HEDGING INSTRUMENTS & STRATEGIES FOR A VOLATILE ASSET IN AN INEFFICIENT MARKET

INNOVATIVE RISK MANAGEMENT ALTERNATIVES APPLIED TO SWEDISH LIVESTOCK FARMERS' COMPOUND FEED EXPENSES

BY

JENS EDHOLM

&

VICTOR BJÖRK-LINDSTRÖM

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SUPERVISOR: FREDERIK LUNDTOFTE

LUNDS UNIVERSITET
Ekonomihögskolan

Lantmännen

Abstract

This Bachelors thesis involves the creation of a market place for animal compound feed risk management, potential hedging instruments and applicable risk management strategies. The market place is a cross hedged portfolio of futures contracts that correlate with the price of animal compound feed in Sweden, defined as an index and referred to as Compound Feed Index.

The thesis has been conducted in collaboration with Lantmännen ek.för Feed Division, the largest producer of animal compound feed in Sweden. The producer looks to expand its' offering to clients, i.e. livestock farmers, by potentially offering risk management solutions. Volatility in commodity raw materials used to produce animal compound feed has increased vastly and thus also the price volatility of animal compound feed has increased. Animal compound feed is the largest expense in the livestock farming business and there are currently no risk management solutions available.

Using future contracts with the same underlying commodities as are used to produce animal compound feed, we conclude that a Compound Feed Index can be created as a portfolio with a cash position and defined weights of each separate futures contract. Unfortunately, due to an inefficient market structure without transparent and observable market prices, the strength of the correlation and the hedging contribution is not sufficiently high to recommend the implementation of the Compound Feed Index.

We hope that this study can provide an example for future studies that aim to solve similar difficulties. As the market for animal compound feed becomes more transparent it is likely that a Compound Feed Index such as presented in this paper would be of value.

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1. Introduction

Livestock breeding has for long been a vital part of human history. Today the agricultural sector suffers under tumultuous conditions where volatility in prices has brought uncertainty to both input and output prices, thus leading to swings in profitability for livestock farmers (OECD, 2011). To minimize these uncertainties, new risk management opportunities can be developed if a reliable and trustworthy index can be constructed (The World Bank, 2005).

For a Swedish livestock farmer there are, as of today, few ways to manage the downside risk of the business's profitability, which is caused from rising or already high animal compound feed prices. According to Wahlgren (2016), the animal compound feed accounts for about 70 % of the total costs for a livestock farmer in the poultry breeding business. Thus, a vital part of the business's profitability relies upon minimizing the price paid for the compound feed. Furthermore, Wahlgren (2016) explains that animal compound feed can be purchased by the farmer at a fixed cost for future deliveries or purchased at spot prices. The end product is then sold either at spot prices or at monthly fixed prices. This, in turn, imposes multiple inefficiencies for the livestock farmer. For instance, if the current market prospects were to change and the product price drops after the livestock farmer has purchased the animal compound feed at a fixed cost for future deliveries there are today no tradable products available to offset this risk. This jeopardizes the profitability of the Swedish livestock farmer and adds unwanted uncertainty as long as it is not possible to offset risk through tradable risk management products.

Previous studies have investigated different risk management methods for farmers outside of Sweden. However, no earlier research has been conducted on how Swedish livestock farmers could hedge their profitability against price fluctuation in the animal compound feed. Hence, Lantmännen ek.för sees an opportunity to offer risk management products for livestock farmers. According to Axel Walle at Lantmännen (2016), these new potential hedging products need to be tradable and have the potential of enhancing business margins and/or lesser fluctuations in the livestock farmer's profitability. By enabling these types of products to livestock farmers, they will be able to better manage the cost of the compound feed. Therefore, in consultation with Lantmännen ek.för, this thesis aims to contribute to the current risk management practices in the Swedish livestock industry.

Ultimately, the thesis's main objective is to create a theoretical marketplace and tradable financial risk management tools. In turn, these tools will be used to design different risk management strategies for compound feed purchases in hope to lesser the significance of the vast uncertainties that the Swedish livestock farmers today face. To enable this, the price fluctuations in the animal compound feed is cross hedged with various futures contracts that has animal compound input commodities as underlying assets. The purpose of the cross hedge is to create a Compound Feed Index, which in turn is the underlying asset when constructing the tradable products.

The thesis is conducted in consultation with Lantmännen ek.för´s Feed Division and thus the scope of the thesis is partly restricted to fit Lantmännen's expectations. Subsequently, the Feed Division's objective when participating is to increase current offerings to its clients, i.e. the Swedish livestock farmers. Hence, the thesis is restricted to treat the segment of the value chain where livestock farmers buy animal compound feed from Lantmännen ek.för, and not the sale of the animal breeding end product. Secondly, to ensure reliability of the Compound Feed Index, only the poultry industry is considered. Thirdly, to ensure maximum transparency of the Compound Feed Index and the hedging capabilities for the market maker, only futures contracts are considered when creating the Compound Feed Index.

To summarize:

1. The thesis only focuses on hedging livestock farmer's animal compound feed expenses and not the sales of the end product.
2. Lantmännen ek. för's largest animal compound feed in the poultry segment is considered when defining the Compound Feed Index.
3. Only futures contracts are considered when defining the Compound Feed Index.

In chapter 2, the paper provides the reader with previous research made in this area. Chapter 3 covers background information on the market, and the economy of the Swedish livestock farmer. Furthermore, in chapter 4, a theoretical overview of hedging and the financial products used in risk management is explained. The paper treats the currently available risk management tools in chapter 5. In chapter 6, selected data is discussed and in chapter 7 the methodology is presented. Results, analysis and discussion are presented in chapter 8 and further conclusions are made in chapter 9. Lastly, chapter 10 provides suggestions for future studies.

2. Previous research

Various risks that farmers face and how it can be managed has been a topic in several research papers. For instance, Miller et al. (2004) focuses their research on the structural and operational risk that farmers face and how it can be managed. The operational risks that they analyze are explained as traditional risks associated with business risk and financial risk, whereas the structural risks are associated with political, government policy, macroeconomic, social and contingencies, and industry dynamics risks. Further, the paper explains how these types of risks can be managed by the use of different risk management strategies. For operational risk they suggest the usage of futures or options contracts in order to lock in profits. For structural risk, it is emphasized that it is hard to manage as it often is hard to anticipate and thus out of the farmer's control.

Another study made by Näslund (2008) examines Swedish farmers' usage of risk management in grain production. Moreover, the paper studies the factors that characterize farmers who use price risk management tools for cereals. The author concluded that farmers who were well informed about the futures market tend to use these tools more than less informed farmers. Furthermore, Noussinov & Leuthold (1998) conducts a study aiming to find optimal hedging strategies for the U.S. cattle feeder by comparing alternative hedging strategies to multiproduct optimal hedging for a Midwestern cattle feeder. Ultimately, the study asses if multiproduct hedging techniques can reduce risks faced by a cattle feeder. Conclusively, the study concluded that all hedging strategies significantly reduce the mean and variance of feeding margins. In other words, it is possible for livestock farmers to reduce risk by the use of different hedging strategies. In addition, the study concludes that all the tested strategies were on the efficient frontier, which ultimately leaves each hedging decision up to the livestock farmer´s degree of risk aversion.

While Miller, et al. (2004) studies how an optimal hedging strategy could reduce risk, and Näslund (2008) emphasizes that Swedish farmers today uses futures contracts as hedging instruments, neither of the studies examines the effects of various hedging strategies. Also, they do not design structured products in order to see how a livestock farmer historically could have been better off by the use of such. Even though, Miller, et al. (2004) provides solid background information about different risks that farmers face, further risk management solutions are not analyzed. As for Noussinov (1998), who postulates examples of how risk can be managed, it is customized for U.S cattle feeders, and not for Swedish livestock farmers.

Two studies most similar to this are made by Nilsson & Söderberg (2007) and Bergmans (2008). Nilsson and Söderberg (2007) investigate the possibility to cross hedge ethanol prices by the use of different commodities futures contracts. More specifically, the study aims to provide risk management tools to Agroetanol, a Lantmännen owned producer of ethanol. In short, they found that sugar has some historical hedging significance as sugar is strongly correlated with the ethanol prices due to Brazil's usage of sugar as commodity input in ethanol production. The other paper conducted by Bergmans (2008) investigates, in consultation with ABN AMRO, the possibilities to develop a sellable financial product for livestock farmers. The result of this study is not for public use, thus no further conclusions can be made. However, the procedure of creating an index by cross hedging is similar to the method used in this paper. For instance, Bergmans (2008) mentions a ´Lego´ approach, which is the building of a product by existing derivatives contracts such as futures contracts and options.

While Nilsson and Söderberg (2007) attempts to cross hedge ethanol prices, they do not target compound feed products. However, the complexity of finding a cross hedging instrument that correlates is emphasized also in this paper. Also, as Bergmans (2008) investigates how livestock farmers could hedge themselves against price risk by the use of financial products, the study does not provide any analysis of different hedging strategies.

Ultimately, previous studies provide information about agricultural risks as well as different hedging methods but they do not provide any usable hedging strategies for Swedish compound feed manufacturers. Hence, there is a research gap, which we aim fill by contributing to previous research with new hedging tools and strategies to the Swedish livestock industry.

3. Compound Feed Market - Background

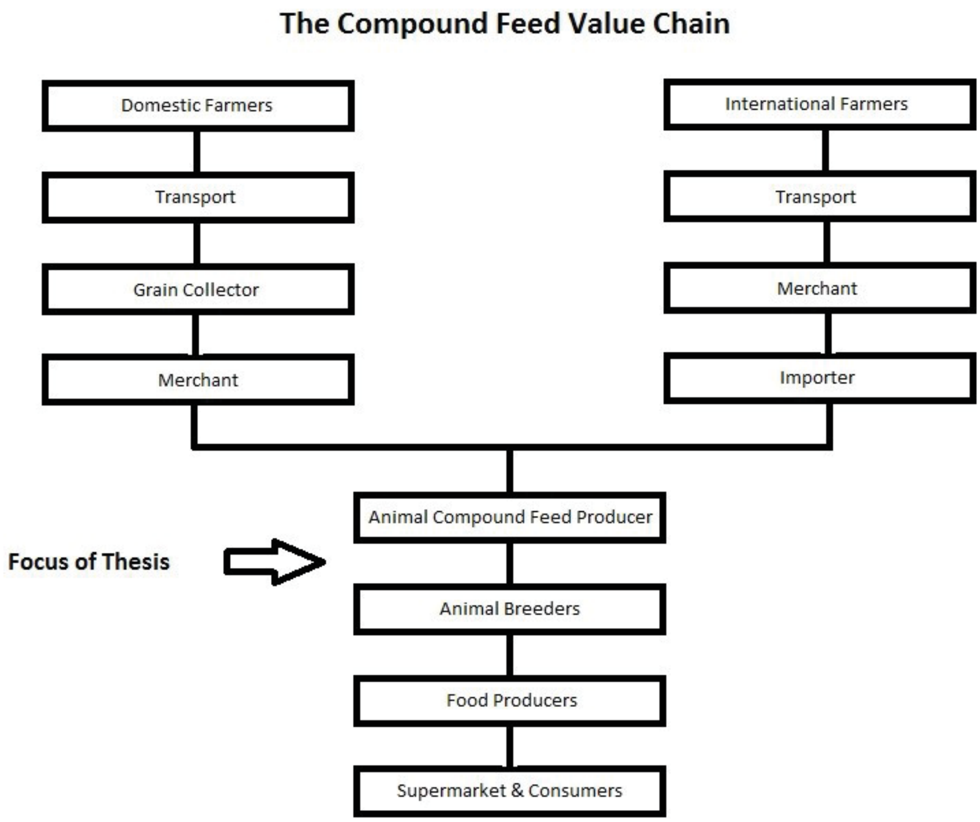
This chapter will present the reader with sufficient information about the Swedish livestock market. Additionally, market characteristics are described for the reader to understand the risk management needs for livestock farmers in Sweden.

3.1 The animal compound feed industry in Sweden

The Swedish compound feed industry is a sub-sector within the agricultural industry that consumes approximately 15 % of the Swedish agricultural production. Moreover, a large share of the commodity raw materials used to produce animal compound feed is imported. The main compound feed producers are large agricultural companies and the consumers are livestock farmers i.e. the farmer that breeds livestock to later sell the proceeds. The main categories of livestock are poultry, pig and cow. Additionally, there are niche categories for animal type such as sheep and reindeer. The different types of livestock categories require different types of animal compound feed to fit the specific dietary needs of the animal. Furthermore, the end product differs between the animals, were cow produces milk and/or meat, poultry produces eggs and/or meat and pigs produce meat. Hence, the economic situation and future prospects can differ significantly between the different categories of livestock breeding. (Jordbruksverket, 2011)

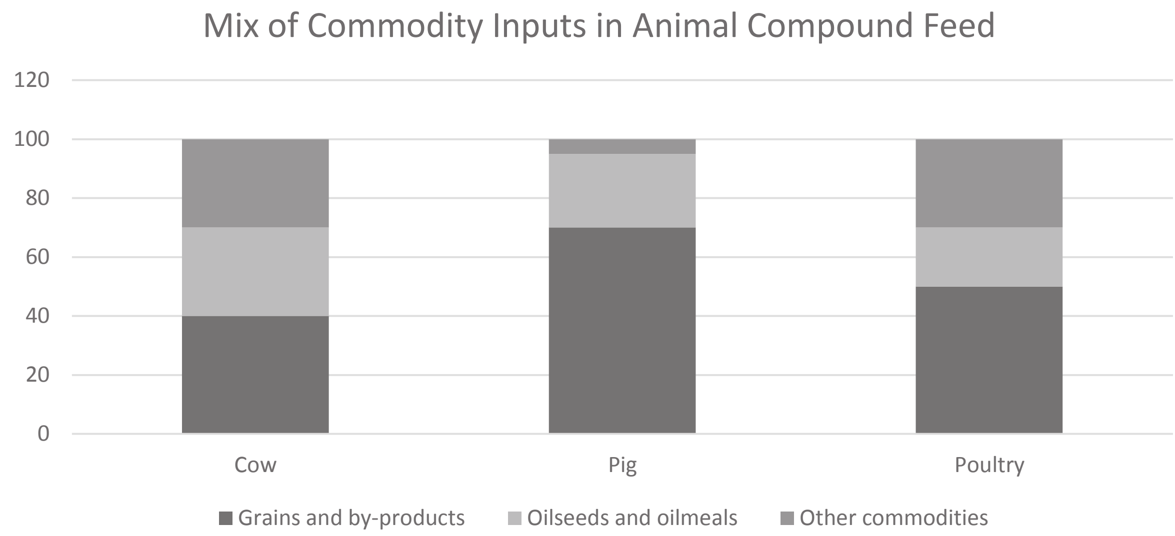
Animal compound feed is used in the livestock industry to breed animals. Moreover, the compound feed products are different from regular feed as the compound feed is a product that the livestock farmer purchases from a compound feed producer. While feed is every other type of nutrient or food, compound feed is a mixture of different nutrients in an appropriate concentration. The animal compound feed has a higher concentration of nutrients and is much more complex than feed. Compound feed largely consists of grains, oilseeds, specific fats and vitamins that the animal needs in order to optimize growth. A large part of feed in the livestock industry consists of grains, which the farmer harvests on the farm. This is especially common in pig breeding where up to 80 % of the animal feed can be produced on the farm, and only 20 % represents animal compound feed. In the poultry industry the majority of feed is purchased compound feed as the animals need specific nutrients, which cannot be found in grains harvested on the farm (Jordbruksverket, 2011). The market's value chain is illustrated in figure 1.

figure 1



Moreover, about 70-80 % of the animal compound feed´s end value consists of commodity inputs, 10-15 % of the value is transportation costs and 10-15 % is production costs (Jordbruksverket, 2011). According to Walle (2016), all compound feeds are produced with a specific recipe made up of proteins, amino acids, water, salt and other nutrients sources from different commodities. Yet, the specific commodity source of these nutrients is often optional. As commodity prices, i.e. the source of various nutrients, are highly volatile, the price of the compound feed can vary significantly depending on commodity availability and price relations. When defining the optimal blend of input commodities, the compound feed producer has to evaluate one certain protein-rich-commodity against another protein-rich-commodity. To achieve this, compound feed production is highly dependent on the "blending problem" which is a mathematical optimization made up of thousands of available commodities and their prices. The mathematical optimization does in turn yield the optimal fit of input commodities for a specific compound feed product. In addition, the blending problem is a dynamic process as commodity prices change, and thus recipes can vary every time the blending problem is recreated. The precise mix of commodities in the recipes for animal compound feed is considered a company secret by Lantmännen ek. för, and hence it is not disclosed in this paper. However, figure 2 contains a distorted overview of the commodity inputs in the compound feed. (Walle, 2016)

figure 2

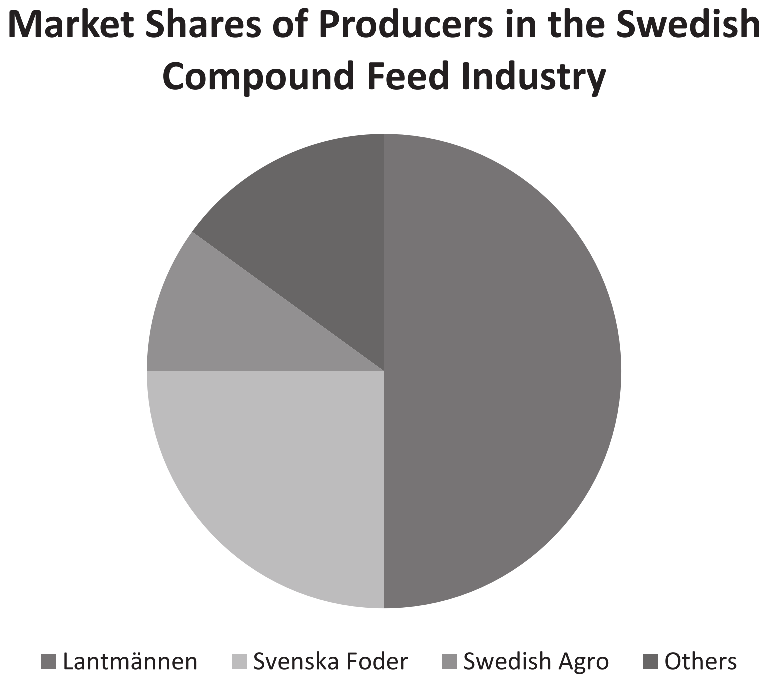


Source: Lantmännen ek.för Feed Division intern information

3.2 Oligopoly market

The Swedish compound feed market consists of no more than 15 animal compound feed producers where the three main compound feed producers account for 85 % of the total market, see figure 3 (Jordbruksverket, 2011). The market structure is often described as an oligopoly, which is characterized by markets where a few companies have a dominant position (Pepall, Richards & Norman, 2014). Conclusively, as only three companies produce 85 % of the animal compound feed, the Swedish animal compound feed market is a typical oligopoly market.

figure 3



Jordbruksverket (2011) describes the Swedish compound feed market as inefficient in price formation, where the producers might take a wait-and-see approach by first awaiting the competitors move before lowering its own prices. This exemplifies an oligopoly and is explained by Game Theory in where every decision made by an actor is called a strategy. The strategy then determines the outcome for each player of the game (Pepall, Richards & Norman, 2014). For instance, if one company moves first and lowers or raises the price of a compound feed, the other actors will then move secondly to compete by setting an even lower price or equal price. However, if none of the actors makes a move then they both can put a higher price on the products, which in turn will result in overall higher profits. Hence, there is an incentive for the actors not to make any competing move unless anyone else does. Jordbruksverket (2011, p.11) lists the following characteristics as a reason why the Swedish compound feed market is a victim of oligopoly:

- High entry barriers
- The companies in the compound feed market has a long time horizon and they continuously meet on the market
- The market is stable
- Almost identical products are produced

- The cost structure for each company is similar
- The pricing is centralized
- The companies can easily exchange information
- The companies have capacity constraints
- The demand for the products are not price sensitive
- The buyers i.e. the livestock farmers have high costs in comparison with the suppliers pricing
- The buyers suffer high costs if changing to a new supplier

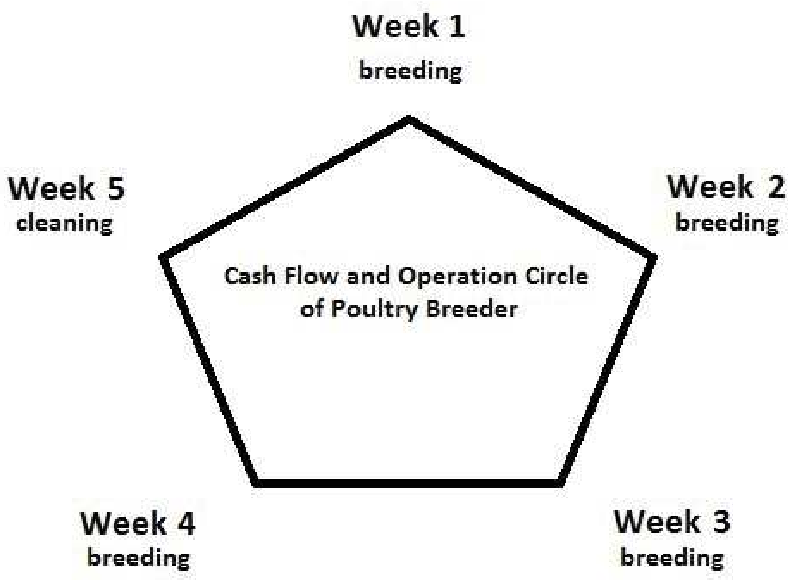
Conclusively, the oligopoly situation in the Swedish compound feed market is an issue for Swedish livestock farmers. Ultimately, they have limited options when buying the compound feed, which results in potentially disadvantageous prices. For the livestock farmer this impacts business profitability as they are not able to pass higher costs for compound feed onto the end product. Therefore, it is mainly the profitability of the livestock farmer and the level of livestock production in Sweden that suffers the biggest consequences from the oligopoly situation. (Jordbruksverket, 2011)

Even though consumers are not required to purchase compound feed from a specific producer, there are certain reasons that makes the consumer's choices of potential suppliers limited. The primary reason is that compound feed is usually sold and delivered on the livestock farmer's farm. This gives rise to transportation costs, which could correspond to about 10-15 % of the total product value. Thus, geographical location is important. Ultimately, animal farmers that are located geographically close to a specific compound feed supplier tend to purchase the product from the closest producer. As Lantmännen is the only producer locally represented across entire Sweden this explains their significant market share. The dependency of geographical location also allows for suppliers to attain different profit margins in different locations across Sweden. In turn, this results in a fragmented market without a transparent and efficient market price quotation on compound feed (Jordbruksverket, 2011). Apart from location, all of the compound feed producers on the Swedish market compete in quality i.e. by product differentiation. Although a better compound feed quality can motivate a slightly larger margin, it does not usually attract new customers. Overall, livestock breeding is a business with small margins and therefore the price of the product is ultimately the main competitive factor (Walle, 2016).

3.3 The Economy of a Livestock Farmer

According to Wahlgren (2016), the most progressive type of livestock farmers is found in the poultry business. They have a quick turnover of working capital and receive cash flow every 35 days. The poultry is bred during the first 35 days of the yearly business cycle. Before this period the poultry farmer purchases poultry compound feed at a fixed price and sells the end product at spot prices or at a fixed price on which the farmer receives/pays a sum depending on better/worse quality than expected. After the 35-day breeding period, the poultry is sold against a cash flow. Before the poultry farmer starts the next 35-day breeding period, the equipment and premises are cleaned during 7 days. Illustrated in figure 4 are the first 5 weeks of the business cycle.

figure 4



Economic calculations within the poultry business are made on basis of profitability per square meter. The profitability within the poultry business is high, according to research made by Hushållningssällskapet (2015, p. 34), see table 1. The calculations in the figure are based on an average farm size of 4000 square meters in southern of Sweden and shows a profit margin before financial costs and taxes (EBIT) of 10,7 %. At 61,3 % of costs, compound feed is the largest expense. Other variable costs such as electricity, medical products, and handling costs represent 8,6 % of costs. Labor and inventory expenses are calculated at 3,5 % of costs. Presented in SEK/KG a chicken yielded a revenue of 9,25 SEK and it required 5,19 SEK in compound feed costs to breed. The common assumption within poultry breeding is that it takes 1,7 kilos of compound feed to reach 1 kilo of chicken growth (HIR, 2015).

table 1

Profitability Poultry Farmer	
Revenue	*338*
Purchase of chicken	*-80*
Costs, compound feed	*-185*
Costs, variable	*-26*
Costs, labour	*-11*
EBITDA	*36*
Margin	*10,7%*

Source: HIR, 2015, p. 34

4. Theoretical overview

This chapter presents theoretical information about financial hedging instruments. Also, a theoretical overview of different risk attitudes and risk perception will be discussed in order to understand the hedging strategies that will be introduced in chapter 5.2.

4.1 Hedging

The basic principle of hedging is to take a position in an asset whose value will move in the opposite direction to the asset being hedged. Moreover, hedging involves the use of derivatives to counteract potential future movements in the assets that is being hedged (Hull, 2012). To put it in context, a farmer who produces corn and has to wait about 6 months from seeding to harvesting may not want to be exposed (long) to price fluctuations during this time period. At the same time, there is a merchant who has sold a cargo of corn to an ethanol plant nearby with a delivery of 6 months. In turn, the merchant does not desire to be exposed (short) to price fluctuations. To reduce the risk associated with the price fluctuations these two parties can enter into an agreement where a future price and delivery date in 6 months is settled. By doing so they agree that the farmer will sell (short) corn and the merchant will buy (long) to a specific price in 6 months. This contract will protect both parties from the price risk, until the contract expires, as they enter into counteracting positions to their initial exposure. This is the basic principle of hedging, which in turn is the original purpose of financial derivatives.

4.2 Financial Hedging Instruments

Financial products are common instruments when hedging as it is easily traded at a low cost. Some of the most common types of financial products used in hedging are standardized futures contracts and options traded on an exchange. Apart from these it is possible to use Over the Counter (OTC) counterparties to design customized financial products that suits specific needs and/or assets that might not have a corresponding exchange traded financial product available.

4.2.1 Forwards & Futures

A forward contract is a derivative where two parties approve to buy or sell an asset at a definite time in the future for a specific price on the OTC market (Hull, 2012). On the delivery day, at time t, the seller of the contract is obligated to deliver the physical asset whereas the buyer of the contract is obligated to pay the agreed price. Futures contracts have the same fundamentals as forward contracts accept that it is traded on the exchange traded market, and thus standardized (Hull, 2012). The exchange guarantees payment for all contracts, through clearing services, by requiring that the traders in question holds a margin account.

A long (bought) futures contract can be cancelled out via the exchange by selling (shorting) the same contract prior to expiration and thereby physical delivery is avoided. This opens up for trading with futures contracts within its maturity period without risking physical delivery. In the context of a farmer who today is seeding next year's productions, a future contract enables to sell the proceeds of future production by selling future contracts and thereby eliminating the price risk. A future contract´s fair price is calculated as equation 1, where F_0 is equal to the fair value of the forward contract, S_0 represents the spot price of the underlying asset, r is the risk-free interest rate and t is the time to maturity (Hull,2012).

equation 1

$$F_0 = S_0 e^{-rt}$$

The payoff from a long (buy) position is:

equation 2

$$S_t - K$$

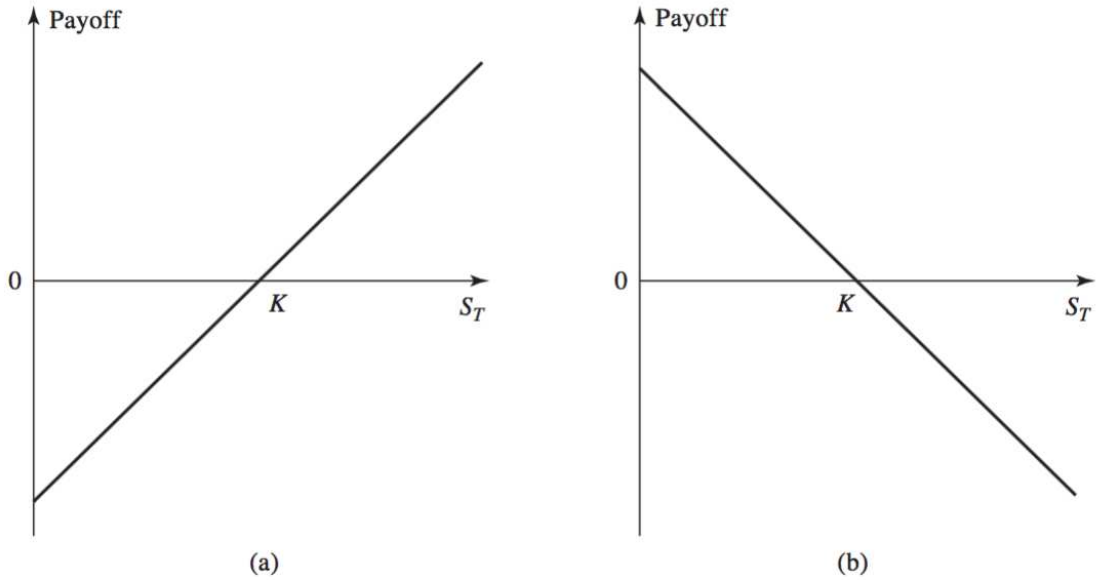
Whereas the payoff of a short (sell) position is:

equation 3

$$K - S_t$$

Where, S_t represents the spot price at time t, and K is the strike price (the agreed price of the contract). Figure 5 illustrates the payoffs for a long position (a) and a short position (b).

figure 5



Source: Hull, 2012

4.2.2 Options

An option gives the buyer the right, but not the obligation, to buy or sell the underlying asset at a specific time in the future for a certain price, the strike or exercise price. When the option can be exercised depends on the type of option; American options can be exercised at any time up to the expiry date while European options can only be exercised on the maturity date. Moreover, options can be traded with various underlying products such as commodities, stocks and bonds etc. (CME Group, 2015). Most of the options traded are of American style (Hull, 2012). To better fit the thesis of this paper, only European options on futures will be considered hereon forth.

As options can be traded on the exchanges as well as OTC, they can either be standardized or designed to suit specific needs. Furthermore, options are similar to insurance contracts where the buyer of the contract pays a premium in order to minimize the risk of price fluctuations in the underlying asset.

An option will be exercised when it is in-the-money, meaning when the price in the case of a put option is below the exercise price (K-S > 0), or for a call option when the spot price is above the exercise price (S-K > 0). When the exercise price and the spot price is the same, the option is said to be at-the-money, and when the spot price is below the exercise price for a call option, and above for a put option, it is said to be out-of-the-money. If an option is in the money, then the option is exercised whereas if it is out of the money it will not be exercised. Furthermore, while the seller (writer) of an option contract is obligated to sell the contract if it is in-the-money, the buyer has the option to buy/sell the underlying asset for the strike price, K. Hence, the European option on a future contract can be exercised on the maturity date at a specific strike price. (Hull, 2012)

The profit for a call buyer when the option is in-the-money is depicted in equation 4 and for a put buyer in equation 5.

equation 4

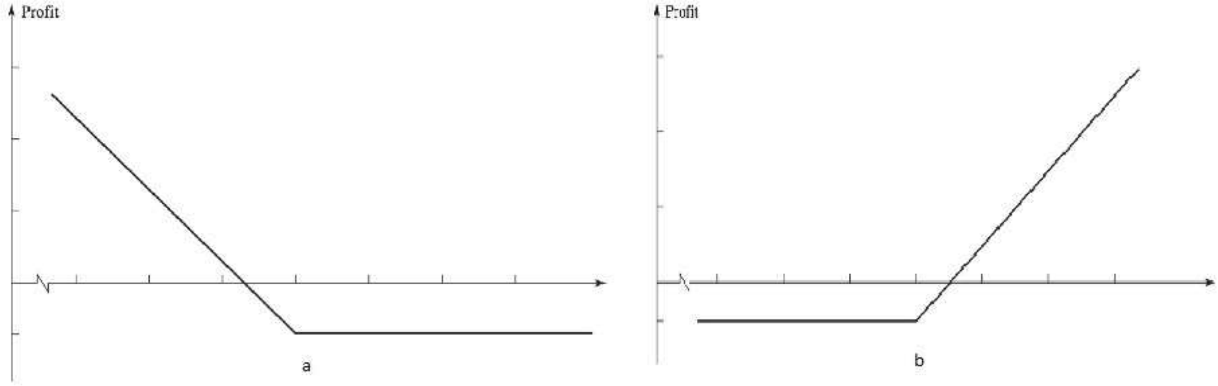
$$Max(S_T - K, 0) - c$$

equation 5

$$Max(K - S_T) - p$$

Where, S_t is the spot price at time t, K is the exercise price, c is the call premium, and p is the put premium. Illustrated in figure 6 are the profit/loss from a long position (a) and the profit/loss from a short position (b).

figure 6



Source*: Hull, 2012*

Furthermore, options are often priced using the Black Scholes formula, presented in equation 6 - 9 (Hull, 2012).

equation 6

$$c = S_0 N(d_1) - Ke^{-rt} N(d_{2)}$$

And

equation 7

$$p = Ke^{-rt} N(-d_2) - S_0 N(-d_1)$$

Where,

equation 8

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

And

equation 9

$$d_2 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

Again, c is the price for a call option and p is the price for a put option. In addition, d_1 and d_2 are the probability that a variable with a standard normal distribution (0,1) having a function of N(X) will be less than X (d_1 or d_2) (Hull, 2012). Figure 7 illustrates this reasoning.

figure 7

Source*: Hull, 2012*

4.2.3 Basis

If an asset is hedged with a futures contract that has the same underlying asset then the hedge is said to be a perfect hedge since it completely eliminates risk (Hull, 2012). The price paid for the asset (S_0) will not change no matter how the future price changes and the profit/loss from the hedged position will be zero. The price fluctuations between today and time t in the physical asset ($S_t - S_0$) is canceled out by the price movements in the futures contract ($F_0 - F_t$). Equation 10 illustrates this relationship.

equation 10

$$(S_t - S_0) + (F_0 - F_t) = 0$$

However, perfect hedges are rare, and in most cases we have to deal with imperfect hedges. An imperfect hedge occurs when the future contract does not have the same underlying asset as the asset being hedged which causes basis risk. According to Hull (2012, p.52-53) there are three main reasons for basis risk:

1. The asset whose price is to be hedged may not be exactly the same as the asset underlying the futures contract
2. The hedger may be uncertain as to the exact date when the asset will be bought or sold
3. The hedger may require the futures contracts to be closed out before its delivery month

Hence, basis can occur if the asset and the hedging instrument´s underlying are not identical assets, also called an asset mismatch. Put into practical context, the only way to hedge a ton of physical wheat placed in a silo in Sweden is with a milling wheat future contracts that are traded on an exchange in France. There are important differences between these two assets. The physical wheat on a farm is a physical asset in Sweden which is subject to a local supply and demand situation, whereas the wheat futures are a financial asset with a delivery date and a different supply and demand situation. Another type of mismatch is the maturity mismatch, which is when the expiration date of a futures contract is not the same as the payment time for the physical asset (Hull, 2012). For example, there might not be any future contracts available for the same crop year as the physical wheat. As the supply and demand situations are different between two consecutive crop years, so will also prices be. This fundamental difference with affecting externalities between the asset and the hedge gives rise to a basis risk that can be defined as the difference between the spot price of physical asset and the price of the futures contract. In equation 11 and 12, b_0 is the basis risk when the position is initiated, and b_t is the basis risk when the position is closed.

equation 11

$$b_0 = S_0 - F_0$$
$$b_t = S_t - F_t$$
$$\Delta b = b_0 - b_t$$

equation 12

$$(S_0 - F_0) - (S_t - F_t) = (b_0 - b_t) = \Delta b$$

According to Hull (2012) the profit/loss from a hedged position with basis therefore depends on the basis at the time when the hedge is initiated and on the basis when the position is closed out. Ultimately, the price paid for the asset depends on the result of the hedge, illustrated in equation 13.

equation 13

$$S_0 + (S_0 - F_0) - (S_t - F_t) = S_0 + (b_0 - b_t) = S_0 + \Delta b$$

Basis risk can be a pressing issue in risk management. However, if there are no correlating hedging tools available then cross hedging is an option. Cross hedging is when the asset is fundamentally different from the hedge, but yet has satisfying similarities to attain an acceptable correlation. Cross hedging involves additional dimensions of basis risk, which occurs as the physical asset and the asset underlying the hedge is different. A modified illustration of Hull's (2012) cross hedging basis risk is defined as a profit/loss in equation 14 where S'_t represents the price of the asset underlying the hedge at time t. The price paid for the asset is illustrated in equation 15.

equation 14

$$(b_0 - b_t) + (S'_0 - S_0) - (S_t - S'_t) = \Delta b - \Delta b'$$

equation 15

$$S_0 + (b_0 - b_t) + (S'_0 - S_0) - (S_t - S'_t) = S_0 + \Delta b - \Delta b'$$

Additionally, cross-hedging can be done by combining multiple futures contracts into one single asset in hope of attaining hedging efficiency on an asset that has no corresponding or similar futures contracts. This combination of futures can later be translated into an index aimed at reflecting the price fluctuations of the asset. This procedure adds several dimensions of basis risk where additional basis occurs between the index and the asset as well as separate basis risk between each of the used futures contracts and their underlying assets arises.

4.2.4 Tailoring Financial Instruments

Per definition, all options and futures are derivatives since a derivative can be defined as a financial instrument whose value depends on (or derives from) the value of other more basic underlying variables (Hull, 2012). Furthermore, all options and futures can be traded over the counter (OTC) as non-standardized contract. As of today, the OTC market has grown to be much larger than the exchange traded markets measured in volume (Hull, 2012). The upcoming of over the counter (OTC) exchanges has introduced possibilities for financial engineering. In turn, this has expanded the offerings of financial instrument and products far beyond the scope of basic futures into combining futures, options and other financial instruments to fit more complex and tailored needs. (Hull, 2012). Ultimately, financial engineering makes it possible for Lantmännen ek.för to create and offer Swedish livestock farmers alternative hedging tools for compound feed purchases. As there are no animal compound feed futures contracts in Sweden, this would be done by constructing a cross-hedging instrument of futures contracts that corresponds to the price fluctuations of compound feed input raw materials.

Subsequently, when a cross hedged instrument is defined, OTC traded instruments can be designed and easily accessible for the livestock farmers. Furthermore, combinations of various financial instruments based on the cross hedged instrument can be combined into sophisticated hedging strategies. After having designed instruments as such, they could also be offered OTC by a bank or by Lantmännen ek.för themselves.

4.3 Risk

To define different hedging strategies, it is necessary to understand the risks that the agricultural sector faces as well as different risk attitudes. Therefore, the following sub-chapters will introduce the readers with a deeper understanding of risk.

4.3.1 Agricultural risk

According to Hardaker, Huirne, and Andersson (1997), agricultural risk consists of five primary factors:

1. Price or market risk
2. Institutional risk
3. Human or personal risk
4. Third-party risk
5. Financial risk

The price or marketing risks concerns variations in commodity prices and quantities that can be managed. The institutional risks i.e. legal and environment risks are, for example, associated with lawsuits that are initiated by other businesses and governmental regulations. Human or personal risk involves labor risks i.e. the risk that family or employees may not be available to undertake labor activity. Finally, financial and third-party risk concerns the ability to pay bills and loans as well as the default probability. This paper addresses the issues of price and market risk. (Hardaker, Hurnie & Andersson, 1997)

4.3.2 Risk Attitudes

How much risk one is willing to take is considered before defining different risk management techniques. Quoting Hans Byström (2010, p. 46); "Most of us prefer a life without risks, at least if we are not adequately compensated of bearing risk". Subsequently, when deciding how much risk a person is willing to take in order to reach an as high profit as possible three different types of risk preferences are normally discussed. In turn these types of risk attitudes will be considered when evaluating different hedging strategies in chapter 5.2.

According to Byström (2010), risk averse individuals who are faced with different investment options with comparable expected yields but with dissimilar risks will favor the asset with the lowest risk. Risk loving preferences imply a preference for investments with high volatility and uncertainty in hope of getting abnormal returns, for example a gambler at a casino. Lastly, there are risk neutral preferences, which concerns risk indifference and ultimately focuses more on the expected return than the risk associated with an investment (Byström, 2010).

Another type of risk discussed by Bergmans (2008) is risk perception, which concerns the subjectivity in the feeling about risk. Essentially, the livestock farmer is subject to an individual feeling regarding the probability of losses. Kahneman, Slovic, and Tversky (1982), means that "the evaluation of information affects risk perception". On effect, the threshold effect, states that people prefer certainty before uncertainty. This supports the assumption that livestock farmers prefer risk management tools. If more certainty can be brought to livestock farmers by risk management, there is a hope that by increasing the awareness of available instruments, this might help the Swedish livestock market become more efficient. Hence, the threshold effect is where this thesis will be able to contribute to livestock farmers risk management, in order to make their compound feed expenses less volatile and uncertain.

5. Risk Management

This chapter explains risk management in the perspective of a livestock farmer in Sweden and illustrates how different hedging strategies could reduce the risks faced by a livestock farmer.

5.1 Risk Management Applied to Compound Feed Expenses

American livestock farmers have had the opportunity to manage risk by hedging output through futures contracts based on live cattle, pork bellies and stored meat since the 1960s, and in earlier days through options and different types of structured products offered Over The Counter (OTC) (CME Group, 2016). In Sweden, however, the development of financial contracts and hedging possibilities for livestock farmers has been at standstill as flat intervention prices has counteracted the need of such a marketplace. Instead, Swedish farmers are referred to the French Euronext Futures Exchange where grain and oilseed futures can be traded. Today, livestock farmers' only possibility to manage risk is by purchasing animal compound feed at a fixed cost for future deliveries and selling the end product (Wahlgren, 2016). This provides some risk protection but it is not a flexible enough method to satisfy different types of risk preferences, as discussed in chapter 4.3.2. Additionally, much can change after the animal farmer has purchased compound feed for future delivery. For example, it can become obvious to the animal farmer that prices on compound feed will fall, and if so happens the farmer will not have any possibility to alter the long exposure.

A cross hedged instrument consisting of a combination of futures contracts restructured as an index that correlates with the price of compound feed in Sweden would in theory add substantial value to a livestock farmer's risk management arsenal. The logic behind the structure of the index is that animal compound feed input commodities comprise approximately 70 % of the product value. These input commodities are mainly grains and oilseeds, and thus the correct combination of these futures contracts should correlate with the price of the compound feed in Sweden. A cross hedged index with these characteristics would in turn enable the creation of various financial instruments such as futures and options based on the index itself. This would enable the livestock farmer to trade risk exposure on and off by both going long and short, thus making the animal farmer able to tailor risk exposure to specific risk preferences and market views. Such an index is heron forth referred to as the Compound Feed Index.

In order to define the Compound Feed Index it needs to be transparent, meaning it needs to be clear to both the hedging party and the counterparty exactly where a price movement in the Compound Feed Index is derived from. This is attained by using futures contracts that can be monitored separately from the Compound Feed Index. Furthermore, the index needs to correspond to the accurate cash flows of a poultry farmer. In the poultry business the end product proceeds are sold every month and hence the poultry business is characterized by a faster turnover than for example cattle breeding where the cash flow stream occurs only once a year. This, in combination with positive operating margins, make the poultry farmer a more agile and progressive farmer and hence this is where new tools for risk management are expected to be best received. Based on the calculations by Hushållningssällskapet (2015) we estimate that the average poultry farmer could risk approximately 5 % of the cost of the compound feed on hedging instruments and still maintain returns of 7,9 %. Our calculations of how the margin varies depending on how much is risked are summarized in table 2 where Scenario 4 is estimated to be the most suitable.

table 2

Profitability Poultry Farmer (sek / m3)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Revenue	*338*	*338*	*338*	*338*	*338*
Purchase of chicken	*-80*	*-80*	*-80*	*-80*	*-80*
Costs, compound feed	*-185*	*-185*	*-185*	*-185*	*-185*
Costs, variable	*-26*	*-26*	*-26*	*-26*	*-26*
Costs, labour	*-11*	*-11*	*-11*	*-11*	*-11*
EBITDA sek / m3	*36*	*36*	*36*	*36*	*36*
…margin	*10,7%*	*10,7%*	*10,7%*	*10,7%*	*10,7%*
Max net loss hedged position as % of feed expenses	**0%**	**1%**	**3%**	**5%**	**10%**
New EBITDA sek / m3	36	34,15	30,45	26,75	17,5
…margin	10,7%	10,1%	9,0%	7,9%	5,2%

5.2 Hedging strategies

Risk Management is as much about minimizing risk as it is about optimizing risk exposure to specific risk preferences. Hence, risk management strategies will differ between animal farmers depending on different risk preferences and desired exposures. Even though, farmers most probably are risk averse there are certainly differences between farmers' willingness to take risks in order to receive greater returns. Hence, examples of how risk averse animal farmers with different risk preferences and market views could act are discussed in the following subchapters. In the strategies the profit, or market valuation, of their compound feed position is considered isolated from the rest of the business. Meaning, only the mark-to-market valuation of the compound feed purchases is considered independent of how prices in the end-product moves.

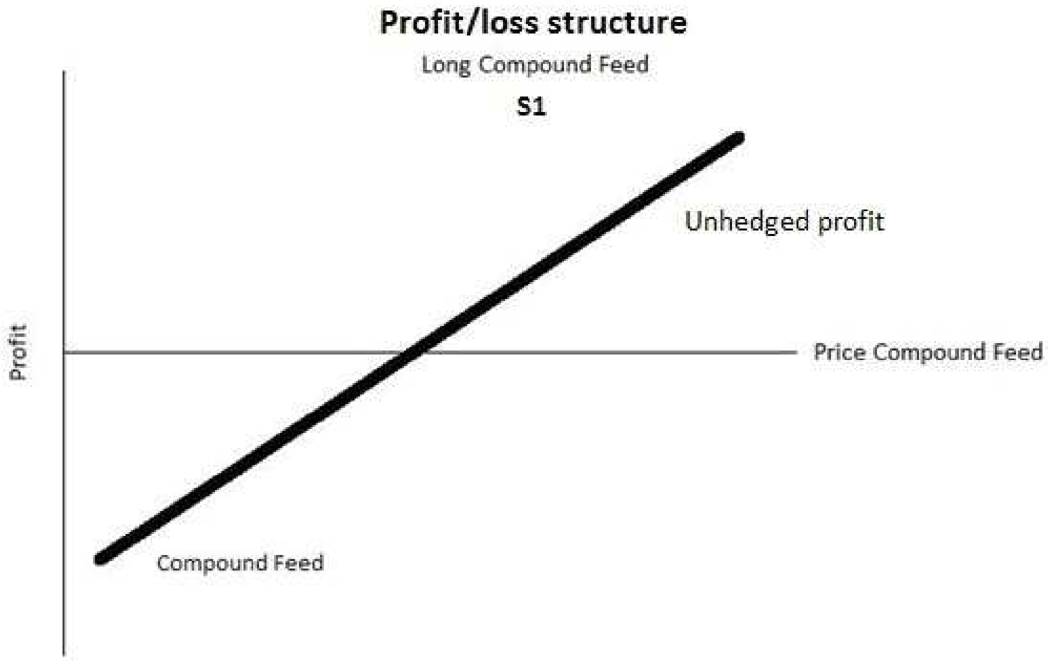
5.2.1 Strategy 1 (current strategy)

Strategy 1 is considered the risky strategy and it is currently the only strategy available for the livestock farmers. In this strategy, the poultry farmer continues with his monthly purchasing of compound feed without any downside protection. As compound feed accounts for 61,3 % of costs (HIR, 2015) the farmer is essentially long the largest expense, and hence this can be defined as a risky purchasing strategy, suitable for a market view that prices will rise. Today, the farmer is restricted to this strategy as there are no other feasible options. The profit/loss structure for this farmer is captured in figure 8*figure 8*, where P_0 is the price of compound feed when it is purchased, and P_t is the price of compound feed at the end of the month. Note here that this is the profit/loss purely from the purchasing strategy treated isolated. The profit/loss is then presented in equation 16.

equation 16

$$Profit = P_t - P_0$$

figure 8



5.2.2 Strategy 2

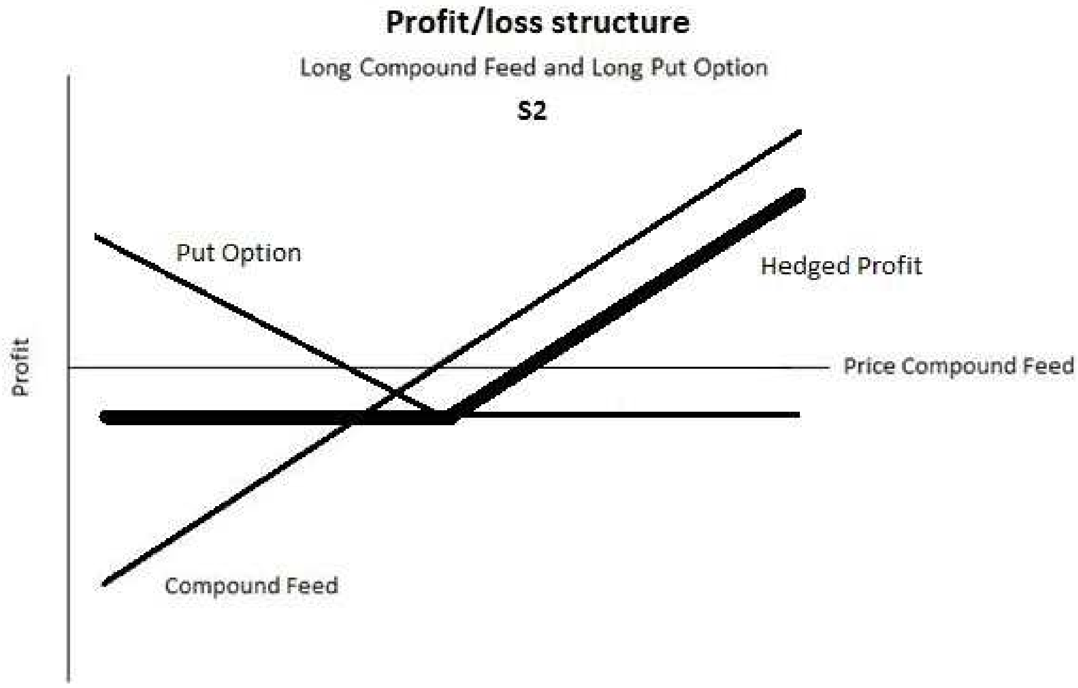
As explained in chapter 3, the poultry farmer purchases compound feed monthly. If the farmer's market opinion is uncertain, then strategy 1 is not the optimal choice. As the farmer is risk averse and has an uncertain market view then the livestock farmer should not mind some degree of risk exposure. The suitable strategy for these preferences is to purchase a month's consumption of compound feed and attach a put option on compound feed. This would allow the farmer to hedge his long position in compound feed for the month without risking more than the option premium if prices were to rise.

Such a strategy with an at-the-money put option would have a profit/loss structure as in figure 9 and as in equation 17, where P_0 is the price of compound feed when it is purchased, P_t is the price of compound feed at the end of the month, K is the strike price, F_t is the price of the Compound Feed Index at the expiry date (end of the month) and p is the put option premium.

equation 17

$$Profit = P_t - P_0 + (K - F_t, 0) - p$$

figure 9



5.2.3 Strategy 3

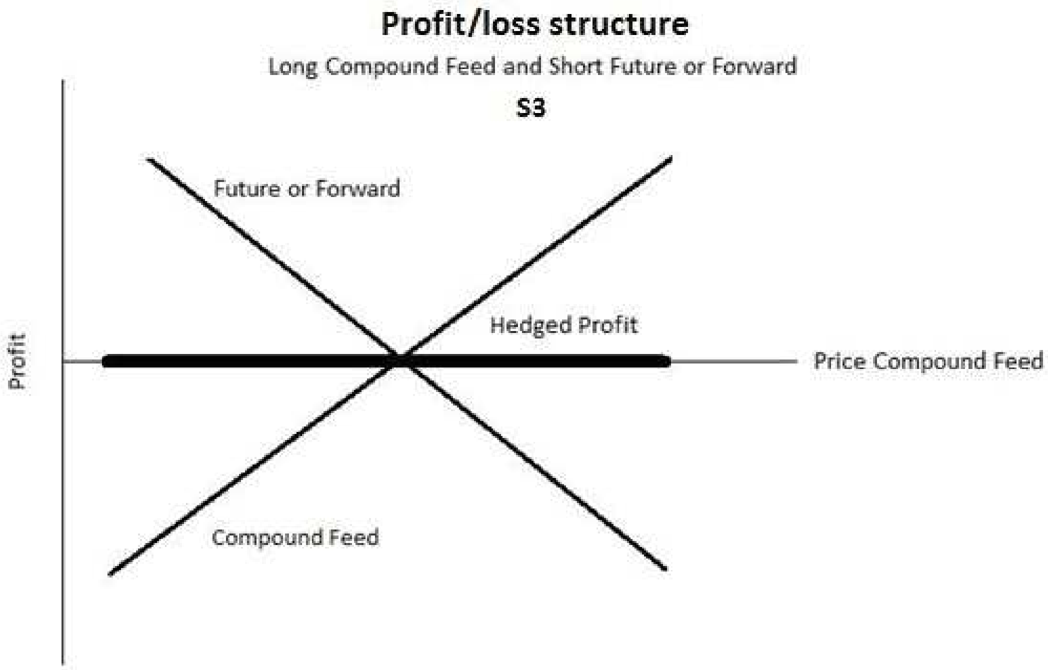
The third strategy is applicable for a risk averse poultry farmer with minimal risk willingness. From monthly compound feed purchases the farmer gains a long exposure, which could be counteracted by selling the same amount of compound feed in futures or in forwards. The net exposure would then be zero, assuming the sold forward or future is a perfect hedge, meaning that it moves inversely 1:1 with the price of compound feed. This strategy is suitable when the livestock farmer's market view is that prices will fall.

The profit/loss structure is depicted in equation 18 and figure 10 where $F_0$the price of the future at the time of the compound feed purchase and F_t is the price of the future or forward at the end of the month.

equation 18

$$Profit = P_t - P_0 + F_0 - F_t$$

figure 10



6. Data

This chapter consists of an overview of selected data and how it has been manipulated in order to fit the objective of our thesis.

6.1 Data collection

The scope of the thesis is restricted to only concern poultry compound feed. Prices were collected from Lantmannen ek.för. Price data of futures contracts trading on Euronext Futures Exchange and the Chicago Board of Trade (CBOT) was collected from a Bloomberg terminal. As these futures contracts are easily accessible and traded daily on exchanges, the usage of these futures contracts contributes to making the results of the thesis more reliable and more easily replicable. In turn, if the cross hedged index is replicable and reliable then so will the hedging tools.

As the compound feed is sold in Swedish kronor and all futures contract prices are noted in euro and American dollar, they were recalculated into Swedish kronor using the closing currency exchange notations for each corresponding trading day. Furthermore, only trading days with closing prices was selected, thus holidays etc. were excluded from the data.

As Lantmännen.för.ek. was only able to supply historical prices from October 2013 to April 2016 it was suspected early on, due to the lack of historical data, that it could be difficult to statistically prove that the strategies would have added value to farmers' hedging in the past. However, as this was as the only data available the creation of the Compound Feed Index was carried on.

6.2 Defining the Compound Feed Index Calendar Year

The end and start date of the Compound Feed Index for each consecutive year was determined depending on the availability of historical data of the poultry compound feed prices and the availability of futures contracts with the correct expiration. Ultimately, only futures contracts with May expiration were chosen as this was the last futures contract available for each crop year. Subsequently, the index calendar year was defined as 1st of April to 30th of March. The reason for this choice of calendar year is that it minimizes the basis risk as discussed in chapter 4.2.3.

Significant basis risk originates as the crop year in Sweden starts on the 1st of July and ends on the 30th of June. During this period animal compound feed is produced with crops from the corresponding harvest year. However, the last futures contract available for each consecutive harvest year is the contract with May expiration. Hence, if the Compound Feed Index was defined on the same calendar year as the harvest year (i.e. 1st of July until 30th of June), the futures contract would have had to be rolled over into the following year's contract with May expiration and thus correspond to the following year's harvest. The rolling over between futures contracts within the Compound Feed Index calendar year would have been damaging for the transparency of the index. Instead, the index's calendar year was dependent on the availability of futures contracts. As there is a significant risk of technical trading situations when futures contract close before expiry (i.e. as the open interest decreases the risk for extreme price movement increase), the final solution was to define the Compound Feed Index year from 1st of April to 31st of March, and always base it on next year's futures contracts with May expiration. This does, however, bring enhanced basis risk during April, May and June as the futures contracts does not correspond to the same harvest year as the physical commodities in the animal compound feed. However, this is the best possible solution. Table 3 summarizes the Compound Feed Index calendar year discussion, where the gray colored boxes from each harvest year are the ones included in the Compound Feed Index

table 3

Compound Feed Index *(derived from May expiration contracts on Harvest Year 2)*	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Harvest Year 1	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*
Harvest Year 2	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*
Basis Risk	Big	Big	Big	Small	Small	Small	Small	Small	Small	Small	Small	Small

6.3 Dependent variable

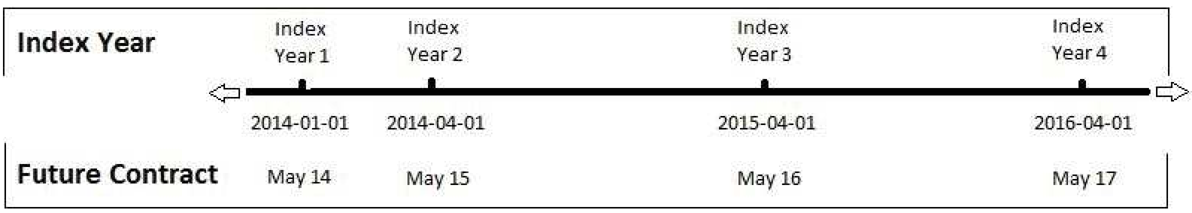
After the calendar year of the Compound Feed Index was defined, the corresponding dates for the poultry compound feed prices were selected. Moreover, historical data was limited as Sweden, apart from many other European countries, does not publish any official compound feed prices. Therefore, we relied on Lantmännen.ek.för. for prices on the largest poultry compound feed product. As Lantmännen's market price includes an inelastic margin this might distort the true correlation between the dependent and independent variables. Instead, Lantmännen supplied us with replacement prices on the poultry compound feed, which are defined as the cost to replace all input commodities in the animal compound feed at a market prices. According to Axel Walle (2016) from Lantmännen, this is the most transparent alternative to observe the correlation between the value of animal compound feed and the market prices of the required input commodities. The replacement prices of the compound feed was chosen as the independent variable. Furthermore, to avoid any mistrust in the data, the replacement prices were manipulated to correspond to the defined index calendar year, see chapter 6.2, *table 3*.

6.4 Independent variables

By studying the input commodities of compound feed that makes up 70 % of product value, the logic is that the major grain futures contract should correlate to grain input commodities in the compound feed. Main oilseed futures contract should correlate to oilseed input commodities and main protein source futures contract should correlate to protein source input commodities. Hence, these futures contracts combined should be acceptable proxies of price fluctuations in the input commodities of compound feed. The future contract for wheat is listed on Euronext Futures Exchange and the proxy for physical prices of all grain types in the animal compound feed. The futures contract for rapeseed is the proxy for oilseed inputs into animal compound feed. Rapeseed meal and soybean meal both are proxies for the protein content of animal compound feed. As these futures contracts best represents the inputs commodities of the poultry compound feed, i.e. the ingredients of the poultry compound feed, it would accordingly be the variables that best explain poultry compound feed prices over the defined time period.

As a consequence of data shortage in each defined index year, the dependent data was regressed on a manipulated spot/avista prices that rolls over from each year's May expiration futures contract into the following year's May expiration futures contract on the 31st of March, as depicted in figure 11. This gave the regression more samples and hence higher accuracy. The risk with this approach was potentially large spreads between the consecutive future contract years, which risk distorting the regression and damaging the results. However, the manipulation needed to be done in order to find a relationship between our variables.

figure 11



7. Methodology

This chapter presents the procedure behind the creation of the Compound Feed Index and the construction of strategies consisting of options and futures contracts. The chapter contains a research method, how non-stationary data was solved by the Vector Error Correction Model (VECM) and how pricing of options was made by the use of the Black-Scholes formula.

7.1 Research Method

The thesis's main objective requires a transparent price notation to be used as an underlying to the tradable hedging instruments, which are used when constructing the strategies. As there is no such price notation available today, we needed to construct it. This was done by defining a Compound Feed Index that correlated as close as possible with the price of poultry compound feed. To design the Compound Feed Index, a quantitative method was used through the data program Eviews, which is widely used, and thus it enhances the reliability of our studies.

7.2 Multivariate Time Series Models

Economic data such as prices tend to follow a trend, so called time series. This is because the current values of economic data are related to past values (Verbeek, 2012). Or as Dougherty (2011, p.110) puts it: “Time series data consists of repeated observations through time on the same entities, usually with fixed intervals between the observations”.

In short, the chosen data had the characteristics of time series data, and we had to be cautious when deciding what regression model to use. The reason for cautiousness is that when performing a regression to find the standard estimations of multivariate time series it is required that the data is characterized by stationarity. To demonstrate what is meant by a stationary time series process, the AR(1) stationary process is introduced in equation 19 (Dougherty, 2011).

equation 19

$$X_t = \beta_2 X_{t-1} + \varepsilon_t$$

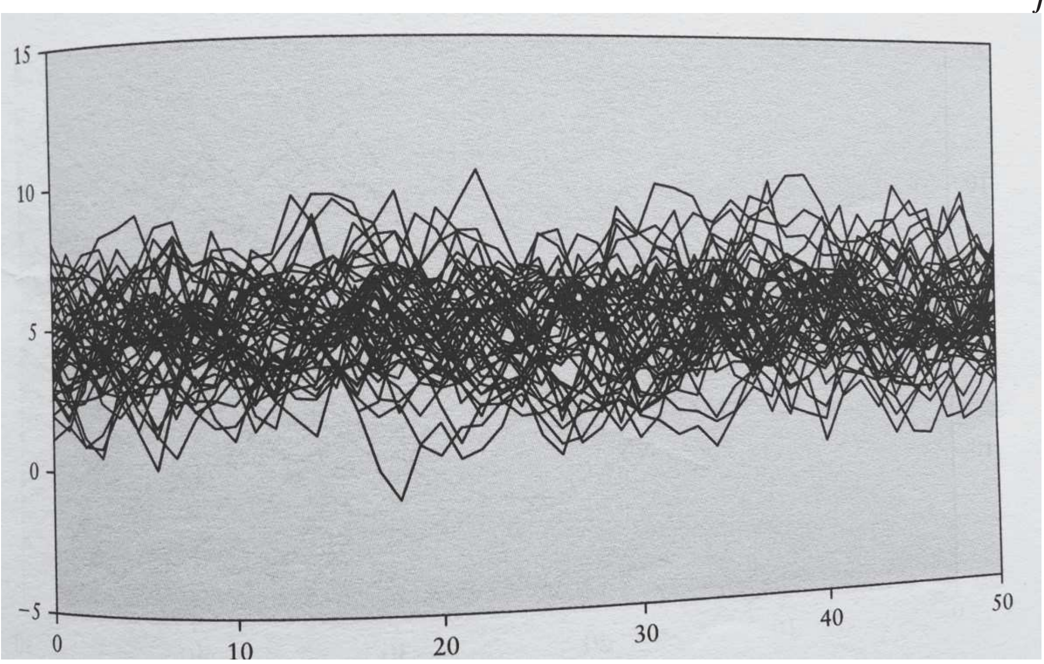
The autoregressive model of first order, AR(1), states that the value of a variable instantaneously is subject to its foregoing values. The error term, ε_t, is said to be IID-independently and identically distributed with a zero mean, and a finite variance, $(0,\sigma^2)$. In short, an autoregressive mode, AR(1), is stationary if the absolute value of the beta coefficient is less than 1, $|\beta 2|<1$. If it is stationary the value of X_t will always returns to the mean, zero, moderately fast. If, however, the value of the beta coefficient is equal to one, the process is said to be non-stationary, $\beta 2=1$, and the variable, $X_t$does not return to its mean of zero, see equation 20. (Dougherty, 2011)

equation 20

$$X_t = X_{t-1} + \varepsilon_t$$

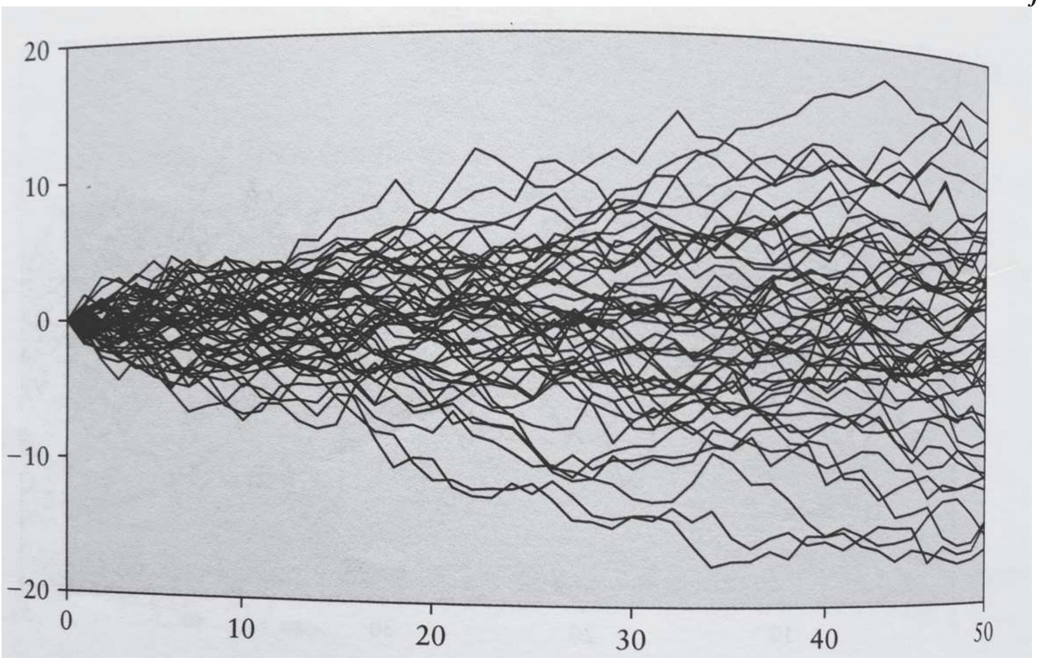
Figure 12 illustrates a stationary data prices whereas figure 13 illustrates a nonstationary process with random walks.

figure 12



Source: Dougherty, 2011

figure 13



Source: Dougherty, 2011

The result of equation 20 is that the value of X in one period is equal to its value in the previous time period, plus an error term, which acts as a random adjustment and referred to as random walk (Dougherty, 2011).

Ultimately, we tested whether our time series were subject to non-stationarity or not. To do so we performed the unit root test, which essentially test if the B2-coefficient is equal to 1 or not, hence it tests for non-stationary data by the use of an autoregressive model (Dougherty, 2011). The used unit root test was the augmented Dickey-Fuller test, which also is the most commonly used. From the test's outcome we could conclude that our independent variables had a unit root on a 5 % significant level, and thus that it was characterized by non-stationarity, see Appendix 1.

7.3 Non-stationary data issues

Since our data were non-stationary the test samples' (co)variances did not converge to the populations' (co)variances due to the fact that the data time series were not fluctuating around a constant mean (Verbeek, 2012).

Verbeck (2012 p. 342) illustrates an example of non-stationarity between Y_t and X_t through equation 21 and equation 22.

equation 21

$$Y_t = Y_{t-1} + \varepsilon_{1t} \qquad \varepsilon_{1t} \sim IID(0, \sigma^2)$$

equation 22

$$X_t = X_{t-1} + \varepsilon_{2t} \qquad \varepsilon_{2t} \sim IID(0, \sigma^2)$$

Here, ε_{1t} and ε_{2t} are IID around the mean 0 and the variance, σ^2., and the error terms are referred to as a random walk. Thus, a data generating process (DGP) where the variables have no relationship should neither indicate a relationship (correlation). Still, when we made use of a multiple Ordinary Least Square Regression (OLS), the most used and the least complicated regression model (Dougherty, 2011) by the form of equation 23, we found a relationship with significant coefficients, and a high R^2-value i.e. the strength of the test was high.

equation 23

$$Y_t = \beta_1 + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + u_t$$

However, this relationship was false i.e. a spurious regression, which means that the output was misleading (Verbeek, 2012). These results were secluded. There is, however, one important exception when nonstationary variables does not inevitably result in misleading estimating outputs, and that is when the variables are integrated of order one, I(1) and if they cointegrate (Verbeek, 2012). Meaning that if the variables are difference-stationary i.e. I(1) and if they are cointegrating valid estimators for our Compound Feed Index could be found. In short, I(1) variables means that the variables are stationary when taking the first difference, which is the returns between two consecutive time periods, equation 24 illustrates this (Dougherty, 2011).

equation 24

$$X_t - X_{t-1}$$

After having differenced the time series variables the unit root test was performed again and this time we could conclude that our variables were stationary, and thus they were integrated of the first order.

7.4 Cointegration

After having concluded that our time series data was integrated of the first order we tested for cointegration between our variables. The logic behind cointegration between two or more time series is that though our time series were nonstationary they could be wandering together (Dougherty, 2011). In order for this to be possible, the disturbance term, u_t, had to be a stationary process, otherwise the time series would diverge. More generally expressed by Dougherty (2011); if there is a relationship between the variables in equation 25 the disturbance term can then be thought of as measuring the abnormality between the variables of the model as in equation 25 and 26.

equation 25

$$Y_t = \beta_1 + \beta_2 X_2 + \cdots + \beta_k X_{kt} + u_t$$

equation 26

$$u_t = Y_t \beta_1 - \beta_2 X_2 - \cdots - \beta_k X_{kt}$$

In other words, if the variables were cointegrated, the disturbance term was stationary and the variables had a long term relationship. To test whether our variables were cointegrating a Johansen cointegration test was performed in Eviews. Ultimately, the result showed that there was one cointegrating equation. This finding was then used to find the coefficients of the long term relationship between the variables. In order to find the long term relationship, we made use of a vector error correction model (VECM).

7.5 Vector Error Correction Model (VECM)

The VECM is a form of vector autoregressive models (VAR), which is a model that consists of a vector of variables that captures the stochastic/random process that produces the time series (Verbeek, 2012). The VECM takes into account any type of cointegration between the variables and it allows for time series to be I(1), as in our case. As the Johansen cointegration test showed one cointegrating equation we performed a VECM by specifying only one cointegrating equation, see Appendix 4.

In short, the logic behind error correction models is that if a set of variables are cointegrated then there should exist an error-correction depiction of the data. For instance, if two variables, Y_t and X_t, are I(1) and have a cointegrating vector then it also exits an error-correction representation such as in equation 27 (Verbeek, 2012). In turn, the error correction model describes how Y_t and X_t behaves in the short-run and how they have a long-run cointegrating relationship.

equation 27

$$Z_t = Y_t - \beta X_t$$

Further, the VECM adjusts the standard VAR equation 28 and 29 as the VAR does not regard elements cointegrated by the first order difference where $\vec{Y_t}$ represents cointegrating vectors, δ represents the intercept of each vector, and $\ominus_1$ is the matrix coefficient.

equation 28

$$\vec{Y_t} = \delta + \ominus_1 \vec{Y}_{t-1} + \vec{\varepsilon}_t$$

equation 29

$$\Delta\vec{Y_t} = \delta + \Gamma_1 \Delta\vec{Y}_{t-1} + \cdots + \Gamma_{p-1}\Delta\vec{Y}_{t-p+1} + \gamma\beta'\vec{Y}_{t-1} + \vec{\varepsilon}_t$$

In general the VECM vectors, $\Delta\vec{Y_t}$ is of k-dimensions (in our case 5 since we have 5 variables) where our variables are piled. The elements i.e. the amount of cointegrating vectors are predicted to be integrated of first order, I(1). Thus, in the VECM there is a set of *k* I(1) variables in where it may be k-1 linearly independent relationships that are I(0) (Verbeek, 2012).

equation 30

$$\Pi = \gamma\beta'$$

In equation 30 the matrix is denoted, Π, where, β' is the matrix´s cointegrating vectors and where γ represents the weights that each cointegrating vector has when entering into each of the $\vec{Y_t}$ equations (Verbeek, 2012). Equation 30 essentially explains the output from the VECM in mathematical terms. Ultimately, when the VECM model had been done in Eviews we collected the coefficients of the independent variables, which then were used to define the weights of each futures contract in the Compound Feed Index.

7.6 Strategies

In theory any financial instrument with practically any characteristic could be created based on the Compound Feed Index. However, in order to restrict the scope of the paper, only the proposed strategies for risk management presented in chapter 5.2 have been calculated and analyzed. These strategies consist of an assumed physical purchase of compound feed for a 30-day operation, based on the business's cash flow cycle as presented in chapter 3.3.

The futures positions included in the proposed strategies were treated as a 1:1 exposure to the price fluctuations of the Compound Feed Index within the 30-day expiry period. The options were priced using the Black-Scholes formula, recall chapter 4.2.2. The calculations were made by using four fixed assumptions:

1. Time: As the poultry farmer's operation runs for 30 days between compound feed purchases, this was the maturity used for the options.
2. Volatility: The defined volatility was derived from the Compound Feed Index data series prior to the start of the index's year. Calculations were made using excel functionality.
3. Strike price: As the proposed strategies take into consideration what the average poultry farmer might pay in premium, this premium derives the strike (by excel solver) and not the other way around.
4. Risk-free rate: The normalized risk-free rate of 2.6 % obtained from PWC (2015).

8 Results & Discussion

This chapter includes the regression results, which ultimately define the Compound Feed Index year 2015/16 and 2016/17. The result is analyzed and discussed in line with its feasibility. Finally, the chapter includes the backtesting results of the strategies that were discussed in chapter 5.2.

8.1 Compound Feed Index 2015/16

Since each index year must be defined on regression results made on historical data prior to the index's starting date, the Compound Feed Index 2015/16 was defined from regression results with the time series 2013-10-01 through to 2015-03-28. The specifics behind the regression procedure are treated in chapter 6 and 7. By the use of a vector error correction model (VECM), all explaining variables were found statistically significant (Appendix 2).

$$c = 3395$$
$$\beta_1 = 1{,}15$$
$$\beta_2 = 0{,}91$$
$$\beta_3 = 0{,}9$$
$$\beta_4 = -2{,}04$$
$$R^2 = 0{,}26$$

or,

equation 31

$$Y\ (2015/2016) = 3395{,}211 + 1{,}15 * X_1 + 0{,}91 * X_2 + 0{,}90 * X_3 - 2{,}04 * X_4 + \varepsilon$$

Equation 31 illustrates the long term relationship between the dependent and independent variables that was found through the VECM. Unfortunately, the strength of the test as defined by the R^2-value was not high enough to statistically determine a general relationship between the futures contracts and the price of compound feed. This result is disappointing as there logically should be a higher correlation since futures prices partly determines the market prices, which in turn defines the replacement cost. There can be many reasons for the weak result, whereas one of the reasons is a lack of compound feed price data point. However, the main reason for the weak strength of the test is believed to be basis risk. The basis risk occurs as the price movements in, for example, wheat futures do not equal the price movements in the physical wheat used to produce the compound feed. Meaning that the basis risk is derived from using exchange traded futures contracts as cross hedge for physical commodities. This basis risk is also believed to be enhanced by the lack of data points in each regression. This as the commodities that has a corresponding futures contract does correlate with the futures contract in the long run. But, in the short run the basis might present deviations large enough to distort this relationship. The commodities that doesn't have a corresponding futures contract present a small part of the total compound feed value, but evidently the use of futures contracts with other underlying assets are not satisfactory proxies and thus further basis is added. Combined, the basis between the commodity inputs, the animal compound feed, and the tested futures contracts is too large to exhibit satisfactory correlation thus affecting the usefulness of the Compound Feed Index as a hedging tool. However, if more data had been available, we strongly believe that a more general relationship could have been statistically proven.

Apart from basis risk, there is another main reason for the low R^2. This is the difference between the index year and the crop year. To clarify, when creating the Compound Feed Index 2015/16 historical price data from futures contracts has been rolled over (combined) to create one single data series consisting of futures contracts with May expiration, recall chapter 6.2. This practice brings significant error to the future contract data series as the price between the two May expiration futures contracts can differ significantly and hence result in a "price gap" when the futures contracts are rolled over. This adds unwanted volatility to the data series. This error in the data series is then transferred to the Compound Feed Index regression, affecting the R^2 negatively.

Despite the unsatisfactory regression results, we continued with defining the Compound Feed Index from the regression results in equation 31 in order to complete the backtesting of the strategies proposed in chapter 5.2. The Index was defined as a portfolio in equation 32 where the intercept from the regression results is considered a cash position and the beta coefficients are translated to the number of futures contracts to be included, where MWF is milling wheat futures contracts, SMF is soybean meal futures contracts, RSM is rapeseed meal futures contracts and RF is rapeseed futures contracts. Positive beta coefficients are a long (bought) position in the corresponding futures contract and negative beta coefficients are a short (sold) position in the corresponding futures contract.

equation 32

$$I\ (2015/16) = 3395{,}211 + 1{,}15 * MWF + 0{,}91 * SMF + 0{,}90 * RMF - 2{,}04 * RF$$

As the Compound Feed Index is defined using data prior to the index's starting date, it is possible to back test the correlation of the Compound Feed Index 2015/16 against the realized price of compound feed during the year. This was done by performing a regression of the Compound Feed Index 2015/16 to the realized price of compound feed during the year. The R^2 coefficient of the backtesting amounts to 0,32 (Appendix 5), which indicates that we are not able to statistically signify the relationship between the compound feed price and our Compound Feed Index.

8.2 Compound Feed Index 2016/17

The Compound Feed Index for 2016/17 is the index for the current year. This index is created for Lantmännen ek. för to present to its clients. This index calendar year was created by the use of all of our data points i.e. from the time series 2013-10-01 through to 2016-03-28. By VECM all explaining variables are statistically significant, except for milling wheat, and the R^2 equals 0,34 (Appendix 6). The results define the regression equation 33.

$$c = 2406$$
$$\beta_1 = 0{,}03$$
$$\beta_2 = 0{,}47$$
$$\beta_3 = 0{,}36$$
$$\beta_4 = -0{,}45$$
$$R^2 = 0{,}34$$

or,

equation 33

$$Y\ (2016/2017) = 2406 + 0{,}03 * X_1 + 0{,}47 * X_2 + 0{,}36 * X_3 - 0{,}45 * X_4 + \varepsilon$$

As with the previous year's index, the R^2 of the regression in equation 33 is not high enough to statistically determine the relationship between the tested futures contracts and the historical price of animal compound feed. The reasons are the same as with Compound Feed Index 2015/16. Despite this, the regression is translated into the Compound Feed Index 2016/17 in equation 34 using the same portfolio composition as for the previous year's index.

equation 34

$$I\ (2016/17) = 2406 + 0{,}03 * MWF + 0{,}47 * SMF + 0{,}36 * RMF - 0{,}45 * RF$$

8.3 Strategies

To evaluate the practical efficiency and feasibility of the Compound Feed Index as a hedging tool, the strategies presented in chapter 6 were backtested on Compound Feed Index 2015/16. More specifically, we tested the historical usage of strategy 2 and 3 compared to the currently used strategy 1. As the correlation between the Compound Feed Index 2016/17 and the yet to come animal compound feed prices only Compound Feed Index 2015/16 could be used to backtest the strategies.

The aim with the backtesting was to best replicate how these strategies would have been used in real life by the livestock farmer. As the strategies are all considered for risk averse poultry farmers the choice of strategy for every month's business cycle might differ depending on the market view. In the backtesting we have assumed that the livestock farmer chooses the same strategy each month of the business cycle. This partly counteracts the aim of the backtesting, but it is the best practice when trying to display deviations in efficiency between the different strategies. It should be emphasized that the strategies were only tested for one index-year, restricted, because of lacking data availability, and hence the results are not a complete representation of the true efficiency of the Compound Feed Index as a hedging tool. Once again the scope of the research was restricted due to the availability of historical data.

The backtesting results showed that strategy 2 and strategy 3 would have performed better than the currently used strategy 1 in terms of profit/loss. The poultry farmer that followed strategy 1 the entire index year 2015/16 would have had a profit/loss of -494 SEK per ton animal compound feed (Appendix 6). The poultry farmer using strategy 2 and strategy 3 would have a profit/loss of 164 and 474 SEK per ton animal compound feed respectively (Appendix 8). Hence, we can conclude that strategy 2 yielded an excess return of 659 SEK per ton of animal compound feed over the currently used strategy 1. Using the same logic, strategy 3 yielded an excess return of 968 SEK per ton animal compound feed.

However, to achieve satisfactory hedging contribution, the variance of the returns should be minimized as it is intended for the put option in strategy 2 and the short future in strategy 3 to counteract price movements in the animal compound feed. Unfortunately the backtesting of strategy 2 and strategy 3 doesn’t exhibit this characteristics and the volatility is in fact higher when using strategy 2 or strategy 3 than the currently practiced strategy 1 (Appendix 6, 7, 8).

Hence, we cannot determine the usefulness of the Animal Compound Feed as a hedging tool based on the results from backtesting of the proposed strategy. But, it is shown that by using these strategies, the poultry farmer would have been better off. It is a returning fact that since the market is inefficient there are only limited historical data available to create the Compound Feed Index. In order to be useful in the future as a hedging instrument, a longer time frame of the index would be essential. In terms of risk attitude, reviewed in chapter 4.3.2, the probability that risk averse poultry farmers would choose strategy 2 or 3 are minimal. Also, in terms of poultry farmers risk perception the results do not give any further certainty in poultry farmers' profitability i.e. the threshold effect heuristics.

9. Conclusion

Considering the lacking hedging efficiency results in the backtesting of proposed strategies based on the Compound Feed Index 2015/16, the usefulness of a Compound Feed Index as hedging tool on animal compound feed cannot be proven. There are two main reasons for the disappointing results.

1. Basis risk
2. Oligopoly resulting in the absence of a transparent market for animal compound feed leading to limited data availability

The basis risk is significant and largely damaging to the results of the regression testing. However, the largest issue in the regression testing of the Compound Feed Index is believed to be that prices are updated only every 2 weeks, resulting in that not all market movements are included in the regression. The replacement prices are updated every two weeks and they are the only prices available. This is evidence of the low transparency in the Swedish animal compound feed market. The market prices are neither available for third parties, nor officially presented by Lantmännen, which results in significant price differences between geography and livestock farmers. Ultimately, this is a result from the Oligopoly market structure of the Swedish animal compound feed industry. Conclusively, there is no general statistically proven correlation as there is no public market and hence no suitable prices to test against.
Yet, as the Compound Feed Index consists of a mix of futures contracts trading on exchanges, it is transparent enough to be presented to livestock farmers and accessible enough for

Lantmännen ek.för to hedge counterparty risks directly on the futures exchange. However, we conclude that the Swedish Compound feed market needs to become more transparent and efficient in order for a hedging tool such as the Compound Feed Index to be successfully created and introduced. We strongly believe that such an index should increase the transparency of the market further but the latter needs to come before the first. If the market becomes more transparent, risk averse poultry farmers could enhance their threshold effect and make their profitability more certain in the future. Nevertheless, since the index is highly transparent and easily replicated through the method presented in this thesis a study similar to this could easily be recreated when the compound feed market becomes more transparent.

10. Suggestions for future studies

Suggestions for futures studies are also dependent on the availability of data, and the need for a more efficient market. Our hope is that this thesis can contribute to a more efficient market. In future studies, it would be of interest to explain the oligopoly situation in the compound feed market. This in order to clarify in what ways this affects the market and how it can be made more transparent. Essentially, a study purely about the Swedish compound farmers and their situation aiming to give advice for how it can be improved would contribute to a more efficient market.

If the market should become more transparent, the method in this thesis could be replicated with larger and more reliable time series. Most likely such a replication would result in a higher R^2 and thus a statistical relationship between the futures contracts and the price of compound feed could be determined. Furthermore, this would in turn facilitate the creation of a Compound Feed Index such a presented in this thesis. Once the Compound Feed Index can be statistically determined hedging instruments such as futures and options can be easily created.

Other futures studies within this area that would be of interest are to include more compound feed products than poultry. Even though, poultry farmers are, as mentioned, the type of farmer where strategies like this would have the biggest impact, it would be of interest to see if other compound feed products such as cow could be hedged more efficiently. Also, futures studies could test different time frames of the options and futures contract to see if different lengths of contracts could be efficient strategies.

Hopefully, this study and other studies will help to enable the transparency in the Swedish livestock breeding market. Because, when it does it will open up for a range of different research topics that will be able to conclude and contribute to the usefulness of different hedging strategies for livestock farmers in Sweden.

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Interviews

Axel Walle, Manager Purchasing, Planning & Optimization. Interviewed in person 14 April 2016.

Bodil Wahlgren, Product Manager of Poultry. Interviewed in person 13 April 2016.

12. Appendix

Appendix 1

Rapeseed Meal

Null Hypothesis: LOWER_RHINE has a unit root
Exogenous: Constant
Lag Length: 5 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.597828	0.0987
Test critical values:	1% level	-3.536587	
	5% level	-2.907660	
	10% level	-2.591396	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LOWER_RHINE)
Method: Least Squares
Date: 05/18/16 Time: 15:17
Sample (adjusted): 3/10/2014 4/19/2016
Included observations: 64 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOWER_RHINE(-1)	-0.581834	0.223969	-2.597828	0.0119
D(LOWER_RHINE(-1)...	-0.437134	0.197531	-2.212985	0.0309
D(LOWER_RHINE(-2)...	0.309160	0.174522	1.771467	0.0818
D(LOWER_RHINE(-3)...	0.335289	0.176289	1.901933	0.0622
D(LOWER_RHINE(-4)...	-0.259381	0.177697	-1.459685	0.1499
D(LOWER_RHINE(-5)...	-0.347758	0.122901	-2.829586	0.0064
C	1155.554	454.0091	2.545222	0.0137

R-squared	0.714923	Mean dependent var	-7.979718
Adjusted R-squared	0.684915	S.D. dependent var	624.6575
S.E. of regression	350.6354	Akaike info criterion	14.66029
Sum squared resid	7007874.	Schwarz criterion	14.89642
Log likelihood	-462.1292	Hannan-Quinn criter.	14.75331
F-statistic	23.82435	Durbin-Watson stat	2.135180
Prob(F-statistic)	0.000000		

Rapeseed

Null Hypothesis: RAPS has a unit root
Exogenous: Constant
Lag Length: 9 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.616554	0.4680
Test critical values:	1% level	-3.544063	
	5% level	-2.910860	
	10% level	-2.593090	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RAPS)
Method: Least Squares
Date: 05/18/16 Time: 15:18
Sample (adjusted): 4/21/2014 4/19/2016
Included observations: 60 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RAPS(-1)	-0.412346	0.255077	-1.616554	0.1124
D(RAPS(-1))	-0.585273	0.254425	-2.300375	0.0257
D(RAPS(-2))	0.232607	0.254734	0.913138	0.3656
D(RAPS(-3))	0.261371	0.253502	1.031039	0.3076
D(RAPS(-4))	-0.430950	0.249534	-1.727020	0.0905
D(RAPS(-5))	-0.521309	0.219964	-2.369968	0.0218
D(RAPS(-6))	-0.000338	0.198822	-0.001700	0.9987
D(RAPS(-7))	0.119092	0.197798	0.602087	0.5499
D(RAPS(-8))	-0.166417	0.196954	-0.844950	0.4022
D(RAPS(-9))	-0.185295	0.139756	-1.325849	0.1910
C	1328.991	826.2712	1.608420	0.1142

R-squared	0.701448	Mean dependent var	2.441233
Adjusted R-squared	0.640519	S.D. dependent var	868.3884
S.E. of regression	520.6575	Akaike info criterion	15.51220
Sum squared resid	13283127	Schwarz criterion	15.89617
Log likelihood	-454.3661	Hannan-Quinn criter.	15.66239
F-statistic	11.51254	Durbin-Watson stat	1.225443
Prob(F-statistic)	0.000000		

Soybean Meal

Null Hypothesis: SOJAMJOL has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.576994	0.1026
Test critical values:	1% level	-3.528515	
	5% level	-2.904198	
	10% level	-2.589562	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SOJAMJOL)
Method: Least Squares
Date: 05/18/16 Time: 15:18
Sample (adjusted): 12/20/2013 4/19/2016
Included observations: 69 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SOJAMJOL(-1)	-0.171633	0.066602	-2.576994	0.0122
C	431.7598	169.6734	2.544652	0.0132

R-squared	0.090179	Mean dependent var	-4.216102
Adjusted R-squared	0.076600	S.D. dependent var	111.7706
S.E. of regression	107.4045	Akaike info criterion	12.21964
Sum squared resid	772894.3	Schwarz criterion	12.28440
Log likelihood	-419.5776	Hannan-Quinn criter.	12.24533
F-statistic	6.640896	Durbin-Watson stat	1.992586
Prob(F-statistic)	0.012174		

Wheat

Null Hypothesis: VETE has a unit root
Exogenous: Constant
Lag Length: 5 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.351924	0.1594
Test critical values:	1% level	-3.536587	
	5% level	-2.907660	
	10% level	-2.591396	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(VETE)
Method: Least Squares
Date: 05/18/16 Time: 15:19
Sample (adjusted): 3/10/2014 4/19/2016
Included observations: 64 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
VETE(-1)	-0.573135	0.243688	-2.351924	0.0222
D(VETE(-1))	-0.443988	0.222111	-1.998947	0.0504
D(VETE(-2))	0.246765	0.196894	1.253290	0.2152
D(VETE(-3))	0.220481	0.192257	1.146800	0.2563
D(VETE(-4))	-0.264106	0.187828	-1.406106	0.1651
D(VETE(-5))	-0.252881	0.130046	-1.944544	0.0568
C	934.5420	405.6646	2.303731	0.0249

R-squared	0.682990	Mean dependent var	-5.553106
Adjusted R-squared	0.649621	S.D. dependent var	469.0860
S.E. of regression	277.6653	Akaike info criterion	14.19363
Sum squared resid	4394588.	Schwarz criterion	14.42976
Log likelihood	-447.1961	Hannan-Quinn criter.	14.28665
F-statistic	20.46753	Durbin-Watson stat	2.009582
Prob(F-statistic)	0.000000		

Appendix 2

Vector Error Correction Estimates
Date: 05/11/16 Time: 10:28
Sample (adjusted): 1/27/2014 3/24/2015
Included observations: 32 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
POULTRY(-1)	1.000000
VETE(-1)	-1.150156 (0.24117) [-4.76904]
RAPS(-1)	2.040713 (0.27039) [7.54727]
LOWER_RHINE(-1)	-0.898411 (0.14896) [-6.03114]
SOJAMJOL(-1)	-0.905940 (0.15520) [-5.83743]
C	-3395.211

Error Correction:	D(POULTRY)	D(VETE)	D(RAPS)	D(LOWER_R...	D(SOJAMJOL...
CointEq1	0.057367 (0.32588) [0.17604]	0.383505 (0.17170) [2.23355]	-0.401555 (0.31330) [-1.28170]	0.079090 (0.48043) [0.16462]	0.132520 (0.38305) [0.34596]
D(POULTRY(-1))	-0.106640 (0.22834) [-0.46702]	-0.064105 (0.12031) [-0.53283]	0.185564 (0.21952) [0.84530]	-0.258247 (0.33663) [-0.76716]	-0.115629 (0.26840) [-0.43081]
D(POULTRY(-2))	-0.205587 (0.20344) [-1.01056]	-0.060078 (0.10719) [-0.56048]	0.045166 (0.19559) [0.23093]	-0.083541 (0.29992) [-0.27854]	-0.216477 (0.23913) [-0.90526]
D(VETE(-1))	0.770311 (0.45562) [1.69068]	0.132657 (0.24006) [0.55259]	0.220329 (0.43803) [0.50300]	0.640317 (0.67170) [0.95327]	0.386600 (0.53556) [0.72186]
D(VETE(-2))	0.005385 (0.42661) [0.01262]	-0.396686 (0.22478) [-1.76481]	-0.065410 (0.41014) [-0.15948]	-0.074497 (0.62893) [-0.11845]	0.379647 (0.50145) [0.75709]
D(RAPS(-1))	0.002963 (0.48274) [0.00614]	-0.214847 (0.25435) [-0.84468]	0.509449 (0.46411) [1.09770]	-0.182805 (0.71168) [-0.25686]	0.758123 (0.56744) [1.33605]
D(RAPS(-2))	-0.250850 (0.41199) [-0.60888]	-0.217854 (0.21707) [-1.00360]	0.103186 (0.39608) [0.26052]	-0.410213 (0.60737) [-0.67539]	-0.232480 (0.48427) [-0.48006]
D(LOWER_RHINE(-1))	0.038221 (0.28115) [0.13595]	0.207831 (0.14813) [1.40300]	-0.252212 (0.27029) [-0.93310]	-0.099909 (0.41448) [-0.24105]	-0.257834 (0.33047) [-0.78020]
D(LOWER_RHINE(-2))	0.211688 (0.25324) [0.83593]	0.159348 (0.13343) [1.19426]	-0.126308 (0.24346) [-0.51880]	0.017051 (0.37334) [0.04567]	-0.086459 (0.29767) [-0.29045]
D(SOJAMJOL(-1))	0.044611 (0.32343) [0.13793]	0.009992 (0.17041) [0.05863]	-0.395960 (0.31094) [-1.27341]	0.310248 (0.47682) [0.65066]	-0.413643 (0.38018) [-1.08803]
D(SOJAMJOL(-2))	0.301748 (0.26879) [1.12262]	0.258267 (0.14162) [1.82363]	0.222033 (0.25841) [0.85922]	0.831029 (0.39626) [2.09717]	0.108927 (0.31595) [0.34476]
C	-9.624871 (20.9277) [-0.45991]	0.493627 (11.0266) [0.04477]	12.08506 (20.1199) [0.60065]	1.800749 (30.8528) [0.05837]	-0.122448 (24.5995) [-0.00498]
R-squared	0.263273	0.443242	0.209097	0.259408	0.269183
Adj. R-squared	-0.141927	0.137025	-0.225899	-0.147918	-0.132766
Sum sq. resids	257268.0	71421.28	237789.5	559154.1	355461.9
S.E. equation	113.4169	59.75838	109.0389	167.2056	133.3158
F-statistic	0.649736	1.447478	0.480687	0.636856	0.669695
Log likelihood	-189.2802	-168.7759	-188.0205	-201.7011	-194.4530
Akaike AIC	12.58001	11.29849	12.50128	13.35632	12.90331
Schwarz SC	13.12967	11.84814	13.05093	13.90597	13.45297
Mean dependent	-6.903125	2.448927	8.677260	7.431113	3.538131
S.D. dependent	106.1350	64.32796	98.48136	156.0613	125.2597

Determinant resid covariance (dof adj.)	2.03E+19
Determinant resid covariance	1.94E+18
Log likelihood	-900.7623
Akaike information criterion	60.36014
Schwarz criterion	63.33742

Appendix 3

Vector Error Correction Estimates
Date: 05/03/16 Time: 14:47
Sample (adjusted): 1/13/2014 4/19/2016
Included observations: 68 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
POULTRY(-1)	1.000000
RAPS(-1)	0.451472
	(0.10138)
	[4.45344]
VETE(-1)	-0.030652
	(0.21242)
	[-0.14430]
LOWER_RHINE(-1)	-0.360055
	(0.15365)
	[-2.34333]
SOJAMJOL(-1)	-0.466092
	(0.15315)
	[-3.04342]
C	-2406.019

Error Correction:	D(POULTRY)	D(RAPS)	D(VETE)	D(LOWER_R...	D(SOJAMJOL...
CointEq1	-0.580183	-1.041940	-0.539982	-0.527917	-0.010532
	(0.11332)	(0.49733)	(0.26962)	(0.38162)	(0.11777)
	[-5.11986]	[-2.09507]	[-2.00277]	[-1.38337]	[-0.08943]
D(POULTRY(-1))	0.160071	0.311984	0.195437	0.210694	0.087431
	(0.11791)	(0.51745)	(0.28053)	(0.39706)	(0.12254)
	[1.35762]	[0.60292]	[0.69668]	[0.53064]	[0.71350]
D(RAPS(-1))	0.006959	-0.037524	-0.064585	0.045558	0.087058
	(0.17102)	(0.75054)	(0.40689)	(0.57592)	(0.17774)
	[0.04069]	[-0.05000]	[-0.15873]	[0.07911]	[0.48981]
D(VETE(-1))	0.280176	0.348130	0.166416	0.252538	0.013065
	(0.26880)	(1.17969)	(0.63955)	(0.90522)	(0.27936)
	[1.04232]	[0.29510]	[0.26021]	[0.27898]	[0.04677]
D(LOWER_RHINE(-1))	-0.166782	-1.100280	-0.553771	-0.932617	-0.116554
	(0.11694)	(0.51323)	(0.27824)	(0.39382)	(0.12154)
	[-1.42617]	[-2.14382]	[-1.99027]	[-2.36813]	[-0.95898]
D(SOJAMJOL(-1))	-0.032357	2.141428	1.157930	1.649332	-0.089471
	(0.12651)	(0.55522)	(0.30100)	(0.42603)	(0.13148)
	[-0.25577]	[3.85693]	[3.84695]	[3.87136]	[-0.68048]
C	-11.57849	16.24514	1.699231	5.997824	-4.721385
	(13.7607)	(60.3916)	(32.7401)	(46.3404)	(14.3014)
	[-0.84142]	[0.26900]	[0.05190]	[0.12943]	[-0.33013]
R-squared	0.339396	0.672996	0.690707	0.651944	0.033950
Adj. R-squared	0.274419	0.640832	0.660285	0.617709	-0.061071
Sum sq. resids	758341.8	14606312	4292863.	8600158.	819115.5
S.E. equation	111.4981	489.3340	265.2825	375.4813	115.8798
F-statistic	5.223301	20.92368	22.70403	19.04322	0.357292
Log likelihood	-413.3468	-513.9213	-472.2883	-495.9125	-415.9679
Akaike AIC	12.36314	15.32122	14.09672	14.79154	12.44023
Schwarz SC	12.59162	15.54969	14.32519	15.02002	12.66871
Mean dependent	-14.58235	2.272447	-6.292630	-3.822800	-4.800032
S.D. dependent	130.8955	816.5003	455.1466	607.2834	112.4956

Determinant resid covariance (dof adj.)	1.12E+21
Determinant resid covariance	6.52E+20
Log likelihood	-2111.926
Akaike information criterion	63.29193
Schwarz criterion	64.59753

Appendix 4

Date: 05/18/16 Time: 15:31
Sample (adjusted): 1/13/2014 4/19/2016
Included observations: 68 after adjustments
Trend assumption: Linear deterministic trend
Series: POULTRY RAPS VETE LOWER_RHINE SOJAMJOL
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.456603	84.35798	69.81889	0.0022
At most 1	0.287092	42.88376	47.85613	0.1354
At most 2	0.175669	19.87234	29.79707	0.4315
At most 3	0.083046	6.735852	15.49471	0.6085
At most 4	0.012282	0.840374	3.841466	0.3593

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.456603	41.47422	33.87687	0.0051
At most 1	0.287092	23.01142	27.58434	0.1730
At most 2	0.175669	13.13648	21.13162	0.4398
At most 3	0.083046	5.895479	14.26460	0.6267
At most 4	0.012282	0.840374	3.841466	0.3593

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

POULTRY	RAPS	VETE	LOWER_RHIN...	SOJAMJOL
-0.008381	-0.003784	0.000257	0.003018	0.003906
0.001411	-0.002214	-0.001725	0.008183	-0.008616
-0.001937	0.001211	0.001613	-0.000470	0.002944
-0.000354	-0.000519	0.006716	-0.003239	-0.004030
-0.001669	-0.005693	0.011047	0.000121	-0.000289

Unrestricted Adjustment Coefficients (alpha):

D(POULTRY)	69.22634	-3.696869	21.89421	9.894895	-4.283007
D(RAPS)	124.3224	-135.6086	-145.9416	-18.01684	9.401566
D(VETE)	64.42966	-71.52151	-80.74003	-16.38734	0.601577
D(LOWER_RH...	62.99012	-146.6033	-89.49484	-3.913797	3.693172
D(SOJAMJOL)	1.256693	5.620968	-23.07263	23.92635	-4.968785

1 Cointegrating Equation(s): Log likelihood -2111.926

Normalized cointegrating coefficients (standard error in parentheses)

POULTRY	RAPS	VETE	LOWER_RHIN...	SOJAMJOL
1.000000	0.451472	-0.030652	-0.360055	-0.466092
	(0.10138)	(0.21242)	(0.15365)	(0.15315)

Adjustment coefficients (standard error in parentheses)

D(POULTRY)	-0.580183
	(0.11332)
D(RAPS)	-1.041940
	(0.49733)
D(VETE)	-0.539982
	(0.26962)
D(LOWER_RH...	-0.527917
	(0.38162)
D(SOJAMJOL)	-0.010532
	(0.11777)

2 Cointegrating Equation(s): Log likelihood -2100.420

Normalized cointegrating coefficients (standard error in parentheses)

POULTRY	RAPS	VETE	LOWER_RHIN...	SOJAMJOL
1.000000	0.000000	-0.296878	1.016076	-1.726202
		(0.34240)	(0.28802)	(0.25239)
0.000000	1.000000	0.589685	-3.048096	2.791113
		(0.70768)	(0.59529)	(0.52165)

Adjustment coefficients (standard error in parentheses)

D(POULTRY)	-0.585400	-0.253751
	(0.11485)	(0.05924)
D(RAPS)	-1.233345	-0.170168
	(0.48226)	(0.24876)
D(VETE)	-0.640931	-0.085438
	(0.26210)	(0.13520)
D(LOWER_RH...	-0.734840	0.086241
	(0.35258)	(0.18187)
D(SOJAMJOL)	-0.002599	-0.017200
	(0.11927)	(0.06152)

3 Cointegrating Equation(s): Log likelihood -2093.852

Normalized cointegrating coefficients (standard error in parentheses)

POULTRY	RAPS	VETE	LOWER_RHIN...	SOJAMJOL
1.000000	0.000000	0.000000	5.770382	-5.188697
			(1.37470)	(2.17339)
0.000000	1.000000	0.000000	-12.49151	9.668620
			(2.73963)	(4.33131)
0.000000	0.000000	1.000000	16.01435	-11.66303
			(4.37033)	(6.90942)

Adjustment coefficients (standard error in parentheses)

D(POULTRY)	-0.627816	-0.227245	0.059476
	(0.11523)	(0.06012)	(0.03140)
D(RAPS)	-0.950610	-0.346855	0.030395
	(0.46704)	(0.24368)	(0.12727)
D(VETE)	-0.484512	-0.183187	0.009659
	(0.25327)	(0.13214)	(0.06902)
D(LOWER_RH...	-0.561461	-0.022107	0.124653
	(0.34755)	(0.18133)	(0.09471)
D(SOJAMJOL)	0.042100	-0.045133	-0.046589
	(0.11959)	(0.06240)	(0.03259)

4 Cointegrating Equation(s): Log likelihood -2090.904

Normalized cointegrating coefficients (standard error in parentheses)

POULTRY	RAPS	VETE	LOWER_RHIN...	SOJAMJOL
1.000000	0.000000	0.000000	0.000000	-1.308821
				(0.26847)
0.000000	1.000000	0.000000	0.000000	1.269608
				(0.79091)
0.000000	0.000000	1.000000	0.000000	-0.895337
				(0.37678)
0.000000	0.000000	0.000000	1.000000	-0.672378
				(0.31800)

Adjustment coefficients (standard error in parentheses)

D(POULTRY)	-0.631322	-0.232380	0.125929	0.136307
	(0.11479)	(0.06023)	(0.09373)	(0.12257)
D(RAPS)	-0.944227	-0.337504	-0.090605	-0.607531
	(0.46699)	(0.24503)	(0.38132)	(0.49863)
D(VETE)	-0.478706	-0.174682	-0.100398	-0.299785
	(0.25282)	(0.13265)	(0.20644)	(0.26995)
D(LOWER_RH...	-0.560074	-0.020076	0.098368	-0.954784
	(0.34781)	(0.18250)	(0.28400)	(0.37138)
D(SOJAMJOL)	0.033623	-0.057551	0.114100	-0.016865
	(0.11667)	(0.06122)	(0.09527)	(0.12457)

Appendix 5

Dependent Variable: REPLACEMENT_COST
Method: Least Squares
Date: 05/13/16 Time: 13:31
Sample: 1 249
Included observations: 249

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2283.939	44.54617	51.27128	0.0000
INDEX_201516	0.190462	0.016846	11.30576	0.0000

R-squared	0.341017	Mean dependent var	2782.378
Adjusted R-squared	0.338350	S.D. dependent var	123.7291
S.E. of regression	100.6436	Akaike info criterion	12.06905
Sum squared resid	2501896.	Schwarz criterion	12.09730
Log likelihood	-1500.596	Hannan-Quinn criter.	12.08042
F-statistic	127.8203	Durbin-Watson stat	0.155638
Prob(F-statistic)	0.000000		

Appendix 6

	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar		Accumulated Net Return	Standard deviation
Excess Return Strategy 1	0	0	0	0	0	0	0	0	0	0	0	0		0	
Net Return Strategy 1	203	-407	-134	47	-101	-164	21	51	87	-48	60	-110		-494	151
Fixed Price Compound Feed	203	-407	-134	47	-101	-164	21	51	87	-48	60	-110		-494	

Appendix 7

	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar		Accumulated Net Return	Standard devation
Excess Return Strategy 2	-46	173	46	-143	37	-102	139	196	209	-56	-10	215		659	
Net Return Strategy 2	157	-234	-88	-96	-64	-266	161	247	296	-104	50	106		164	175
Fixed Price Compound Feed	203	-407	-134	47	-101	-164	21	51	87	-48	60	-110		-494	

Appendix 8

	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar		Accumulated Net Return	Standard devation
Excess Return Strategy 3	44	244	-427	-101	143	-12	240	277	275	-16	40	262		968	
Net Return Strategy 3	247	-163	-561	-55	42	-176	262	327	362	-64	101	153		474	252
Fixed Price Compound Feed	203	-407	-134	47	-101	-164	21	51	87	-48	60	-110		-494	