Where: p_t^*: expected price for next period
p_{t-1}: price this period

However, each past price represents only a very short-run market phenomenon, and equilibrium of forces which are present in the market at that certain time. It can be an explanation why farmers may not react solely to last year`s price. In practice, in fact, it is more likely that producers form their expectations by considering the direction of recent historical data and adjust them based on the current observations to predict future prices. This hypothesis is known as adaptive expectations. The origins of the adaptive expectations can be traced back to Irving Fisher. It was formally introduced in the 1950s by Marc Nerlove among others (Evans and Honkapohja, 2001). Nerlove's adaptive expectations model is an elaboration of the cobweb model and therefore consistent with it. He assumes that producers form their expectations in terms of price in the following way:

$$p_t^* - p_{t-1}^* = \beta[\, p_{t-1} - p_{t-1}^*] \,, \quad 0 < \beta \leq 1 \qquad (1)$$

Where: p_t^* : expectations for next period based on current observations
p_{t-1}^* : expectations for this period based on the observations of the previous period
p_{t-1} : current observation
β: coefficient of expectation

In words, farmers revise their previous expectations for prices in each period in the proportion to the difference between actual price and what was previously expected. β is the proportion of the error by which producers adjust their expectations. It ranges between zero and one (Waud, 1968). When β is equal to 1, it means $p_t^* = p_{t-1}$ that is the producers' expectations for the future stem by 100% from what they observe today. This is the cobweb model, practically. When β is equal to 0, it means producers do not consider what is happening today when they form their expectations for the future (Nerlove, 1956). Most of us can agree upon that none of them seems to be reasonable in reality since farmers are likely to consider both the current market situation and their previous predictions. The β is expected to fall somewhere between the two boarders.

According to Nerlove, "farmers react, not to last year's price, but rather to the price they expect, and this expected price depends only to a limited extent on what last year´s price was" (Nerlove, 1956). Akerman also remarks that "if the price has been rising, the farmers generally will be not convinced it may remain so elevated until several years have elapsed" (Nerlove, 1958). Thus it might be stated that farmers respond to expected prices rather than observed. Therefore the supply equation in an output-price context is:

$$q_t = \alpha_0 + \alpha_1 p_t^* + \varepsilon_t \qquad (2)$$

Where : qt : quantity supplied in *t* time
p_t^* : expected price in *t* time
ε_t : error term in *t* time

If it is assumed that expected price (p_t^*) should not be identified with the previous period´ s price (p_{t-1}), in other words, the static expectations are rejected, the situation becomes more complicated because p_t^* cannot be observed in practice. One can tell what today's expected prices are, but cannot find what expected prices were in the past. That is what makes expected prices be not observable. Hence, there is a need for a variable which can represent it and which is observable. If we combine the first two equations, and go through some mathematics, we will get the final model:

$$q_t = \pi_0 + \pi_1 p_{t-1} + \pi_2 q_{t-1} + \varepsilon_t \quad (3)$$

Where $\pi_0 = \alpha_0\beta$, $\pi_1 = \alpha_1\beta$ and $\pi_2 = 1\text{-}\beta$. These equations come from the calculation. By estimating this multiple regression model, πs are produced and αs can be expressed to know the predictive power of p_t^*. All in all, using the hypothesis that farmers revise their expectations by a portion of error they make in prediction, estimates both of elasticity of supply to expected and historical prices and of the coefficient of expectation.

3.3.2 Adaptive expectations model based on Nerlove´s model

As it could be seen, the original model from Nerlove uses the adaptive expectations assumptions solely on the price of output. This study, on the other hand, attempts to find answers not only to the function of the output price in the expectations of the farmers but also the role of the feed price to be able to draw some conclusions on the increased price volatility farmers are facing with these days. Unfortunately, adaptive expectations assumption cannot be used on both of them, because the derivation breaks down if we try to do so.

Let us assume that pig producers respond to relative prices i.e. price of pork over price of feed rather than absolute prices. It seems reasonable since they want to maximize gross margin and to achieve this goal they probably take into consideration the effect of the price movements together and not isolated. In this case the linear model would be:

$$q_t = \alpha_0 + \alpha_1 \frac{p_t{}^*}{w_t{}^*} + \varepsilon_t \quad (4)$$

Where: q_t : quantity supplied in *t* time
p_t*: expected output price of pork in *t* time
w_t* : expected input price of feed in *t* time
ε_t : error term in *t* time

It means that the quantity supplied in period *t* is based on the output-input price ratio (p_t*/ w_t*) expected by the farmers for period *t* based on what they observe currently. If the same steps are followed as in Nerlove´s model, estimable model becomes:

$$q_t = \pi_0 + \pi_1 \frac{p_{t-12}}{w_{t-12}} + \pi_2 q_{t-12} + \varepsilon_t \quad (5)$$

Where *t-1* is replaced with *t-12* because the database consists monthly data, and minimum 12 months are required to produce a pig. This time period assumes to be the fastest possible response of the farmers to change in prices. It can be considered to be the first scenario. Although throughout this report it was mentioned several times that the farmers may have certain reaction time, and the time-lag involved in the pig cycle consists not only of the breeding time. The general assumption is that approximately 18 months are needed until the pork producers react to the price changes, if the lifecycle of the pig (10-12 months) plus the time needed for producers for decision making are taken into consideration. In this second scenario, the estimable model is:

$$q_t = \pi_0 + \pi_1 \frac{p_{t-18}}{w_{t-18}} + \pi_2 q_{t-18} + \varepsilon_t \quad (6)$$

The aim is to reveal in both scenarios how the change in output-input price ratio might affect the producers´ decision making on next period´s production which can help to draw conclusions about the impact of the increased volatility.

In order to be able to assess the results easily, logarithms are applied in the supply equations to get directly elasticity which will show the change in the outcome variable (production) in percentage caused by 1% change in the predictors. Equation (7) below is the logarithm form of (5), and equation (8) is the logarithm form of (6).

$$log\ q_t = \pi_0 + \pi_1 log \frac{p_{t-12}}{w_{t-12}} + \pi_2 log q_{t-12} + \varepsilon_t \quad (7)$$

$$log\ q_t = \pi_0 + \pi_1 log \frac{p_{t-18}}{w_{t-18}} + \pi_2 log q_{t-18} + \varepsilon_t \quad (8)$$

4 Results

This chapter presents the findings of the research. Firstly, the results of the logarithm models are shown followed by the results of the linear models which were run to confirm the value of coefficient of expectation. Finally, a so called Chow-test is implemented to reveal if there is any change in the way farmers form their expectations for the future prices due to the increased volatility of commodity prices.

4.1 Assessment of the results of the logarithm models

Table 9 shows the results of the logarithm model (7). The upper, smaller table provides the number of observations that is 211, the value of R-square (R^2) which is 0.77 and tells us that the independent variables - output-input price ratio 12 months before and production 12 months before as well - can account for 77% of the variation in the production in t time. In other words, 77% of the variance in the production is explained by the model. The rest could be explained by other factors, the drivers of the supply such as weather conditions, animal diseases, changes in income, policies, etc., which are not incorporated in the model. Furthermore, the table also represents the F-ratio which is significant at $p < .001$. This result tells us that there is less than 0.1% chance that F-ratio this large would happen by chance. F-ratio is a measure of how much the model has improved the prediction of the outcome compared to the inaccuracy of the model. According to F-ratio (356.04) the model is a good representative of the data.

Table 9
The results of the logarithm model using 12-month time-lag

Equation	Observation	"R-sq"	F	P-value
log_production	211	0.77	356.04	0.000

Model	Coefficient (π)	Std. Error	t	Sig.	95% Confidence Interval for π	
					Lower Bound	Upper Bound
(Constant)	1.11	0.23	4.68	0.00	0.64	1.58
L12 log_ratio	0.04	0.02	2.36	0.01	0.01	0.07
L12 log_production	0.85	0.03	25.82	0.00	0.78	0.91

Source: own calculation, 2010

The value of parameter π_1 is 0.04 which can be interpreted as the supply elasticity with respect to the price ratio is small, while π_2 is 0.85 i.e. 1% increase in the supply this period would lead a 0.85% increase in production in the following period.

In Table 10 we can see the results of the logarithm model (8). The number of observations is less in this case because larger time-lag is used (N=205), the value of R-square (R^2) is 0.23, that is 23% of the variance in the production is explained by the model. It is remarkably smaller than what was observed within the previous model. The table also represents the F-ratio which is significant at $p < .001$ but much less comparing to the previous F-ratio in table 9 which means model with 18-month lag is a worse representative of the data.

Table 10
The results of the logarithm model using 18-month time-lag

Equation	Observation	"R-sq"	F	P-value
log_production	205	0.23	30.08	0.000

Model	Coefficient (π)	Std. Error	t	Sig.	95% Confidence Interval for π	
					Lower Bound	Upper Bound
(Constant)	4.04	0.42	9.73	0.00	3.22	4.86
L18 log_ratio	0.08	0.03	2.52	0.01	0.01	0.14
L18 log_production	0.444	0.06	7.76	0.00	0.33	0.55

Source: own calculation, 2010

The value of parameter π_1 is 0.08 which indicates the supply elasticity with respect to the price ratio is small, while π_2 is 0.44 i.e. 1% increase in the supply this period would lead a 0.44% increase in production in the following period. The validity of the elasticity is verified in Appendix (see Verification) to be sure proper results were produced by the model.

Given πs, αs and the β can be easily calculated the way it is indicated in Table 11. Parameter α_1 in the 12-month lagged model is equal to 0.26 which means that 1% increase in the expected output-input price ratio will result in 0.26% increase in production. As a conclusion, a positive relation can be detected between the production and the ratio by the adaptive expectations model. It is quite reasonable since the pork price is the numerator while the feed price is the denominator of the ratio, so the ratio itself will increase mathematically when the pork price increases and the feed price stays the same or increasing in a lower rate, and it is known from the theory, when the pork price increases, it will induce the increase in production after a while. Thus it is statistically proved that increase in pork price will lead to increase in production and supply. On the other hand, following the same logic as before, it is also proved that increase in feed price will decrease production due to higher input costs since increase in feed price will decrease the value of the ratio. As for the 18-month lagged model, the parameter α_1 is 0.14. That is, the supply elasticity regarding the expected out-put-input price ratio is less comparing to the parameter estimate produced by the 12-month lagged model.

Table 11
Calculation and values of αs and the β in the 12-month lagged model and the 18-month lagged model

Calculation	Parameter	Value besides 12 months	Value besides 18 months
$\Pi_0 = \alpha_0\beta$	α_0	7.40	7.21
$\Pi_1 = \alpha_1\beta$	α_1	0.26	0.14
$\Pi_2 = (1-\beta)$	β	0.15	0.56

Source: own calculation, 2010

β gives relevant information about the farmers´ behaviour regarding to how they form their price expectations. The value of β according to the 12-month lagged model is 0.15 which is rather low. It might be capturing an effect that has to do with farmers not having enough time to respond to price changes if the actual lag needed is 18 rather than 12 months. In the meantime, in the 18-month model is 0.56. In the linear model the interpretation of β would be that farmers form their expectations for the future output-input price ratio in 15% (in 12-month lagged model), 56% (in 18-month lagged model) based on what they observe today. Although in the logarithm model the interpretation of β can change slightly due to the logs since comparing to equation (1), the logarithm model produces a β that is the parameter of a difference of two logged prices:

$$logp_t^* - logp_{t-1}^* = \beta[\,logp_{t-1} - logp_{t-1}^*\,]$$

Therefore to get how much percent farmers base their future expectations on the current output-input ratio, the linear models, (5) and (6) are also run.

4.2 Assessment of the results of the linear models

After running the linear models to get to know the real values of β, the following tables were produced (see Table 12 and Table 13). The parameters of the linear model are denoted by π* to be able to distinguish from the parameters of the logarithm models.

It can be seen in Table 12 that π_2^* is 0.86 that is the value of β is 0.14, almost the same as what the logarithm model with 12-month lag produced.

Table 12
The results of the linear model with 12-month time-lag

Equation	Observation	"R-sq"	F	P-value
production	211	0.77	346.68	0.000

Model	Coefficient (π^*)	Std. Error	t	Sig.	95% Confidence Interval for π^*	
					Lower Bound	Upper Bound
(Constant)	152.07	62.60	2.43	0.01	28.65	275.48
L12 ratio	62.70	25.48	2.46	0.01	12.47	112.93
L12 production	0.86	0.03	25.46	0.00	0.79	0.92

Source: own calculation, 2010

The value of π_2^* produced by the linear model with 18-month lag is 0.440 (see Table 13) which is almost the same as in Table 10 thus it results in the same value for β as well that is 0.54. Hence it can be concluded that the current observations account for 14-15% in forming future expectations according to the model with 12-month lag, while 56% according to the model with 18-month lag. The rest comes from what they previously predicted. It has to be noted that Nerlove also got similar results for the β occurred in the model with 18-month lag when he was dealing with the role that farmers´ expectations for future relative prices plays in shaping their decisions regarding how many acres should be devoted to each crop (cotton, wheat, corn). He found that β ranges between 0.51 and 0.54 for these crops (Nerlove, 1956).

Table 13
The results of the linear model with 18-month time-lag

Equation	Observation	"R-sq"	F	P-value
production	205	0.21	27.35	0.000

Model	Coefficient (π^*)	Std. Error	t	Sig.	95% Confidence Interval for π^*	
					Lower Bound	Upper Bound
(Constant)	686.43	110.28	6.22	0.00	468.97	903.89
L18 ratio	124.27	46.20	2.69	0.01	33.17	215.36
L18 production	0.440	0.06	7.38	0.00	0.32	0.56

Source: own calculation, 2010

4.3 Could any change occur in the way farmers form their expectations due to the increased price volatility?

In the previous section the coefficient of expectations was calculated for the entire observation period, from 1991 to 2009 taking both 12-month and 18-month time-lags. Despite the fact that, theoretically, the value of β should not change within a time period and using a certain time-lag because it is a "deep" parameter, in other words, a draft estimation about how farmers form their expectations in general within this period, testing the hypothesis that β has changed at a specific point in time is rather concerned in this research since in 2006 the effect of the commodity boom could already be observed and since then prices have become more volatile than they used to be. The question arises whether this "structural break" could have changed β, in other words, does the value of β differs before and after 2006?

To test the hypothesis that the β has changed since 2006, a so-called Chow-test is needed to implement within which the timeframe initially examined is split into two parts, one before 2006 and one after it. For simplicity, the period of 1991-2005 will be called the "first" period and from 2006 will be the "second" period. The test produces the parameters of the predictors for the first period and the parameter estimates of initially created dummy variables which express changes relative to the parameters before the break. The test is run with 12-month and 18-month time-lag as well. The results are presented in Table 14 and in Table 15.

Table 14
The results of the Chow-test for structural break with 12-month time-lag

Equation	Observation	"R-sq"	F	P-value
production	211	0.77	172.13	0.000

Model	Coefficient (π)	Std. Error	t	Sig.	95% Confidence Interval for π	
					Lower Bound	Upper Bound
(Constant)	1.57	0.25	6.28	0.00	1.08	2.07
Period 1991-2005						
L12 log_ratio	0.04	0.02	1.90	0.06	-0.01	0.07
L12 log_production	0.78	0.03	22.58	0.00	0.71	0.85
Period 2006-2009						
L12 change log_ratio	0.04	0.03	1.43	0.15	-0.02	0.1
L12 change log_production	0.01	0.01	2.24	0.03	0.00	0.01

Source: own calculation, 2010

Table 15
The results of the Chow-test for structural break with 18-month time-lag

Equation	Observation	"R-sq"	F	P-value
production	205	0.30	21.73	0.000

Model	Coefficient (π)	Std. Error	t	Sig.	95% Confidence Interval for π	
					Lower Bound	Upper Bound
(Constant)	4.83	0.44	11.11	0.00	3.97	5.69
Period 1991-2005						
L18 log_ratio	0.09	0.03	2.54	0.012	0.02	0.17
L18 log_production	0.33	0.06	5.54	0.00	0.21	0.45
Period 2006-2009						
L18 change in log_ratio	-0.05	0.06	-0.78	0.44	-0.17	0.07
L18 change in log_production	0.01	0.01	4.59	0.00	0.01	0.02

Source: own calculation, 2010

They suggest that the null hypothesis (same parameters before and after 2006) can be rejected regardless of the lags since the values of π_2 before and after 2006 are not the same. With a 12-month lag, the parameter of expectation (β) in the first examination period (1991-2005) is 22%, while in the second examination period (2006-2009) β is lower due to the fact that π_2 increasing (0.78+0.01). With respect to the 18-month time-lag, the same can be stated. The parameter of expectation is 67% for the first period and a bit decreasing for the second due to a positive change occurring in π_2. It can be seen that π_2 goes up in the period of 2006-2009 for both scenarios which indicates that β goes down. The difference between β before and after 2006 suggests that the effect of the commodity boom and the increased price volatility can be observed in the way farmers form their expectations for future prices. Results reveal that farmers tend to react less to recent information on prices from 2006 according to the results. It seems quite reasonable since prices are characterized by wide swings in the market currently. All in all, making decisions is likely to be based on current observations to a less extent than it used to be.

Taking a look at the parameters of the ratio in the 12-month lagged model before and after 2006, it can be concluded that supply elasticity with respect to the price ratio has increased, quite precisely multiplied after the break. It is a bit against what the change in β indicates, though, it has to be considered that this result is not significant. Regarding supply elasticity after 2006 in the 18-month lagged model, it is negative (-0.05) which indicates that the production responds to the change in prices to a less extent after 2006 than before. Despite it is not significant either, forgetting statistics for a moment, it would mean that farmers are not responding to prices the way they did before which is exactly what the change in β indicated before. Prices are rising and falling rapidly, no one can tell what they will be next month, then why would they react to them too much? Nowadays it is hard to make profit in short run. Pig farmers produce negative margins, but, despite all this, the practice shows that most of them seem to continue producing and make plans for longer run since they have no alternative activity. As for the significance, the fact cannot be ignored that if producers are assumed to respond to prices of 12 or 18 months ago and the "structural break" occurred in 2006, there are rather few observations after 2006 onwards.

4.4 Summary of results

The results of the adaptive expectations models indicate that supply elasticity regarding the output-input price ratio is relatively small in both scenarios. For the model contains 12-month time-lag, it is 0.04 and for the model includes 18-month lag is 0.08. While the supply elasticity with respect to the *expected* ratio is a bit larger 0.26 in the case of 12-month lag and 0.14 in the case of the 18-month lag. This relatively small elasticity might be due to the fact that once farmers have invested into animal keeping (the cost of insemination, stables, machines, labor, etc.) it is not likely that a radical change occurs in production due to increase or decrease of the prices. Even in unfavorable circumstances they tend to continue with production despite of negative profit margins realized in short-run.

The model also gives estimation about how farmers might form their future price expectations. According to the model with 12-month lag, farmers base in 14-15% on what they observe in the present when they form their expectations for the future prices at least in short run. As for the model with 18-month lag, the parameter of expectations indicates that farmers considering the current situation in 56% when they are forming their future price expectations. It is suggested not to take these values severely. If farmers have decided on producing in large scale, they will not react to these expectations very much.

Finally, it was tested whether there was a change in the way farmers form their expectations for the future prices due to the increased price volatility of commodities. It seems that the null hypothesis that is there is no change can be rejected. Although, it is not easy to predict accurately what extent it changed due to the few data available from 2006. The model indicates that after 2006 producers consider current prices less than they did before. In fact, the point is whether they plan for short run or long run. If they make long run investments, they are not likely responding to current prices very much.

5 Conclusions and discussions

5.1 Conclusions

The phenomenon of cycles can be regularly observed in the agriculture in certain types of markets such as the pork market. Cyclicality finds several ways of expression, still, one common attribute of the cycles is the complex nature of macroeconomic relations among factors which are continuously shaping them.

Pork production and pork prices are the main determinants of the pig cycle in the past and present and they will be in the future as well. Besides them, commodity prices also play a role though it seems to cause some extra noise in the supply rather than to be a core determinant. Apparently the increased volatility of commodity prices leads to increased uncertainty and risk, however its impact could have been observed more in the incomes of farmers who realized negative profit margins in the last two years than in production so far. Among the drivers there are structural (long-term) and temporary (short-term) factors. Within the structural factors the increasing global demand, changing policies and increased energy prices have to be emphasized. In the future global demand is expected to increase further forcing increasing production. As for policy changes, the next major reform of the CAP, scheduled for 2013 which will impact investment and production plans. As for temporary factors, the global economic crises hit the economy and agricultural sectors in general causing tightening credit availability. In the future besides the adverse selection and diseases which exist all the time, changes in supply of competing products and income are also expected.

This paper affirms that pork production, pork prices and commodity prices are directly or indirectly related to each other in the pig cycle. Therefore it is quite logical to state that changes in one of the variables may induce changes in the other two within a certain time period. The question was to what extent they are related i.e. how heavily the change in a variable affects the rest of them. Theoretically, when the prices of feed increase the production and then the quantity supplied are likely to decrease due to the increased input costs. At the point when supply cannot satisfy demand, the pork prices start to rise which will motivate farmers to introduce new gilts (increase production). Increase in production will increase the demand for feed leading to increasing feed prices and the cycle starts again, perpetuating eternally.

Despite these seemingly clear dependences, simple statistical models such as correlations and simple linear regressions appeared to be unable to grab how they are actually connected to each other. The main reason of this can be the isolated treatment of the variables within these relatively simple models. The production, pork prices and commodity prices exist in a solid context, they cannot be evaluated separately from each other. Not to mention that several other factors which are not included in these simple models may impact them and their relationships. More complex models are needed to explain the phenomenon of the cycle to reveal the linkage among production, pork prices and commodity prices.

The Cobweb model is an economic model which serves as a theoretical explanation of the pig cycle. The theorem is operational, revealing a series of reactions, still the static expectations assumption of the model does not seem to be realistic enough. This previous statement supports the decision on implementing an adaptive expectations model based on Nerlove´s model. In the model the major assumption is that farmers are likely to respond to relative prices (output price over input price) rather than absolute prices since they seek to maximize gross margins. The results indicate that the supply elasticity with respect to the output-input price ratio is positive as it was expected but relatively small. The reaction of quantity supplied to *expected* ratio is a bit larger but the difference is not remarkable. It means that the volatility of commodity prices impacts the quantity supplied but may not cause such a great volatility in production. In particular, two reasons can be mentioned to explain this. On the one hand, when farmers produce in large scales, they do not seem to pay much attention to price volatilities in short run. On the other hand, before 2006 the pig-cycle was mainly determined by solely the demand-driven supply and the price of pork. It can easily happen that the time elapsed since 2006 was not enough to detect the actual effect of the volatility.

It can be expected that the number of farmers who will continue to operate and produce will be larger than those who will stop their activity. Consolidated, highly specialized and dedicated farms will continue to produce despite the volatility of feed prices, while smaller or mixed farms tend to leave their production in abeyance permanently or temporarily. This can also explain the low supply elasticity. In addition, until 2006 the feed prices were relatively stable. Why could not they stabilize again later on? Besides, it should be also considered that farmers would probably find themselves with lower incomes if they extensively revise their production plans in response to the wide swings that take place currently in the prices of commodities. They may base their decisions on some reasonable assessment of the supply and demand conditions of pork meat. Even if they cannot realize profit in a short run, most farmers tend to continue to produce. It should also be taken into consideration during the evaluation of the findings that it has been “only” four years that the commodity boom occurred. It can also happen that the effect of the increased volatility of commodity prices could be observed in the profit margins and not in the production yet. Although, there is no doubt that increased volatility in prices heavily impacts pig farmers and the pig industry due to increased uncertainty and risk.

The model also gives information about how farmers may form their future price expectations. Apart from the numbers, it has to be emphasized that the model assumes that farmers revise their expectations in every 12 or 18 months. Therefore it is short run estimation. For a longer run projection it must be different since in long-run plans current prices are not likely to pay such a great role.

The question has arisen whether the way how farmers form their expectations changed or not after 2006 due to the increased price volatility comparing to the period of 1991-2006. The results suggest that the null hypothesis (same parameters before and after 2006) should be rejected. In more precisely there must have been a change in the way how farmers behave during predicting prices. The model indicates that farmers tend to react less to recent information after 2006 which sounds intuitive considering that prices are changing rapidly and continuously. Note that, the numbers the models produced are indications. They cannot be taken too seriously since after 2006 there are few data available. As for the parameter of the ratio, both scenarios produced insignificant results, which also foreshadow the limitations of the model to predict the accurate effect of the increased volatility of commodity prices on production. Though, despite the insignificance of the results, the model indicates that the production is less elastic with respect to relative prices after 2006.

From the pig cycle`s point of view it can be said if farmers are unresponsive to price changes, then the cycle can be longer or shorter as well in the future depending on other drivers which are also shaping the cycle. On the one hand, if farmers are not convinced about current prices will remain for a longer run, they may wait to make decisions on production. It is especially true for not so specialized and small farms like in Spain and Italy and especially Central and Eastern Europe. This way the cycle is lengthening and becomes more pointed. On the other hand, consolidated, large farms such as farms in the Netherlands may try to adopt the new circumstances, and if they really do so, it may lead to the flattening of the cycle. It is called the “dampening effect” which can occur due to the fact that prices are changing rapidly forcing producers to make decisions and acting faster. As a consequence, the pig cycle might become flatter and in the meantime the length is getting shorter. Notwithstanding, it cannot be ignored that the relatively long life-cycle of the pig causes some limitations in reacting very fast because 10-12 months are needed to raise a pig therefore an enormous change cannot be expected in the length of the cycle.

All in all, the pig industry is a finely tuned agricultural industry. External shocks such as fluctuations in feed prices, currency and import/export conditions can threaten its future development if it is not able to adapt to these changing conditions. Undoubtedly the volatility of feed price is a major issue that needs to be addressed to ensure that pig producers can continue to operate and produce pork meat. For this purpose, the pig industry must continue to grasp the adjustment challenge to have the potential to grow.

5.2 Discussions

The adaptive expectations model which was implemented is one of the easier, less complicated econometrics models for explaining the phenomenon of cycles. Therefore it has certain limitations to reveal what is really happening in the pig market and what changes occur due to the increased price volatility. Literature highlights that economists who dealt with the statistical estimation of the parameters of economic models possessing dynamic characteristics applied either “adaptive expectations” models or “partial adjustment” models. The reduced forms of these models are indistinguishable from each other from the point of estimating parameters, that is, both models lead to equivalent estimating equations, though they are generally believed to be conceptually different models. More precisely, while the adaptive expectations model attributes lags to uncertainty and the discounting of current information, the partial adjustment model attributes the same lags to technological and psychological limitations (Waud, 1966). Waud argues that the adaptive expectations model and the partial adjustment model are special cases of a more general model. He assumes that the reduced forms of the two models derive from a specification error made in the general model. Namely, it was pointed out that the use of the adaptive expectations model can often be a misspecification of habit persistence in the partial adjustment sense, likewise the use of the partial adjustment model may often be a misspecification of expectations formation in the adaptive sense. If it is true, then estimates of the adaptive expectations model and the partial adjustment model will naturally be biased when the “true generator of the data” is the general model. Waud also emphasizes in his study that even if one of these special cases of the general model is the true specification, it is not statistically possible to tell which one (Waud, 1966). This general model and how it was generated using the adaptive expectations model and partial adjustment model can be learnt in more detail in his scientific article.

Data used in the model applied are monthly data. Weekly data would probably produce even more accurate results. The prices are deflated with Consumer Price Index (CPI) in order to avoid the undesirable effect of spurious relationship. They could be also deflated by their own inflation rates to be more precise but for simplicity CPI was used. One limitation of the model stems from the fact that only a few observations are available after 2006. Since it is assumed that the effect of price changes today will be observed in quantity supplied after 18 months (it attributes to one cycle), approximately two cycles can be examined after 2006 which are not representative enough and the results are insignificant for that relatively short period.

Another topic to discuss can be the issue of policy changes in the EU and their possible effect on production in the past and in the coming future. Since 1992, the EU's Common Agricultural Policy has undergone significant changes as subsidies have been decoupled from production i.e. there was a shift from production support to direct income support for farmers. This is the so-called Single Farm Payment. Most industries were highly impacted by this shift especially the grain industry but the pork industry was not hit because it was much less supported comparing to other industries. It might be due to the fact that when CAP policies came into forth the pig industry was a leader and it could maintain its status ever since. There was an export subsidy for pork meat for a couple of years but around 2006 it was also left in abeyance. The next major reform of the CAP, scheduled for 2013, is currently being negotiated, although, given European budgetary constraints and international trade regulations, it is possible that the single payment regime (SPR) and price support mechanism will be drawn up causing increased price risks for farmers in general (Thomas, 2007). The more the risk is, the more the speculation in the markets which generally lead to increased price volatility. The challenge is to find instruments which provide the producers with an adequate safety net such as farming insurance, income protection insurance or futures contracts in the case of the need to cut down public support to farms. However it has to be noted that the pig industry is more likely to be impacted indirectly by changes in CAP through changes in prices of competing products or increased price volatility of feed.

6 Recommendations

The statistical problems associated with the estimation of models containing lagged values of the dependent variable among the predictor(s), such as the adaptive expectations model used in this paper, are partly due to the complexity of the phenomenon and the fact that they cannot easily separate short- and long run effects."The cobweb phenomena have operated with one unique normal supply schedule without distinguishing between short- and long-term schedule" (Nerlove, 1958). To solve this problem, mathematical models may be constructed which distinguish between long- and short run elasticity of supply and which incorporate both a long run supply curve and its associated short run supply curves into the analytical framework. Before giving a short description on how the model that is used in this paper can be improved, firstly Nerlove`s assumption has to be considered. He argues that from any point on a long run supply schedule, a range of short run supply curves may exist which gradually approach the long run supply schedule. In other words, the consideration suggests modeling the relation between current (or short run) output and long run output. In this context let Qs_t be the long run equilibrium supply curve while qs_t the short run supply curve. The following equation produces a wide range of short run supply curves through each point of the long run curve:

$$qs_t - qs_{t-1} = \gamma_s [Qs_t - qs_{t-1}], \qquad 0 < \gamma_s \leq 1$$

The constant term, γ_s is called as the coefficient of adjustment. It is the rate of adjustment to long run equilibrium which is proportional to the difference between current output and the long run equilibrium supply curve. This model can also be supplemented with the current demand and the long run equilibrium quantity demanded. More detailed explanation and application of the model can be found in Nerlove`s article about Adaptive Expectations and Cobweb Phenomena.

Another interesting research topic would be to test the stability of the pig cycle. In particular, to reveal whether it is characterized by convergent fluctuation (stable) or divergent fluctuation (unstable). Akerman assumes that "cobweb fluctuations involving growing disequilibrium are improbable" (Akerman, 1957), though testing his assumption regarding pig cycle might be relevant. First and foremost, the elasticity of pork supply and the elasticity of pork demand should be estimated and the adaptive expectations model. They could be known from the following supply and demand equations:

$$Qs_t = \alpha_0 + \alpha_1 P_t^* + \varepsilon_t$$
$$Qd_t = \omega_0 + \omega_1 P_t + \varepsilon_t$$

$$p_t^* - p_{t-1}^* = \beta[\, p_{t-1} - p_{t-1}^*] , \quad 0 < \beta \leq 1$$

Where: Qs_t : quantity supplied in t time
Qd_t : quantity demanded in t time
P_t* : expected price for t time
P_t : price in t time
ε_t : error term in t time

Secondly, the necessary and sufficient condition for stability should be set. Going through some mathematics Nerlove indicates that the stable condition is the following (Nerlove, 1958):

$$1 - \frac{2}{\beta} < \frac{\alpha_1}{\omega_1} < 1$$

The methods outlined above may be used to construct further models for explaining cycles which can be adapted to fit complex, individual situations wished to investigate. Though it should be taken into consideration that it is difficult to draw conclusions about reality from a purely theoretical model.

References

Agriculture Marketing Resource Center (AgMRC), 2009, Impact of rising feed prices on pork profitability, AgMRC Renewable Energy Newsletter.
Available online at:
http://www.cmp.org/CD_DEFENSA_PORCICOLA/ventasUSA/Impact%20of%20Rising%20Feed%20Prices%20on%20Pork%20Profitability.pdf

Akerman, G., 1957, The Cobweb Theorem: A Reconsideration, The Quarterly Journal of Economics, Vol. 71, No. 1: 151-160.

Anonymous, 2009, The year of declining sow numbers, World market review, Pig International, July/August: 8-9.

Anonymous II., 2008, "Cobwebs" to appear in Famous Diagrams in Economics, eds. Mark Blaug and Peter Lloyd, Edward Elgar Publishing.
Available online at: http://faculty.arec.umd.edu/mnerlove/Cobwebs%20Draft%20102408.pdf

CIRCA, 2009, EU reference prices for meat species.
Available online at: http://circa.europa.eu

Chisholm, M., 1962, Tendencies in agricultural specialization and regional concentration of industry, Regional Science Association, Papers, X., Zurich Congress.
Available online at: http://www.springerlink.com.ezproxy.library.wur.nl/content/t41550076gpg228k/

Cohen, R., Barker, J. D., 1935, The Pig Cycle: A Reply, Economica, New Series, Vol. 2, No. 8: 408-422

Beek, V., 2007, Feed prices rise everywhere: a case study from France, Pig Progress, Vol. 23, No. 8: 9-10.

Best, P., 2009, Output grows before the storm, Pig International, July/August: 10-12.

Boston, C., Ondersteijn C., Giesen G., 2004, Using stakeholder views to develop strategies for the Dutch pork supply chain, Paper presented at the 14th annual IAMA Conference, June 12-15, 2004, Montreux, Switzerland, Wageningen University, Social Science Group, Business Economics.

Breimyer, H.F., 1959, Emerging Phenomenon: A Cycle in Hogs, Journal of Farm Economics, Vol. 41, No. 4: 760-768.

Clark, E., 2009, Silver lining, finally?, Pig International, Sept: 4.

Coase, R.H., Fowler, R.F., 1937, The Pig-Cycle in Great Britain: An Explanation, Economica, New Series, Volume 4, No. 13: 55-82.

Donald, P.F, Pisano, G., Rayment, M.D., Pain, D.J., 2002, The Common Agricultural Policy, EU enlargement and the conservation of Europe's farmland birds, Agriculture, Ecosystems and Environment 89: 167–182.

European Commission, Directorate-General for Agriculture and Rural Development, 2009, Economic analysis of EU agriculture.
Available at: http://www.vleva.eu/system/files/food10_2009_en%5B1%5D.pdf

Ezekiel, M., 1938, The Cobweb Theorem, The Quarterly Journal of Economics, Vol. 52, No. 2: 255-280.

Environment, Food and Rural Affairs Committee, 2009, The English pig industry.
Available online at: http://www.publications.parliament.uk/pa/cm200809/cmselect/cmenvfru/96/9605.htm#n27

Evans, G. W., Honkapohja, S., 2001, Expectations, Economics of, International Encyclopedia of the Social & Behavioral Sciences, Elsevier Science Ltd.:5060-5067

Field, A., 2000, Regression, Discovering Statistics Using SPSS, SAGE publications:144-157.

Harlow, A.A., 1960, The Hog Cycle and the Cobweb Theorem, Journal of Farm Economics, Vol. 42, No. 4: 842-853.

Holt, C.A., Villamil, A.P., 1986, A laboratory experiment with a single-person cobweb, Atlantic Economic Journal, Vol. 14, No. 2: 51-54.

Lianos,T.P., Rausser, G.C, 1972, Approximate Distribution of Parameters in a Distributed Lag Model, Journal of the American Statistical Association, Vol. 67, No. 337: 64-67.

Mataragas, M., Skandamis, P.N., Drosinos, E.H., 2008, Risk profiles of pork and poultry meat and risk ratings of various pathogen/product combinations, Agricultural University of Athens, Department of Food Science and Technology, Laboratory of Food Quality Control and Hygiene.
Available online at:
http://www.sciencedirect.com.ezproxy.library.wur.nl/science?_ob=ArticleURL&_udi=B6T7K-4SJP77R-2&_user=533256&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_acct=C000026798&_version=1&_urlVersion=0&_userid=533256&md5=2ce300c9681a401e0afbf1fe7c52990d

Meyer, S., Steiner, L., 2009, Daily Livestock Report, CME Group, Vol. 7, No. 209.

Mitchell, D., 2008, A note on rising food prices, Policy Research Working Paper, The World Bank, Development Prospects Groups. Available online at:
http://www.wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf

Morgan, J.J., 1928, Factors affecting prices of pigs in Wales, Welsh Journal of Agriculture, Vol. 4: 5-21.

Muth, J.F., 1961, Rational Expectations and the Theory of Price Movements, Econometrica, Vol. 29, No. 3: 315-335.

Nerlove, M., 1956**,** Estimates of the Elasticities of Supply of Selected Agricultural Commodities, Journal of Farm Economics, Vol. 38, No. 2:496-509.

Nerlove, M., 1958, Adaptive Expectations and Cobweb Phenomena, The Quarterly Journal of Economics, Vol. 72, No. 2: 227-240.

OECD-FAO, 2009, Agricultural Outlook 2009-2018.
Available online at: http://www.oecdilibrary.org/oecd/content/book/agr_oecd-2009-en

Rabobank, 2008, Animal Proteins: Costs and Commodities (Available in Rabobank).

Rabobank, 2009, Changing Industry Landscapes; Risks and Rewards in the Feed-to food Value Chain (Available in Rabobank).

Thomas, A., 2007, Price Risk Management post 2013, Introductive paper to the task force 10, Project PAC 2013.
Avaiable online at: http://www.notre-europe.eu/fileadmin/IMG/pdf/AC_Thomas_-_Price_Risk_Management.pdf

Topliff, M.M., Kees de Roest, M., Roguet, C., Chouttea u, M.P., Mottet, A., Sarzeaud, M.P., Beaumond, M. N., Magdelaine, P., Hoste, M.R., Van Horne, M.P., Deblitz, C., 2009, The impact of increased operating costs on Meat Livestock in the Eu.
Available online at: http://www.europarl.europa.eu/studies

Quanbeck, K., Johnson, R., 2009, Livestock, Dairy and Poultry Outlook, Economic Research Service, USDA.

USDA Foreign Agricultural Service, 2009.
Available online at: http://www.fas.usda.gov/psdonline/psdQuery.aspx

Waud, R.N., 1966, Small Sample Bias Due to Misspecification in the “Partial Adjustment” and “Adaptive Expectations” Models, Journal of the American Statistical Association, Vol. 61., No. 316: 1130-1152.

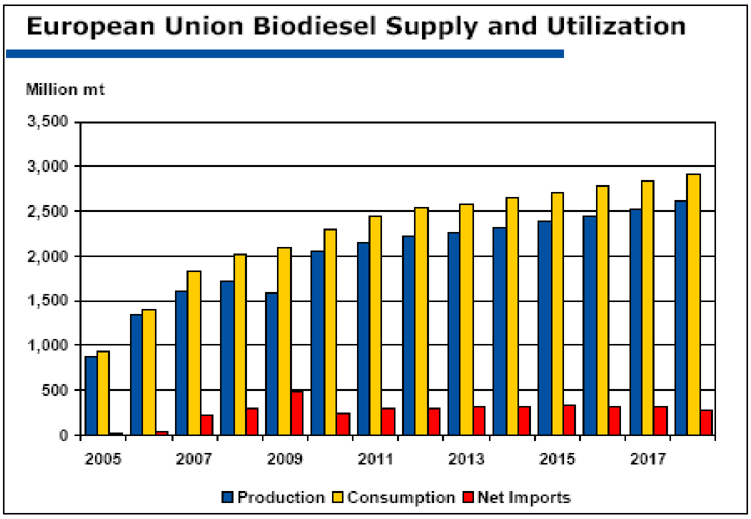
Waud, R.N., 1968, Misspecification in the "Partial Adjustment" and "Adaptive Expectations" Models, International Economic Review, Vol. 9, No. 2: 204-217.

Waugh, F.V., 1964, Cobweb models, Journal of Farm Economics, Vol. 46, No. 4: 732–750.

Wognum, P.M., M. Wever, O. Nijhof-Savvaki., 2008, General description of pork chains in The Netherlands, Wageningen University, Management Studies group.

Appendix

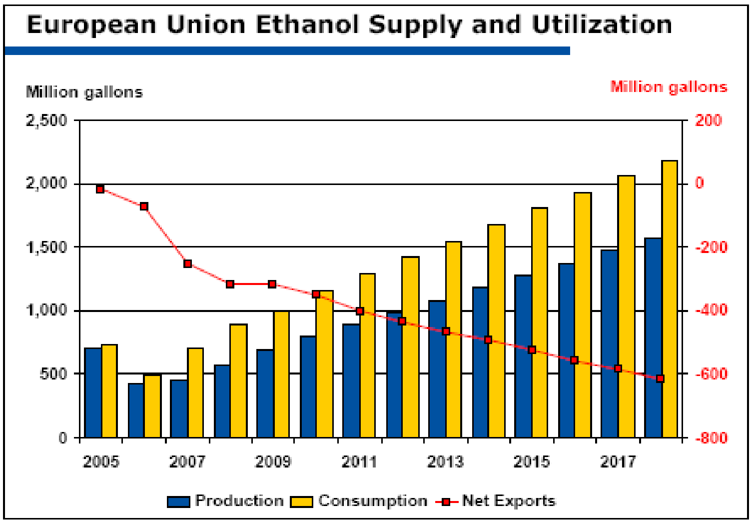
Figure A1: European Union Biodiesel Supply and Utilization



The production of biodiesel shows upward movement although in 2009 it declines by approximately 7 percent due to lower biodiesel prices and strong supply. The consumption continues to grow in the outlook period.

Source: FAPRI, 2009

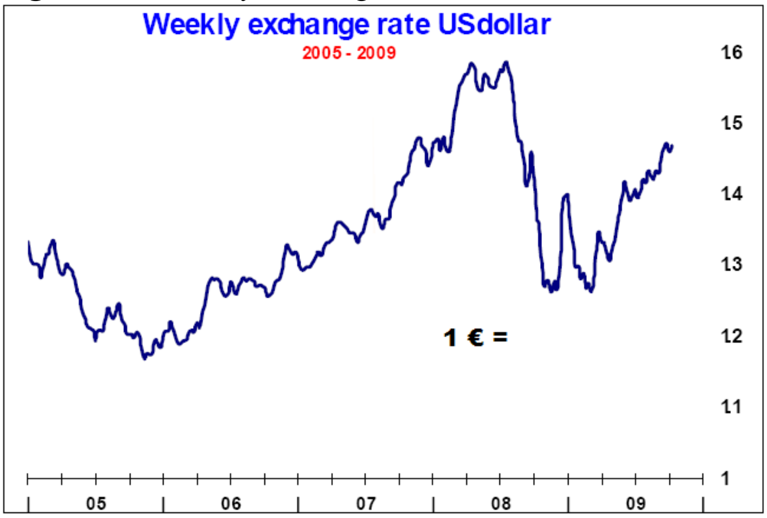
Figure A2: European Union Ethanol Supply and Utilization



The production of ethanol continues to expand. It increased by 26 percent in 2008. The consumption will likely to increase by 146 percent over the decade.

Source: FAPRI, 2009

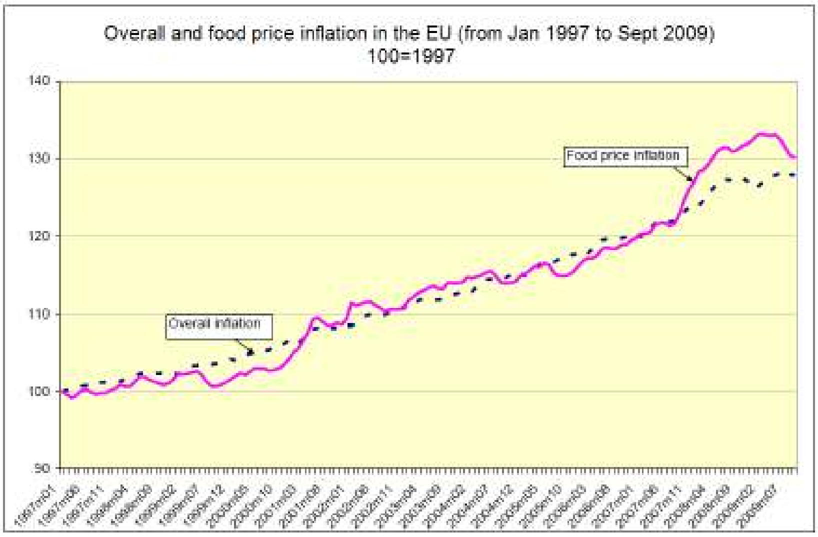
Figure A3: Weekly exchange rate US dollar



The decline of the US dollar can be seen in this graph. While €1 was equal to approximately $1.25 in the beginning of 2009, in the second half of the year €1 was equal to about $1.45. The inflation of the USD is high.

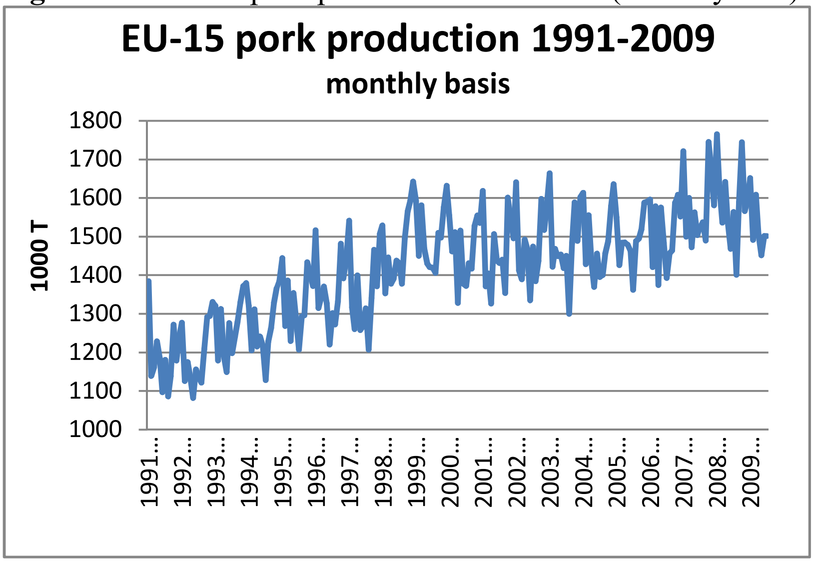
Source: DG AGRI, 2009

Figure A4: Overall and food price inflation in the EU



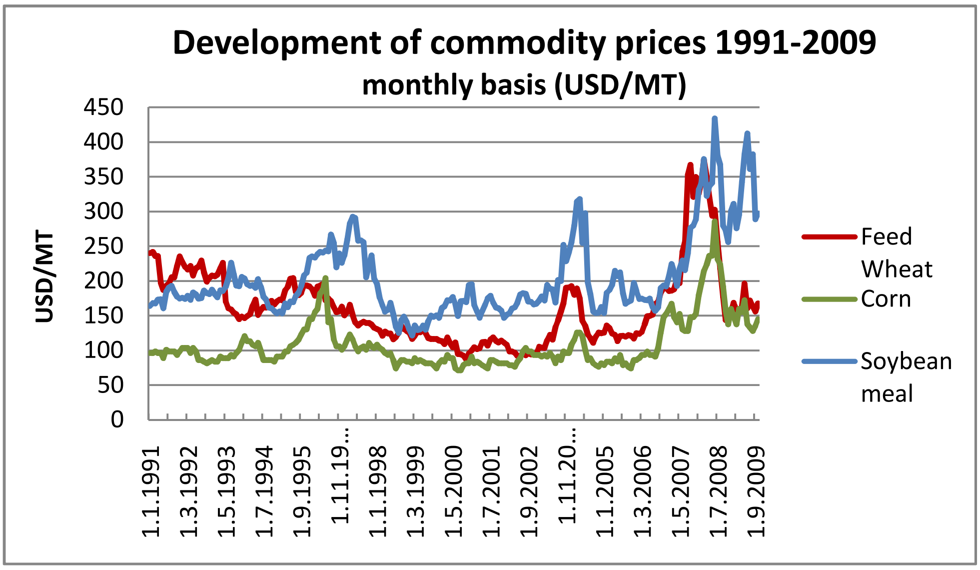
Source: Eurostat, 2009

Figure A5: EU-15 pork production 1991-2009 (monthly data)



Source: Own configuration based on Eurostat, 2009

Figure A6: Development of commodity prices 1991-2009 (monthly basis)



Source: Own figure based on Bloomberg, 2009

Verification

Testing the accuracy of the elasticity produced by the logarithm model

The question may rise whether the elasticity given in the logarithm models are accurate and appropriate. To verify that the elasticity produced by the logarithm models is correct, the elasticity of the output-input price ratio is calculated manually with respect to the model containing 18-month lag using the following elasticity formula:

$$\epsilon^{*} = \frac{\mathrm{d}q_{\mathrm{t}}}{\mathrm{d}x_{\mathrm{t}}} * \frac{x_1}{q_t}$$

Where: q_t: mean of production
x_{t} : mean of output-input price ratio
ϵ^{*}: elasticity

Elasticity of the ratio (ϵ) is the parameter of π_1 in Table 10 that is 0.08. The aim is to find out whether the manual calculation of elasticity (ϵ*) produces similar result. The value of dq_t/dx_t is 124.27, the estimate of π_1^{*} found in Table 13. Table A1 below shows the sample means.

Table A1
Mean of the production and the output-input price ratio between 1991 and 2009

	Observations	Mean	Std. Error	95 % confidence interval	
				Lower Bound	Upper Bound
Production 1000T	223	1418.63	9.70	13399.51	1437.75
ratio	223	1.06	0.01	1.03	1.08

Filling the elasticity formula with these values, ϵ* becomes 0.09 which is very close to ϵ that is 0.08 produced by the logarithm model with 18-month lag. As a conclusion, the elasticity produced by the logarithm model is sound.

Table A2
EU-15 Pork Production 1991-2008

Net Production (1000 MT)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Belg-Lux.	888	951	1003	1021	1043	1070	1015	1086	1005	1065	1082	1056	1041	1044	1024	1016	1073	1066	1091
Denmark	1326	1372	1490	1519	1475	1457	1523	1631	1642	1625	1714	1759	1762	1810	1793	1749	1802	1707	1604
Germany	3891	3684	3747	3604	3602	3635	3564	3834	4113	3982	4074	4111	4239	4308	4500	4662	4985	5111	5254
Greece	153	153	147	145	142	142	142	143	138	141	137	139	134	137	130	123	122	119	9097
Spain	1861	1912	2081	2102	2175	2316	2401	2744	2892	2912	2993	3070	3190	3076	3164	3230	3439	3484	3237
France	1773	1903	2034	2126	2144	2183	2220	2313	2349	2312	2315	2350	2333	2311	2274	2263	2281	2277	2004
Ireland	168	202	212	215	211	210	220	239	250	226	240	230	219	204	205	209	205	202	196
Italy	1222	1328	1370	1347	1346	1410	1396	1412	1472	1489	1510	1536	1589	1590	1515	1556	1603	1606	1588
Netherlands	1806	1586	1747	1673	1622	1624	1376	1725	1711	1623	1433	1377	1253	1287	1297	1265	1290	1318	1268
Austria	...*	421	437	438	466	481	489	508	520	502	488	512	506	516	509	505	531	526	533
Portugal	215	238	288	292	282	299	303	330	344	327	315	328	328	315	327	339	364	381	373
Finland	...*	175	168	169	166	171	179	184	183	172	176	184	193	198	204	208	213	217	206
Sweden	...*	276	290	306	309	320	329	330	325	277	276	284	288	295	275	264	265	267	262
UK	995	971	999	1035	992	998	1094	1155	1047	923	782	795	715	720	706	697	739	740	757
EU-15	14297	14300	15118	15079	15975	16316	16251	17634	17991	17576	17535	17732	17787	17811	17923	18086	18914	19021	27470

Source: Eurostat, 2009
* : missing data

Table A3
Production, domestical consumption and ending stocks of soybean meal 1991-2009

SOYBEAN MEAL	Country	1991/1992	1992/1993	1993/1994	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010
Production (1000 MT)	Argentina	6290	6925	7000	6950	8200	8867	10357	13468	13712	13718	16559	18663	19761	21601	25012	26061	27070	24954	27370
	Brazil	11728	12205	14491	15837	17096	15728	15729	16651	16478	17725	19407	21449	22360	22740	21920	24110	24890	24330	24680
	United States	27062	27546	27682	30182	29508	31035	34633	34285	34102	35730	36552	34649	32953	36936	37416	39037	38360	35482	36578
	World	72650	76447	80886	87646	88806	90117	97997	106383	107166	116151	125070	130647	128854	139072	145816	153940	158522	151351	159542
	YOY growth	4,9%	5,2%	5,8%	8,4%	1,3%	1,5%	8,7%	8,6%	0,7%	8,4%	7,7%	4,5%	-1,4%	7,9%	4,8%	5,6%	3,0%	-4,5%	5,4%
Industrial Dom. Cons. (1000 MT)	World	341	312	293	316	296	300	300	313	313	311	898	979	932	1060	1042	1079	1111	1134	1194
	YOY growth	-31,9%	-8,5%	-6,1%	7,8%	-6,3%	1,4%	0,0%	4,3%	0,0%	-0,6%	188,7%	9,0%	-4,8%	13,7%	-1,7%	3,6%	3,0%	2,1%	5,3%
Food Use Dom. Cons. (1000 MT)	World	198	208	222	253	240	266	307	342	337	319	316	314	392	420	434	423	421	421	426
	YOY growth	10,0%	5,1%	6,7%	14,0%	-5,1%	10,8%	15,4%	11,4%	-1,5%	-5,3%	-0,9%	-0,6%	24,8%	7,1%	3,3%	-2,5%	-0,5%	0,0%	1,2%
Feed Waste Dom. Cons. (1000 MT)	Argentina	112	150	308	315	325	323	346	341	342	355	390	439	525	545	567	592	623	634	675
	Brazil	3847	3885	4122	4927	5364	5365	6060	6665	7086	7063	7580	8055	7696	8960	9328	11118	12257	12340	12630
	United States	20733	21851	22828	23974	24085	24694	25964	27305	27289	28363	29545	29096	28531	30446	30114	31166	30148	27903	27941
	World	72130	75835	80553	87012	87877	90518	97833	105369	107991	115412	122409	128864	127077	135212	144065	150760	155940	150463	156568
	YOY growth	6,4%	5,1%	6,2%	8,0%	1,0%	3,0%	8,1%	7,7%	2,5%	6,9%	6,1%	5,3%	-1,4%	6,4%	6,5%	4,6%	3,4%	-3,5%	4,1%
Total Dom. Cons. (1000 MT)	Argentina	112	150	308	315	325	323	346	341	342	355	390	439	525	545	567	592	623	634	675
	Brazil	3847	3885	4122	4927	5364	5365	6060	6665	7086	7063	7580	8055	7696	8960	9328	11118	12257	12340	12630
	United States	20733	21851	22828	23974	24085	24694	25964	27305	27289	28363	29545	29096	28531	30446	30114	31166	30148	27903	27941
	World	72669	76355	81068	87581	88413	91084	98440	106024	108641	116042	123623	130157	128401	136692	145541	152262	157472	152018	158188
	YOY growth	6,2%	5,1%	6,2%	8,0%	0,9%	3,0%	8,1%	7,7%	2,5%	6,8%	6,5%	5,3%	-1,3%	6,5%	6,5%	4,6%	3,4%	-3,5%	4,1%
Ending Stocks (1000 MT)	Argentina	1090	1775	2180	2215	1813	1481	2258	1962	2023	1661	1244	1000	1017	1423	1647	1480	1114	1088	1065
	Brazil	884	1195	903	1368	974	972	1298	1540	1080	1253	1560	1647	1801	1577	1469	1913	2588	1683	1735
	United States	209	186	136	203	193	191	198	300	266	348	218	200	191	156	285	311	267	217	272
	World	4116	5463	5271	6210	5407	4839	5798	6553	5901	5695	5850	6026	5955	6572	6226	6517	6114	4574	4661

Source: USDA, 2009

Table A4
Production, domestical consumption and ending stocks of corn 1991-2009

CORN	Country	1991/1992	1992/1993	1993/1994	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010
Production (1000 MT)	United States	189868	240719	160986	255295	187970	234518	233864	247882	239549	251854	241377	227767	256229	299876	282263	267503	331177	307386	328207
	World	492950	535605	475773	559288	516321	592903	574404	605859	608039	591382	601216	602954	626798	714919	698786	712380	791871	791917	789730
	YOY growth	9,1%	8,7%	-11,2%	17,6%	-7,7%	14,8%	-3,1%	5,5%	0,4%	-2,7%	1,7%	0,3%	4,0%	14,1%	-2,3%	1,9%	11,2%	0,0%	-0,3%
Feed and Residual (1000 MT)	United States	121873	133409	118874	138682	119196	134042	139243	138890	143896	148396	148959	141304	147150	156356	156275	142018	150209	133470	137166
	World	334370	348667	342013	371469	365111	387643	401146	404629	422951	427905	436630	433186	445317	475077	477618	477693	496429	479584	488514
FSI Consumption (1000 MT)	United States	38953	39518	40977	43569	41356	43544	45844	46898	48600	49706	51982	59444	64445	68254	75740	88656	111423	125808	139199
	World	159996	160421	165148	166928	166696	171691	172450	176284	177432	180374	185120	193212	202713	211273	227779	246242	274539	296404	312550
Total Consumption (1000 MT)	United States	160826	172927	159851	182251	160552	177586	185087	185788	192496	198102	200941	200748	211595	224610	232015	230674	261632	259278	276365
	World	494366	509088	507161	538397	531807	559334	573596	580913	600383	608279	621750	626398	648030	686350	705397	723935	770968	775988	801064
	YOY growth	4,1%	3,0%	-0,4%	6,2%	-1,2%	5,2%	2,5%	1,3%	3,4%	1,3%	2,2%	0,7%	3,5%	5,9%	2,8%	2,6%	6,5%	0,7%	3,2%
Ending Stocks (1000 MT)	United States	27949	53672	21595	39571	10819	22433	33220	45391	43628	48240	40551	27603	24337	53697	49968	33114	41255	42523	41277
	World	140848	162529	129253	152929	132733	165581	166248	190757	193611	174810	151078	126733	104813	131434	124298	109074	129716	145946	132409

Source: USDA, 2009

Table A5
Production, domestical consumption and ending stocks of wheat 1991-2009

Wheat	Country	1991/1992	1992/1993	1993/1994	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010
Production (1000 MT)	United States	53,891	67,135	65,220	63,167	59,404	61,980	67,534	69,327	62,475	60,641	53,001	43,705	63,805	58,698	57,243	49,217	55,821	68,016	60,314
	World	543,275	562,436	558,226	522,682	537,136	581,295	610,008	590,246	586,745	582,899	583,078	567,880	554,063	625,724	619,933	595,702	610,456	682,682	676,127
Feed and Residual (1000 MT)	United States	6,653	5,270	7,396	9,376	4,184	8,371	6,818	10,634	7,600	8,176	4,953	3,150	5,512	4,916	4,263	3,186	434	7,029	4,627
	World	113,820	110,918	107,971	99,559	91,922	96,652	100,948	103,649	98,923	104,422	107,606	111,855	96,298	105,370	110,935	105,877	96,317	112,701	110,607
Total Consumption (1000 MT)	United States	30,799	30,688	33,738	35,014	31,028	35,397	34,212	37,589	35,373	36,184	32,434	30,448	32,498	31,783	31,320	30,940	28,614	34,291	32,168
	World	550,023	547,079	547,543	543,458	542,723	565,011	576,539	577,445	580,766	583,570	587,612	602,158	580,560	605,525	617,117	618,563	613,169	633,273	642,424
Ending Stocks (1000 MT)	United States	12,928	14,442	15,472	13,787	10,234	12,073	19,663	25,744	25,848	23,846	21,150	13,374	14,872	14,699	15,545	12,414	8,323	17,867	26,554
	World	162,852	176,680	182,207	163,093	155,604	163,451	196,294	207,817	209,540	207,336	203,176	166,636	131,964	150,241	147,475	127,594	121,069	163,944	195,604

Source: USDA, 2009