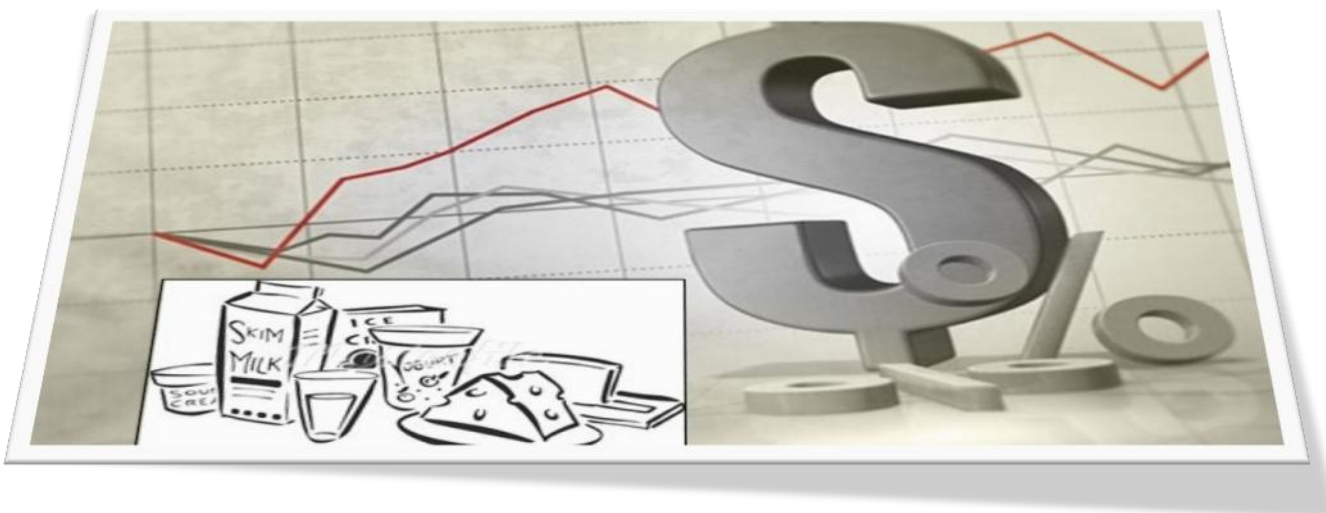
Master Thesis

Risk management towards increasing price volatility in the EU dairy sector

--- A study on dairy futures



Name	Wenjuan Mu
Registration Number	880-331-585-120
Study Program	MSc Management Economics and Consumer study
Course Code	BEC-80433
Supervisor	Dr. Ir. W.E. Kuiper (Business Economics Group)
Examiner	Prof. Dr. Ir. A.G.J.M. Oude Lansink (Business Economics Group)
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Wenjuan Mu

Wageningen University, July, 2012

Executive Summary

Background

There has been a significant increase in the price volatility of the global dairy commodities over recent years but the excessive price movements in the European Union (EU) dairy markets are unprecedented. In the past, the dairy price in the EU was rather stable under the EU price support policy and other stabilising instruments because internal EU dairy prices were protected from the substantial price swings associated with world market prices; nevertheless, bigger price fluctuation will be caused by the declined Common Agricultural Policy (CAP) support prices, lower level of intervention and a more liberal global trading system under the World Trade Organization (WTO) rules; in this case, internal EU dairy prices will be more close to world market prices.

This increasing price volatility in the dairy sector can expose its stakeholders to uncertain revenues and expenditures, which makes forecasting and anticipation very difficult. Therefore, risk management on price volatility has once again become an important issue in the EU dairy sector since stakeholders like farmers, processors, cooperatives, retailers, banks etcetera will all be affected to varying degrees of price risks. However, although there are strong needs to hedge the risks; compared to other agricultural commodity industries, dairy has been lacking of effective instruments to manage risks and create price certainty.

Purpose of this study

This study provides information on the consequences of increased price volatility on stakeholders in the EU dairy sector and how the futures market can be used as an effective hedging instrument to manage the price risks. Afterwards, empirical analysis will be conducted; different modeling methods will be applied to predict the price volatility by using the historical data and information from the futures and spot markets, and then optimal hedging ratios will be estimated based on the predicted price volatility. Next, the hedging effectiveness of different hedge ratios will be evaluated and the hedge ratio with the best performance will be selected. Finally, based on the results of the empirical analysis, recommendations with regard to managing price volatility in the EU through futures market will be formulated.

Methodology

-- Literature study

At the beginning stage, an extensive literature review will be conducted in order to identify the most vulnerable stakeholders in the dairy chain, explain how the existing dairy futures exchanges function in managing price volatility, as well as discuss the method for computing the optimal hedge ratio and measuring performance of the hedge ratio.

-- Empirical Analysis

In order to evaluate to what extent the Chicago Mercantile Exchange (CME) dairy futures can function in minimizing the variance of returns, data analysis will be applied to estimate the optimal hedge ratios and examine the effectiveness of the futures. Firstly, two data sets are selected for data analysis; one consists of the CME block cheddar cheese spot price series and the CME Milk Class III futures price series, and the other one consists of the fluid milk of Wisconsin spot price series and the CME Milk Class III futures price series. Secondly, the fitness of the simple Ordinary Least Squares (OLS) model, the advanced OLS model and the Multivariate Generalized Autoregressive Conditional Heteroscedasticity (MGARCH) model will be assessed based on the results of data analysis. Last but not least, both in-sample and out-of-sample diagnostics will be computed to evaluate the performance of the different hedge ratios as obtained from the models just mentioned. The data for the empirical analysis are obtained from the website of "understanding dairy markets" which is maintained by Prof. Brian W. Gould of the Dept. of Agric. and Applied Economics of Wisconsin University. The software package applied for the computations will be EViews version 6.

Results

The data analysis results proved that the CME Class III milk futures contract can be used as an effective hedging instrument in managing price volatility risks since it can reduce the variance of returns compared to the un-hedged portfolio; therefore, establishing a dairy futures exchange in the EU can facilitate the industry stakeholders to better manage their risks, especially under the situation that the EU dairy industry is facing ongoing liberalisation of the market. However, there are several conditions which are necessary for the successful establishment of futures markets. The following conditions are identified: (a) substantial price volatility; (b) a large number of potential interested participants; (c) limited government intervention; (d) existence of regulators; (e) reasonable basis risks; (f) a reliable and auditable commodity price index; (g) reliable public information; and (h) education and information in price risk management.

The EU is the leading supplier to the world cheese market and, according to the International Dairy Federation, it will still hold this position in 2019. However, reduction of import tariffs as part of the WTO agreement exerts influences on the EU internal cheese markets; on the other hand, the abolishment of the export subsidies makes exporting cheese to the world market to be very difficult and vulnerable to price fluctuations (Jongeneel et al., 2010). Therefore, it could be interesting for the EU dairy futures exchange to start with the cheese category first. In addition, the time varying hedge ratio which is estimated by the MGARCH model should be selected for hedging purpose since it outperforms the constant ratios in most of the cases.

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List of abbreviations

CAP: Common Agricultural Policy

CME: Chicago Mercantile Exchange

CS: Spot price series of CME block cheddar cheese

EU: European Union

F: Futures price series of the nearby (that is, delivery-month) futures contracts of CME Milk Class III

F2: Futures price series of those contracts one month before delivery

GARCH: Generalized Autoregressive Conditional Heteroscedasticity

MGARCH: Multivariate Generalized Autoregressive Conditional Heteroscedasticity

MV: Minimum Variance

NZX: New Zealand Exchange

OLS: Ordinary Least Squares

SMW: Spot price series of fluid grade milk of Wisconsin

U.S.: The United States of America

USDA: U.S. Department of Agriculture

WTO: World Trade Organisation

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Chapter 1: Introduction

1.1 Background

Price volatility in commodity markets has been elevated over recent years and has become a significant global issue. Around 2002, commodity markets began to show a stable uptrend, prices of most commodities increase dramatically and reached their peak by mid-2008; however, from the second half of 2008, commodity prices decline sharply to a trough due to the negative impact of the global financial crisis, since then, commodity prices started to recover and the prices of some commodities even exceeded their peaks in mid-2008 (Devlin et al., 2011).

Price volatility of commodities is often caused by the following factors: supply, demand, changes in policy and institutional environment (South Centre, 2005). Unexpected changes in demand or supply of commodities can result in big price fluctuations since many commodities have inelastic demand and supply (Devlin et al., 2011). In addition, policy changes like reducing the level of price support systems, which are designed to stabilise the price of commodities, can generate large price swings (Jongeneel et al., 2010).

1.2 Problem statement

There has been a significant increase in the price volatility of the global dairy commodities over recent years. Figure 1.1 shows the annual average European Union (EU) milk prices compared to the calculated U.S. Class III milk prices and the prices of Fonterra (a New Zealand multinational dairy co-operative owned by almost 10,500 New Zealand farmers). Prices are expressed in national currencies and compared to the base year 1999 (=100). As can be seen in the figure, the noticeable price swings have already existed in the United States and New Zealand since 1990 and even stronger price fluctuations started to show since 2007. Unlike the U.S. and New Zealand, the milk price trend in the EU was rather stable until 2007. However, the average milk price began to rise since the beginning of 2007 and reached its peak in 2008, after that the milk price started to decline and achieved its lowest point in the middle of 2009 and since then it has been showing a gradually increasing trend.

The excessive price movements in the EU dairy markets are unprecedented (International Dairy Federation, 2010). In the past, the dairy price in the EU was rather stable under the EU price support policy and other stabilising instruments, therefore internal EU dairy prices were protected from the substantial price swings associated with world market prices. Nevertheless, bigger price fluctuations will be caused by the declined Common Agricultural Policy (CAP) support prices, lower level of intervention and a more liberal global trading system under the World Trade Organization (WTO) rules; in this case, internal EU dairy prices will be more close to world market prices (O'Connor et al., 2009).

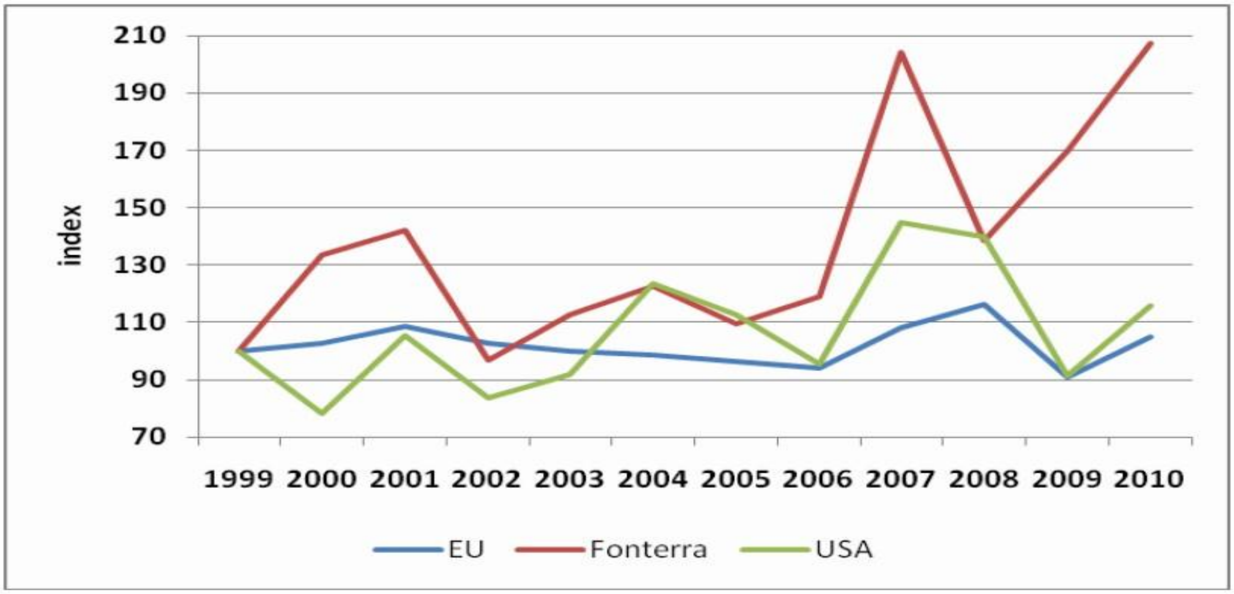

Figure 1.1 Milk price fluctuations in the EU, U.S. Class III and Fonterra (in national currency, 1999 = 100)
Source: LTO-International Milk Price Comparision, www.milkprices.nl

This increasing price volatility in the dairy sector can expose its stakeholders to uncertain revenues and expenditures, which makes forecasting and anticipation very difficult (Varangis and Larson, 1996). Therefore, risk management on price volatility has once again become an important issue in the EU dairy sector since stakeholders like farmers, processors, cooperatives, retailers, banks etcetera will all be affected to varying degrees of price risks as discussed in detail later. However, although there are strong needs to hedge the risks, compared to other agricultural commodity industries, dairy has been lacking of effective instruments to manage risks and to create price certainty (International Dairy Federation, 2010).

1.3 Research objectives

The general research objective addressed in this study is

- To find out the consequences of increased price volatility on stakeholders in the EU dairy sector so as to investigate how the futures market can be used as an effective hedging instrument to manage the price risks faced.

Based on this general research objective the following specific research objectives will be considered:

- To find out the most vulnerable stakeholders with regard to risks that caused by price volatility.
- To evaluate how one of the largest existing dairy futures exchanges functions in managing price volatility.
- To compute different optimal hedge ratios and compare their hedging effectiveness.

1.4 Research questions

With the intention of accomplishing the research objectives, the research questions have been formulated as follows:

- Which stakeholders are the most vulnerable towards price volatility?

  -- Who are the stakeholders in the EU dairy sector?

  -- To what extent are the different stakeholders influenced by price volatility?

- How does the existing dairy futures exchange function in managing price volatility?

  -- Which hedging strategies are available for dealing with price volatility?

  -- What are the major components of futures markets and which tasks do they perform?

  -- How does a futures contract work as a risk management tool?

  -- How did the dairy futures market develop?

  -- What conditions are crucial for establishing a successful futures market?

  -- To what extent does the CME dairy futures function in minimising variance of returns?

- How is the optimal hedge ratio determined?

  -- Which objective will be fulfilled when estimating the optimal hedge ratio?

  -- Which models will be applied to estimate the optimal hedge ratio?

  -- How can the performance of the optimal hedge ratio be measured?

  -- Which optimal hedge ratio performs best?

1.5 Materials and methods

-- Literature study

At the beginning stage of this study, an extensive literature review will be conducted in order to identify the most vulnerable stakeholders in the dairy chain, to explain how the existing dairy futures exchanges functions in managing price volatility, as well as to address the method for computing the optimal hedge ratio and measuring its performance.

-- Empirical Analysis

In order to evaluate to what extent the CME dairy futures can minimise variance of returns, a data analysis will be applied to estimate the optimal hedge ratios and to examine their effectiveness. Firstly, two data sets are selected for data analysis; one consists of the CME block cheddar cheese spot price series and the CME Milk Class III futures price series, and another one consists of the fluid milk of Wisconsin spot price series and the CME Milk Class III futures price series. Secondly, the fitness of the simple OLS model, advanced OLS model and MGARCH model will be assessed based on the results of the data analysis. Last but not least, both in-sample and out-of-sample tests will be performed to evaluate the performance of the different hedge ratios. The data for the empirical analysis are obtained from the website of "understanding dairy markets" which is maintained by Prof. Brian W. Gould of the Dept. of Agric. and Applied Economics of Wisconsin University. The software package used will be EViews 6.

1.6 Thesis outline

The thesis is continued by Chapter 2 which provides an overview of the consequences that the unexpected price volatility exerts on the different stakeholders and identifies the most vulnerable stake-holders with regard to the price risks. Then, Chapter 3 introduces the most frequently used hedging instruments with a focus on the background and mechanism of the futures market; meanwhile, it also describes the models for computing different hedge ratios and the method to evaluate the hedging effectiveness of these ratios. After that, the empirical analysis and the results of the two data sets analysis are discussed in Chapter 4. Last but not least, the main conclusions, recommendations, limitations and suggestions for further study are elaborated in Chapter 5.

Chapter 2: The consequences of increasing price volatility in the EU dairy sector

Along the dairy chain, several stakeholders are involved. It starts with farmers collecting milk from animals, i.e. cows, goats, etc. and shipping directly to the cooperatives of which the farmers are member or to other dairy processors; from there, the raw milk will be processed into all kinds of drinking milk with a shelf life of a few weeks or longer and other longer storable products like butter, cheese, whey powder and milk powder, etc. Processed dairy products will be delivered to traders, retailers and finally being purchased by end consumers. Meanwhile, external parties, like the government and the banks provide various support and services to make sure the dairy chain functions well.

Being exposed to the world market price with declining support policies the EU dairy industry faces increasing price risks. Moreover, the EU dairy sector is also indirectly being impacted by the increasing price on the feed market and the demand for substitutes of common feed stuffs which are caused by the energy markets (bioenergy, vegetable oils) (Jongeneel et al., 2010). However, different stakeholders in the EU dairy sector will be influenced to different degrees. In order to find out the impact that the price risks exert on different stakeholders, a stakeholder analysis is essential.

2.1 Stakeholder analysis

2.11 Farmers

According to Keane and O'Connor (2009), the price volatility at the farm level is greater than the price volatility faced by the participants in the downstream stages (close to the final customer) of the dairy supply chain, because supply and demand at the farm level are rather inelastic so that small changes in supply or demand can cause big fluctuations in prices. Bailey (2001) and Shields (2011) have both shown that a high degree of price volatility causes difficulties for farmers to plan their budgets for regular feed purchases (feed accounts for about 75% of a dairy firms' operating expenditure), labor cost and other relevant operating costs; therefore, they may run into some cash flow problems when market prices are lower than the estimated prices. Therefore, farmers are affected highly by volatile prices for both input and output.

2.12 Processors

The ability to provide fixed price contracts to farmers with the intention of retaining constant milk supply is vital for dairy processors; in order to do so, the dairy processors need to make decisions on investment and production in advance with certain confidence (NZX, 2011). However, due to the requirement of large asset specific investment of the dairy processing industry and arising substantial price swings, the decisions on which varieties of dairy products should be processed are difficult to make (Henriksen, 1999 cited in Krol et al., 2010). Thus eventually, financial difficulties for the processors can arise when the prices fall sharply; on the other hand, when the price rises significantly, the dairy products can be replaced by non-dairy substitutes, which will also bring negative impacts on the business of the dairy processors (Hoogwegt, 2011).

2.13 Cooperatives

As stated in Van Bekkum and Nilsson (2000), if the prices are too low, the members as producers may not get sufficient earnings to continue investing in the cooperatives. In addition, under high price fluctuations, adjusting the product portfolio to maximise the profit has become an even challenging issue for the dairy cooperatives because they cannot easily predict the lucrative product categories in the coming future. Meanwhile, big price swings will cause difficulties for cooperatives to plan their operating activities, which may lead to reduced investment on research and development, liquidation, etcetera.

2.14 Traders

Traders are often operating under tight margins, which make them vulnerable when prices are highly volatile (Varangis and Larson, 1996). Therefore, without government support, i.e. export subsidy and import tariff, it will be tough for EU traders to make profit under the substantial world price movement since the EU market prices are relatively higher than the world prices (Keane and O'Connor, 2009).

2.15 Retailers

Price volatility can cause planning uncertainty and revenue instability for retailers, which may result in losing market share (wrong pricing strategy is adopted) in the nature of competition among retailers and even may cause retailers to run into severe problems like major cash flow crises (Keane and O'Connor, 2009).

2.16 Consumers

Keane and O'Connor (2009) pointed out that price instability can exert an adverse influence on consumer demand. When the price increases significantly, consumers may be reluctant to buy the products because of their financial status, therefore welfare of consumers will be lowered.

2.17 Government

Varangis and Larson (1996) expressed that the high price fluctuation may result in reduction on government revenues which dependent on export taxes, import duties, income and expenditure taxes.

2.18 Banks

Banks cooperate with the participants in the dairy industry to provide lending facilities; therefore, having stable cash flows and reducing payment risks are banks' best interests (NZX, 2011). Nevertheless, under the situation of high price volatility, banks may run into the problems of credit default risks.

2.19 Identification of the most vulnerable stakeholders

As stated in several studies, participants in the beginning (upstream) stages of the dairy chain are more vulnerable towards increasing dairy price volatility compared with the more downstream stages (Keane and O'Connor, 2009; Jongeneel et al., 2010; Viaggi et al., 2011). As such, Stakeholders like farmers, processors and cooperatives are more likely to be exposed to risks because they have high asset specific investments which weaken their bargaining power and lowers their profit margin; meanwhile, demand for products produced in these early stages is extremely price inelastic (Henriksen, 1999 cited in Krol et al., 2010).

Chapter 3: Hedging strategies towards price volatility

Hedging can be effectively used to mitigate market price volatility risks for stakeholders in the dairy sector. There are three most frequently used hedging instruments which can help chain participants to lock in prices and avoid uncertainty, namely forward contracts, futures contracts and option contracts.

Forward contracts give buyers and sellers an opportunity to lock in a price of a given commodity before delivery in the future, for a range of several months to several years in advance. Meanwhile, forward contracts are usually not fungible (i.e., liquid), because they are tailored to the particular market circumstances and transfer of the contract requires that the credit risks of the counterparty be evaluated (Varangis and Larson, 1996).

Unlike forward contracts, futures and option contracts are standardised with regard to the amounts, grades, delivery dates, etc.; meanwhile, transaction processes are organised by a clearing house. Therefore, these two kinds of contracts considerably decrease the default risk which could emerge in the forward transactions. For futures contracts, market participants who are obligated to fulfill the contracts, can hedge their position in the market by taking an offsetting position in the spot and futures markets. On the other hand, option contracts are like a special type of insurance which provides its holders the right, but not the obligation, to buy or sell at a fixed price in the future. Since the option holders have the right to drop the contract, they can retain some upside potential benefit. For example, if the future spot price is higher than the futures market price, the holder can choose to sell at the future spot price. However, option contracts require the payment of a premium (futures do not), which could be costly at times (Varangis and Larson, 1996). In this study, the attention is paid only on hedging by using futures contracts.

3.1 The basics of futures markets

In order to get a good understanding of futures markets and futures contracts, identifying the major components of a futures market is crucial. Generally speaking, the futures market consists of a clearing house, broker agents, regulators, hedgers and speculators.

-- *Clearing house*

The clearing house is a third party that is responsible for clearing and settlement service in order to balance all transactions and money flows, besides it also guarantees the financial integrity of the transactions by daily margin requirement on open positions. All customers are required to open a margin account with a deposit fund before a futures contract is bought or sold; the initial margin deposit is for ensuring the performance requirements of the contract and the additional maintenance margins can be required if market conditions change. For instance, if the futures market moves in an unfavorable direction, the additional maintenance margin requirement can increase which is called a margin call. To be more specific, during each trading session, each account is "marked-to-the-market" (the current or closing market price of each contract) and money is transferred into or out of each account accordingly. Customers may be asked to post more performance bond funds if prices move too far against their positions; if prices move in favour of a customer, his or her account is also credited accordingly (Hoogwegt, 2011).

-- *Broker agents*

As defined in Bailey (2001), brokers acting as middle men are responsible for actually placing buy or sell orders on behalf of their customers with floor brokers who attempt to execute the trade, and then they charge commission for their service.

-- *Regulators*

Futures exchanges are usually regulated by a national governmental or semi-governmental agency. The brokers or firms must be registered with the regulators in order to issue, buy or sell futures contracts. Regulators ensure the financial integrity of the clearing process and encourage the competitiveness and efficiency of the futures market. Therefore, participants of the futures market are protected against manipulated trading practices and fraud.

-- *Hedgers*

The intention of hedgers participating in the futures market is to secure the futures price of a commodity, thus the futures contract provides them a price certainty, which diminishes the risks associated with price volatility and locks them in an acceptable profit margin between the cost of the input and sales of the output. In reality, hedgers usually need to know their optimal hedge ratio in order to minimise their risks to the greatest extent. A hedge ratio is the number of units or the value of futures contracts purchased or sold relative to the units or values of the spot asset; the optimal hedge ratio can be defined as the ratio which minimises the variance of the returns of a portfolio containing the spot and the futures position (Brooks, 2008).

-- *Speculators*

Speculators assume risks for hedgers. Unlike hedgers, speculators are trying to get benefits from the various price changes in the futures market. For example, they make profits by buying a contract at a low price in order to sell it back at a higher price in the future.

3.2 How does a futures contract work as a risk management tool?

As mentioned before, futures contracts can be used as an effective risk management tool for hedgers like farmers, processors, cooperatives, etc. The following terminologies are explained with the purpose of providing an insight of how the hedging process works.

-- *Long hedge vs. short hedge*

Bailey (2001) stated that buying or selling a futures contract of a commodity is more about taking a position in the market rather than literally buying or selling the commodity and there are two types of position namely sell (short) and buy (long). Selling of a future contract is called “go short” and this can be applied, for example, when a dairy farmer wants to protect milk prices against price decreases. A short position gains when prices drop and vice versa; on the other hand, buying a futures contract is called “go long” and this can be applied when a dairy processor wants to protect against increasing prices of the input milk, a long position gains when prices increase and vice versa (Bailey, 2001).

-- *Offsetting contract*

In most cases, both buyers and sellers of the futures contracts are required to accept/deliver the products. If they do not want to be getting involved to the physical delivery of the products, they need to offset the contracts by taking an opposite position in the market place before the maturity of the contracts (Bailey, 2001).

-- *Cash settlement*

Cash settlement of a futures contract means that the participants do not have to deliver or accept the physical products; instead of physical delivery, the obligations are fulfilled by paying or receiving the loss or the gains related to the contract in cash when the contract expires. Cash settlement is particularly preferable for dairy commodities where food safety criteria and the actual delivery process are complex and not globally standardised (NZX, 2011).

-- *Basis risks*

The basis is the difference between the spot price of the hedged asset and the futures price at the day the hedge is lifted. The imperfect correlation between spot prices and futures prices for a commodity is called basis risk (Varangis and Larson, 1996). Due to the difficulty of predicting the basis perfectly, the future cash price cannot be known for certain. Therefore, the participants will face the problem of basis risks.

-- *Numerical example of hedging*

In order to make the hedging process more clear to understand, a numerical example of a dairy farmer placing a short hedge to protect his milk price is provided in Table 3.1.

3.3 Development of the dairy futures market

The United States is the first country in the world with an established dairy futures market. The Chicago Mercantile Exchange (CME) dairy futures market was founded in 1995 and became a worldwide leading futures exchange. Seven different dairy product futures and options are offered by CME: two on different types of milk (Milk Class III, which is used in cheese production and Milk Class IV, which is used to produce butter and nonfat dry milk), two different butter contracts (one deliverable and one non-deliverable), two different nonfat dry milk contracts (one deliverable and one non-deliverable) and a dry whey contract, most of these trading exchanges are closed by cash-settlement. According to Jesse and Cropp(2009), the CME Class III contract is the most actively-traded contract within the CME dairy complex. The open interest in the Class III futures contract was about 10,000 contracts in the late 2000, and exceeded 25,000 contracts in mid-2008. From May 2010, CME started to offer international dairy traders the same instrument for hedging price risks as it has offered US dairy participants and the contracts can be delivered to the locations in Australia, New Zealand and Rotterdam; in addition, CME also offers the largest global network for electronic trading through the CME Globex platform, with hubs in Amsterdam, Dublin, London, Milan, Paris, Singapore, Sao Paulo and Seoul (CME, 2010).

Table 3.1 Example of a dairy farmer placing a short hedge to protect the milk price that he obtains in October 2012

Date	Cash market	Futures market	Net price to farmer
March 2012 ***Farmer intends to participate in the futures market to protect the milk selling price in October 2012***	***Basis* is $0.8*** ***Hedge price is $16.8 (=$16.0+$0.8 basis)***	***Farmer sells an October contract at $16.0, the cost for commission is $0.03***	**Not applicable**
October 2012 **Case #1 futures milk price drops (basis unchanged)**	**Future milk price is announced at $15.0** **Farmer's milk price $15.8 (=$15.0+$0.8)**	**Farmer cash settles the contract at $15.0 and gain a profit $1.0 (=$16.0-$15.0)**	**$15.8** **+futures gain of $1.0** **-commission cost$0.03** **Net price =$16.77**
October 2012 **Case #2 futures milk price increases (basis unchanged)**	**Future milk price is announced at $17.0** **Farmer's milk price $17.8(=$17.0+$0.8)**	**Farmer cash settles the contract at $17 and have a loss of $1.0 (=$16-$17)**	**$17.8** **-futures loss of $1.0** **-commission cost$0.03** **Net price =$16.77**

Source: adapted from "Risk Management Tools for Dairy Farmers" Congressional Research Service, http://www.nationalaglawcenter.org/assets/crs/R41854.pdf

Note: *Basis is the farm price (price received by the producer) minus the futures price. The example assumes that the expected and actual basis is the same.

In 2010, three other futures exchanges, namely NYSE Liffe, Eurex and NZX also added dairy product futures to their trading categories. NYSE Liffe launched a skimmed milk powder futures contract with the option for physical delivery; Eurex offers futures on European butter and skimmed milk powder with cash settlement and the underlying indices (calculated weekly based on the market prices in France, Germany and Netherlands) are used to determine the final settlement prices; NZX started futures on global whole milk powder, global skim milk powder and global anhydrous milk fat, which are all required to be cash settled.

3.4 Conditions for the successful establishment of futures markets

Several articles discussed the conditions which are necessary for the successful establishment of futures markets. Based on the work of Carlton (1984), Varangis and Larson (1996), Sarris (1997) (cited in Keane and O'Connor (2009)) and Buckley (2009), the following conditions are identified: (a) substantial price volatility; (b) a large number of potential interested participants; (c) limited government intervention; (d) existence of regulators; (e) reasonable basis risks; (f) reliable and auditable commodity price index; (g) reliable public information; and (h) education and information in price risk management.

(a) Substantial price volatility

The most basic pre-requisite for establishing a successful futures market is substantial price volatility because it can provide incentives to hedgers to manage their risks and also contract speculators to make profits by assuring the risks.

(b) A large number of potential interested participants

There must be a large number of traders, speculators and financial institutions getting involved into the futures exchange. If the trade volume is not sufficient, market manipulation can become much more of a risk.

(c) Limited government intervention

If there is too much government intervention or protection on the price mechanism, the price will become more stable, which leads to unattractiveness of the futures market. In addition, the government should not place too much physical or legal barriers and controls on the trade transactions.

(d) Existence of regulators

Regulators are essential for safeguarding the financial integrity of the futures market and prevent fraud and manipulation rules for trading, meanwhile, regulators can act as an intermediary to resolve disputes and conflicts.

(e) Reasonable basis risks

In order to have a well-functioning futures market, the cash commodity prices and futures prices must be closely correlated. Hedgers will lose interest in using futures as a price risk management instrument if there are too many basis risks.

(f) Reliable and auditable commodity price index

A reliable and auditable commodity price index is vital for pricing futures contracts and such an index is often provided by governmental institutions. As stated in Buckely (2009), the CME price index is provided by the US Department of Agriculture (USDA); however, such a reliable and auditable index does not exist in the EU at this moment, therefore, he suggested that the European Commission should be the one to provide such a milk price index if a successful futures market is to be establish in Europe.

(g) Reliable public information

Reliable and accurate public information on factors (i.e. stock level, current supply trend, etc.) that affect commodity prices can gain market participants' confidence in making the right judgments on the commodity price movements and deciding on effective strategies towards futures markets.

(h) Education and information in price risk management

Sufficient education and information in price risk management by using futures markets is also vital for getting more participants involved in the market and improving market effectiveness and efficiency.

3.5 Optimal Hedge ratio

The first prioritize decision that hedgers should make to successfully manage their risks by using a futures market is choosing the optimal hedge ratio. Traditionally, hedgers tended to hedge one unit of the spot asset by one unit of the futures contract; in that case, the optimal hedge ratio would be 1; however, because the movement between the spot and futures prices is not synchronized, there will be risks, i.e. basis risks which lead to imperfectly effective hedging results. Since then, the optimal hedge ratio refers to the proportion of the position taken in futures relative to the size of the exposure spot assets, which can meet the objectives of the hedger. Two frequently studied objectives are risk minimisation and profit maximisation. Furthermore, the hedge ratio can be static (remain constant over time) or dynamic (time varying).

-- *Static hedge ratio with the objective of risk minimisation*

The original motivation for hedging is reducing risks. According to Chen et al. (2003), the most widely-used hedge ratio with the objective of minimisation of the variance of the hedged portfolio is the minimum variance (MV) hedge ratio which is proposed by Johnson (1960). For estimating this MV hedge ratio, ordinary least squares (OLS) is the simplest method to apply. The OLS method, however, is only valid and efficient when the OLS regression assumptions are met. The linear regression equation can be written as:

$$\mathrm{R}_{st} = \mathrm{a} + \mathrm{b}^{*}\mathrm{R}_{ft} + \varepsilon_t \quad (1)$$

where $R_{st} = \ln(s_t) - \ln(s_{t-1})$ and $R_{ft} = \ln(f_t) - \ln(f_{t-1})$ are the return on spot market and the futures market for the period t, respectively, a (intercept) and b^* (slope) are both constants, where b^* ($b^* = \frac{\sigma_{sf}}{\sigma_f^2} = \rho\frac{\sigma_s}{\sigma_f}$) is optimal hedge ratio under the objective of minimum variance, see Appendix 1a for the mathematical deviation of b^*. The variable ε_t represents the error term.

-- Co-integration and error correction

The possibility that the spot price and the futures price series could be non-stationary is not considered in the OLS method, however if these two series contain a unit root and are co-integrated, then the OLS equation discussed above will be mis-specified and an error correction term must be added in the equation (Chen, et al., 2003). Therefore, co-integration analysis needs to be performed in order to find out whether the series are co-integrated. The analysis consists of two steps: first, a unit root test like the Augmented Dickey-Fuller (ADF) test should be applied for each series and then if both series are found to contain a single unit root, a co-integration test like the Engle-Granger two-step method must be performed (Chen, et al., 2003).

As defined in Engle and Granger (1987), if time series are integrated of the same order and there exists a linear combination of them which is already stationary, then these time series are said to be co-integrated, which means the deviations from the equilibrium (i.e., co-integrating) relationship will be corrected overtime so as to restore the equilibrium. Based on this definition, Engle and Granger (1987) suggested a two-step method for testing whether two integrated time series are co-integrated. The first step is measuring the co-integrating vector by taking the residuals from the regression of one time series on another; the second step is to regress the changes of the co-integrated variables on the one-period lagged equilibrium error which is given by the one-period lagged residuals obtained in step 1.

-- Dynamic hedge ratio with the objective of risk minimisation

Many studies found out that a dynamic MV hedge ratio performs a better estimation compared to a static hedge ratio, see, among others, Castelino (1990), Baillie and Myers (1991), Kroner and Sultan (1993), Park and Switzer (1995), Brooks et al. (2002) and Lien et al. (2002), as cited in Lien and Li (2008). The reasons for this are well explained by Hatemi-J and Roca (2006), namely, the anticipation of policy changes, the effect of unexpected events and some other non-observable factors such as expectations can change the agent's behavior correspondingly, therefore, the data generating process can also be affected by the changes. In this case, it could be beneficial to allow the hedge ratio to vary over time by calculating the hedge ratio based on conditional information on the covariance (σ_{sf}) and variance (σ_f^2) instead of unconditional estimates (Chen et al., 2003). Thus, the time-varying hedge ratio can be expressed as:

$$h_{tv|\Omega_{t-1}} = \rho \frac{\sigma_{s|\Omega_{t-1}}}{\sigma_{f|\Omega_{t-1}}} \tag{2}$$

Where $h_{tv|\Omega_{t-1}}$ is the time varying hedge ratio based on the information set Ω_{t-1} which contains the known information at time t-1, ρ is the correlation coefficient between return on the spot position and the return on the futures position (which might be allowed to be time-varying as well), and σ_{st} and σ_{ft} are the standard deviations of return on the spot position and return on the futures position, respectively, which are also allowed to be time varying conditional on the information set Ω_{t-1}.

When more information on spot and futures positions become available, the hedge ratios can be updated by using conditional heteroscedastic models such as generalised autoregressive conditional heteroscedasticity (GARCH) model. A GARCH(p,q) formulation indicates that the current conditional variance is parameterised to depend upon p lags of the conditional variance and q lags of the squared error; however, in general, a GARCH(1,1) model will be sufficient to capture the volatility existing in the data and any higher-order model estimated is rarely adopted in the academic finance literature (Brooks, 2008). As stated in Bhaduri and Durai (2008), a vector autoregression (VAR) with multivariate GARCH (MGARCH), like the one in Bollerslev et al. (1998), can be applied to take care of autoregressive conditional heteroscedasticity effects so as to retrieve the time-varying hedge ratio by modeling the conditional variance and covariance of the interacted spot and futures return series simultaneously. The VAR(m)-MGARCH(1,1) consists of a mean equation system, which is the VAR of order m, denoted as VAR(m), and a variance equation system, namely the MGARCH(1,1) model. The two systems can be expressed as follows:

Mean equation system (VAR(m)):

$$R_{st} = a_0 + \sum_{i=1}^{m} a_i \, R_{s,t-1} + \sum_{j=1}^{m} a_j^* \, R_{f,t-1} + \varepsilon_{st}$$

$$R_{ft} = b_0 + \sum_{i=1}^{m} b_i \, R_{s,t-1} + \sum_{j=1}^{m} b_j^* \, R_{f,t-1} + \varepsilon_{ft} \tag{3}$$

Variance equation system (MGARCH(1,1)):

$$\begin{bmatrix} \sigma_{st}^2 \\ \sigma_{sft} \\ \sigma_{ft}^2 \end{bmatrix} = \begin{bmatrix} c_{ss} \\ c_{sf} \\ c_{ff} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_{s,t-1}^2 \\ \varepsilon_{s,t-1}\varepsilon_{f,t-1} \\ \varepsilon_{f,t-1}^2 \end{bmatrix}$$

$$+ \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{bmatrix} \begin{bmatrix} \sigma_{s,t-1}^2 \\ \sigma_{st}\sigma_{ft} \\ \sigma_{f,t-1}^2 \end{bmatrix} \tag{4}$$

where σ_{st}^2 and σ_{ft}^2 represent the conditional variance of the errors ε_{st} and ε_{ft} , respectively, from the bivariate VAR(m) in (3). The term σ_{sft} represents the conditional covariance between the spot position and the futures position. The c_{ss}, c_{sf} and c_{ff} elements are the intercept terms.

According to the above model specification, 21 parameters need to be estimated. In order to simplify the parameter estimation, Bollerslev (1990, as cited in Dawson et al., 2000) proposed a restricted version of the above model which is build up according to the constant conditional correlation specification. The new specification for the variance equation can be expressed as follows:

$$\begin{bmatrix} \sigma_{st}^2 \\ \sigma_{sft} \\ \sigma_{ft}^2 \end{bmatrix} = \begin{bmatrix} c_1 \\ 0 \\ c_3 \end{bmatrix} + \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & a_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_{s,t-1}^2 \\ \varepsilon_{s,t-1}\varepsilon_{f,t-1} \\ \varepsilon_{f,t-1}^2 \end{bmatrix} + \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix} \begin{bmatrix} \sigma_{s,t-1}^2 \\ \sigma_{st}\sigma_{ft} \\ \sigma_{f,t-1}^2 \end{bmatrix} \quad (5)$$

where b_{22},the conditional correlation, stay constant over time.

-- *Measuring hedging effectiveness*

Measuring hedging effectiveness is essential for examining the performance of certain hedging strategies. According to Ederington (1979), as cited in Bhaduri and Durai (2008), through comparing the variance in the hedged portfolio with the variance in the un-hedged portfolio, hedging effectiveness can be determined; the hedged portfolio is built up by the combination of both the spot and the futures contracts held and the un-hedged portfolio only consists of spot asset. The return of the hedged and un-hedged portfolios can be expressed as follows:

$$\mathrm{E}(U) = X_s R_{st} \quad (6)$$

$$\mathrm{E(H)} = X_s R_{st} + X_f R_{ft} - K(X_f) \quad (7)$$

where, $\mathrm{E}(U)$ and $\mathrm{E}(H)$ are the expected return on the un-hedged and hedged portfolio, respectively, X_s and X_f represent spot market holdings and future market holdings, respectively, and $\mathrm{K}(X_f)$ are the brokerage and other costs of participating in futures transactions including the cost of margin call.

Likewise, the variance of the hedged and un-hedged portfolio can be written as follows:

$$\mathrm{Var}(U) = X_s^2 \sigma_s^2 \quad (8)$$

$$\mathrm{Var}(H) = X_s^2 \sigma_s^2 + X_f^2 \sigma_f^2 + 2X_s X_f \sigma_{sf} \quad (9)$$

where $\mathrm{Var(U)}$ and $\mathrm{Var}(H)$ represent the variance of un-hedged and hedged portfolio respectively, σ_s^2 and σ_f^2 are variances of $\mathrm{R_{st}}$ and $\mathrm{R_{ft}}$ respectively**,** and σ_{sf} is the covariance of R_{st} and R_{ft}. The measurement method of hedging effectiveness by calculating the percentage reduction in variance of the hedged portfolio as compared with the variance of the un-hedged portfolios was proposed by Ederington (1979). Since the objective of the MV method is to minimise the variance of the return of the hedging portfolio, the hedging effectiveness can be calculated as follows:

$$\mathrm{e} = \frac{\sigma_{sf}^2}{\sigma_s^2 \sigma_f^2} = \rho^2 \quad (10)$$

Where e is the hedging effectiveness, ρ^2 is the population coefficient of determination between the change in the cash price and the change in the future’s price. For a detailed derivation of the formula, see Appendix 1b.

3.6 Rollover

A long duration of price data is vital for successfully analyzing the hedging effectiveness. However, futures contracts usually expire periodically, which means that each contract covers a limited time span with a range from weeks to months. Therefore, a long series of price data need to be created artificially by using a sequence of nearby futures contract prices. In order to do this, two decisions need to be made: (a) choose the rollover date, that is, when to switch the contract from the current one to the next and (b) choose a price adjustment method which will be applied on the rollover date in order to correct discrete changes in prices (Knoot and Polenghi, 2006).

(a) Rollover date

There are various methods that can be applied in choosing rollover dates to construct a long price series. According to Saunier (2010), the most used and simple method in theory is called "Last Day" that is using the data of the nearest futures contract up to its maturity and then roll over to the following contract on the next day; besides this method, there are other additional rolling over methods: "Volume", "Open interest" and " Open positions". In the following, these methods will be specified into details.

-- *Last day*

The "Last day" method defines the date to switch the contract as the last trading day before maturity. Therefore, the time series constructed by this method takes the first contract's closed price of the last trading day and then switch to the next price which will be the closed price of the nearby contract on the next trading day. However, many scholars (Samuelson, 1965; Wei and Leuthold, 2000; Gwylim, et al., 2001; cited in Saunier, 2010) have realized the problem of existing price jumps when switching to the nearby contract on the last day because the volatility of futures prices increase when the expiration of a futures contract comes closer.

-- Volume

The "Volume" method determines to roll over the contracts when the volume of the current contract is constantly lower than the volume of the next contract. Lien et al. (2002), as cited in Saunier (2010), stated that the rollover date under this approach mostly falls one week before maturity.

-- Open interest

The "Open interest" approach shared a similar idea with the "Volume" method. This approach chooses to switch the contracts when the open interest of the first maturity is always less than the second one. Ripple et al. (2009), as cited in Saunier (2010), selected the rollover date by analyzing both trading volume and open interest. They decided to switch contract when both the daily trading volume and open interest for the next contract exceeds the current contract.

-- Open positions

The “Open positions” method means to jump between the contracts when the number of closed positions is always more than the number of opened positions for the current contract. Unlike the “open interest” approach which is to compare different contracts, the “open positions” method only considers the current contract for determining the switching date.

(b) Price adjustment method

Ma et al. (1992) pointed out that still some artificial jumps may arise when constructing the artificial long price series by using a rollover method and that these jumps can generate excessive price volatility which may distort the parameter estimates of the true underlying distributions and as a result the validity of the test statistics may be questioned; however, traders do not agree with making ex post adjustment since only real transaction prices can be used in practice, thus a decision needs to be made with regard to whether a series of prices should be adjusted to remove the price jumps which arise at the rollover date or not. If a price adjustment at the rollover date is necessary, one typical method to be applied is to “subtract the difference in the price levels between the new contract and the old contract, at each rollover date, from all new prices, or add the difference to the previous prices; through this way, by adjusting price levels backward or forward, the price gaps resulting from contract rollover are eliminated (Ma et al., 1992).”

Some researchers may consider cost of carry when they want to build up a continuous time series of futures prices. Cost of carry is defined in Pindyck (2001) as “a portion of the total cost of storing a commodity, namely the physical storage cost plus the forgone interest”, which is the difference between the futures price and the spot price. However, in the case of constructing a futures price series by the means of nearby futures contract with many dates of delivery, the cost of carry is not an issue anymore.

Chapter 4: Empirical Analysis

The intention of the empirical analysis is to examine the effectiveness of the theoretical model. In order to do so, a scenario illustration is essential for providing a concrete concept of how the futures market works as an effective hedging instrument. Next, data analysis will be conducted to evaluate the fitness of the simple OLS model, advanced OLS model and MGARCH model by using historical data sets. After that, both in-sample and out-of-sample tests will be performed to examine the performance of different hedge ratios. Therefore, the prediction on different types of hedge ratios will be formulated and hedging effectiveness will be measured by comparing the variance reduction of the different hedging portfolios. The data sets are collected from the website of "understanding dairy markets" which is maintained by Prof. Brian W. Gould of the Dept. of Agric. and Applied Economics of Wisconsin University

4.1 Scenario illustration

In order to clearly explain how the futures market works as a hedging instrument, a scenario illustration is essential. In Subsection 2.19, stakeholders like farmers, processors and cooperatives are defined as most vulnerable parties towards risks caused by increasing dairy price volatility. Therefore, the scenario will be constructed based on the situation of dairy producers in general. Suppose a dairy producer conduct his business by producing dairy products and sell them at prices with reasonable profit margins to customers, i.e. wholesalers, supermarkets, exporters, etc. However, in the situation of high price volatility of dairy products, the market prices of the products can decline sharply, which may cause severe revenue issues for the dairy producer; therefore, the dairy producer need to apply hedging instruments to protect his income against the low prices. Table 4.1 simply presents the whole procedure about how a dairy producer can protect his income against the potential downside market. Suppose the hedging period for the dairy producer is one month. At time t-1, the dairy producer calculated S_{t-1} as the expected selling price of the dairy products based on the cost price and expected profit margin; at the same time, he went short in the futures market and sold the dairy products for the price of F_{t-1} with the delivery date at time t because at that time, he will sell the products to his customers. When the time t arrives, the dairy producer will sell the products at the spot market for the price S_t, meanwhile, he will close his position at the futures market for the price F_t with the delivery date t.

Table 4.1 Dairy producer's hedging strategy

	Dairy producer's hedging strategy	
Spot Market	Purchase	S_{t-1}
	Sell	S_t
Futures Market	Sell	F_{t-1}
	Purchase	F_t

If the dairy producer does not hedge, then the return at time *t* will be $S_t - S_{t-1}$; however, if the producer uses the futures market to hedge the risks, then the return will be $(S_t - S_{t-1}) + h(F_{t-1} - F_t)$, where *h* is the optimal hedge ratio. The purpose of hedging is to minimise the variance of the return; with this objective, the optimal hedge ratio can be calculated. In addition, the hedging effectiveness will be evaluated by comparing the variance reduction in the hedged portfolio relative to the un-hedged portfolio.

4.2 Data analysis

The EU remains the leading supplier to the world cheese market, with the export market share of 31%. The leading member states in the EU cheese export are Germany (18%), the Netherlands (14%), France (13%) and Italy (12%), which together represents almost 60% of total EU third country exports; therefore cheese is the only product for which the EU output will not reduce in the coming decades meanwhile, the EU and the United States will remain to be the two main cheese producers in the world in 2019, which account for more than half of the global production (Anon, 2010a). However, reduction of import tariffs as part of a WTO agreement exerts influences on the EU internal cheese markets; on the other hand, the abolishment of the export subsidies makes exporting cheese to the world market to be very difficult and vulnerable to price fluctuations (Jongeneel et al., 2010). Therefore, it is interesting to evaluate how effective a futures market can be as a risk management tool for the cheese category. Due to the reason that the CME Block Cheddar Cheese futures contract was launched since mid-2010 which means that only a short period of data is available for analysis, the CME Milk Class III (milk used in cheese production) was selected instead. Meanwhile, the CME block cheddar cheese spot price series and the fluid milk of Wisconsin spot price series were selected as the spot markets of interest.

4.21 CME block cheddar cheese spot price series vs. CME Milk Class III futures price series

In the first part of the empirical analysis, the data set consists of one time series for monthly spot prices of CME spot block cheddar cheese and two time series of estimated monthly futures prices for the nearby and next to nearby futures contracts which are composed by taking the average daily price of the CME Milk Class III contract for the period of the delivery month of the maturity contract and for the period of the month before the delivery month respectively. The whole sample period is from January 2001 to January 2012. Two out-of-sample periods are used which are February 2011 to January 2012 (12 months) and February 2010 to January 2012 (24 months).

4.211 Model selection for computing hedge ratios

In order to obtain the MV hedge ratio, the conventional OLS technique will firstly be applied by taking the regression of the return of spot position on the return in futures position. In this case, the equation can be written as:

$$\Delta\,\mathrm{LOG}(CS_t) = \mathrm{a} + \mathrm{b}[\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)] + \varepsilon_t \qquad (11)$$

where $\Delta\mathrm{LOG}(CS_t) = \mathrm{LOG}(CS_t) - \mathrm{LOG}(CS_{t-1})$ denotes the return of the spot position by taking the first difference of the spot price of CME block cheddar cheese in natural logarithms, $\mathrm{LOG}(F_t)$ is the futures price for the nearby futures contract of CME Milk Class III in natural logarithms, that is, the price in the month of delivery, $\mathrm{LOG}(F2_t)$ is the natural logarithm of the futures price of the same futures contract but then in the penultimate month before delivery , and $\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)$ represents the return in futures position.

Based on the information provided by Table 4.2, the coefficient of $\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)$ is significant (prob. < 0.05), thus the optimal hedge ratio in this case is 1.361954, which means the ratio for proportion of futures position taken relative to the proportion of the spot position taken is 1.361954.

Table 4.2 Regression statistics results for $\Delta\, \mathbf{LOG}(\boldsymbol{CS_t}) = \mathbf{a} + \mathbf{b}[\mathbf{LOG}(\boldsymbol{F_t}) - \mathbf{LOG}(\boldsymbol{F2_t})] + \boldsymbol{\varepsilon_t}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.005327	0.006461	-0.824524	0.4112
LOG(F)-LOG(F2)	1.361954	0.163152	8.347772	0.0000

R-squared	0.348976	Mean dependent var	0.002681
Adjusted R-squared	0.343968	S.D. dependent var	0.090628
S.E. of regression	0.073405	Akaike info criterion	-2.370625
Sum squared resid	0.700470	Schwarz criterion	-2.326946
Log likelihood	158.4612	Hannan-Quinn criter.	-2.352876
F-statistic	69.68530	Durbin-Watson stat	1.482040
Prob(F-statistic)	0.000000		

The OLS technique applied above did not take the possibility of co-integration of these three series into consideration. If the series are co-integrated, then the OLS regression will be incomplete. Therefore, the co-integration relationship among three series should be tested first.

The spot price series for the CME spot block cheddar cheese (CS) and the futures price series for CME Milk Class III (F and F2) are shown in Figure 4.1. There seems to be a close relationship among the spot price series of the CME spot block cheddar cheese and the two futures price series since they share a similar trend, at least, based on this visual inspection. However, these three series are non-stationary and the order of integration for these three series data are denoted as *I*(1) since in Figure 4.2, Figure 4.3 and Figure 4.4, all three price series become stationary around 0 after taking the first difference of their logarithm and do not show a more stationary pattern like that when taking first differences again (called second differences). Next, it's necessary to conduct a co-integration test in order to find out whether these series are co-integrated by sharing a common stochastic trend and as such being related through a long-term equilibrium relationship. The first check on co-integration to be performed concerns the relationship between *F* and *F*2, as we have implicitly assumed in Table 4.2 that LOG(*F*)–LOG(*F*2) is stationary. This check simply consists of a regression of LOG(*F*)–LOG(*F*2) on a constant term in order to obtain the Durbin-Watson (DW) statistic. The regression finds a DW statistic of 1.33 which is quite larger than 0.6 and hence, in the acceptable range indicating stationarity.

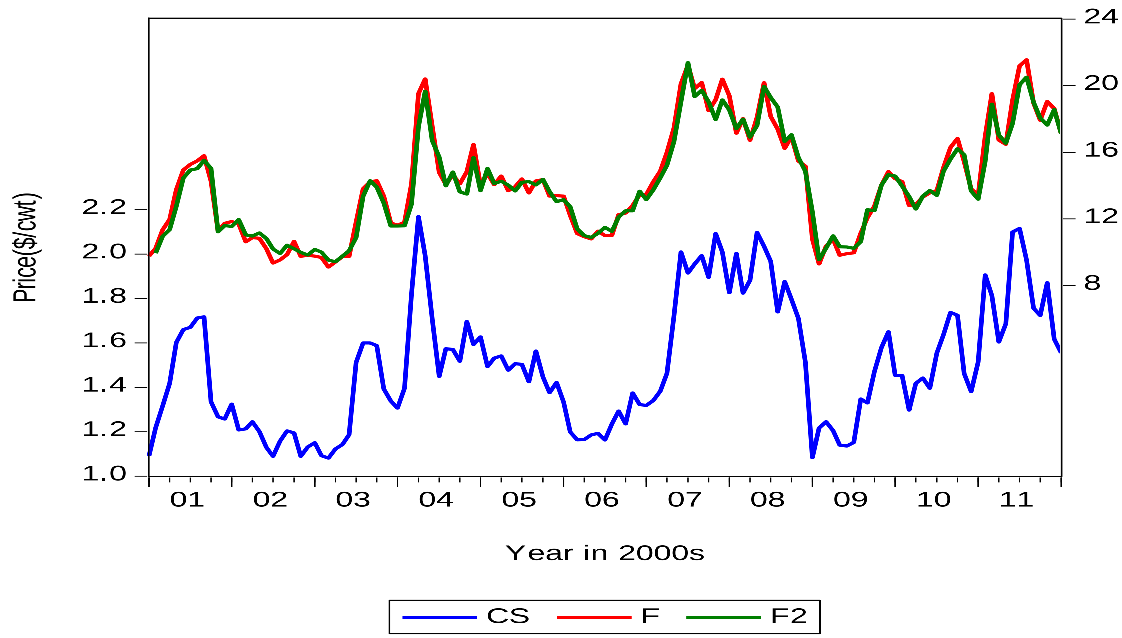

Figure 4.1 Spot price of CME spot block cheddar cheese (the blue line), futures price of the nearby (that is, delivery-month) futures contracts of CME Milk Class III (the red line) and the futures price of those contracts one month before delivery (the green line)

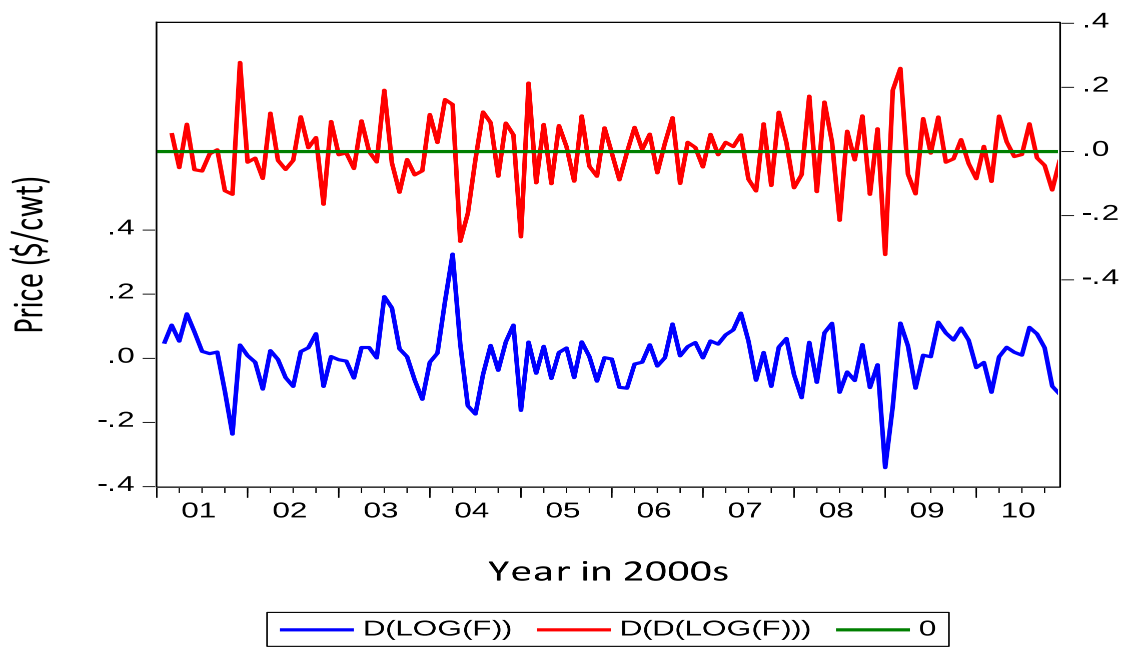

Figure 4.2 First difference (the blue line) and second difference (the red line) of the futures prices for the nearby futures contract of CME Milk Class III in natural logarithms

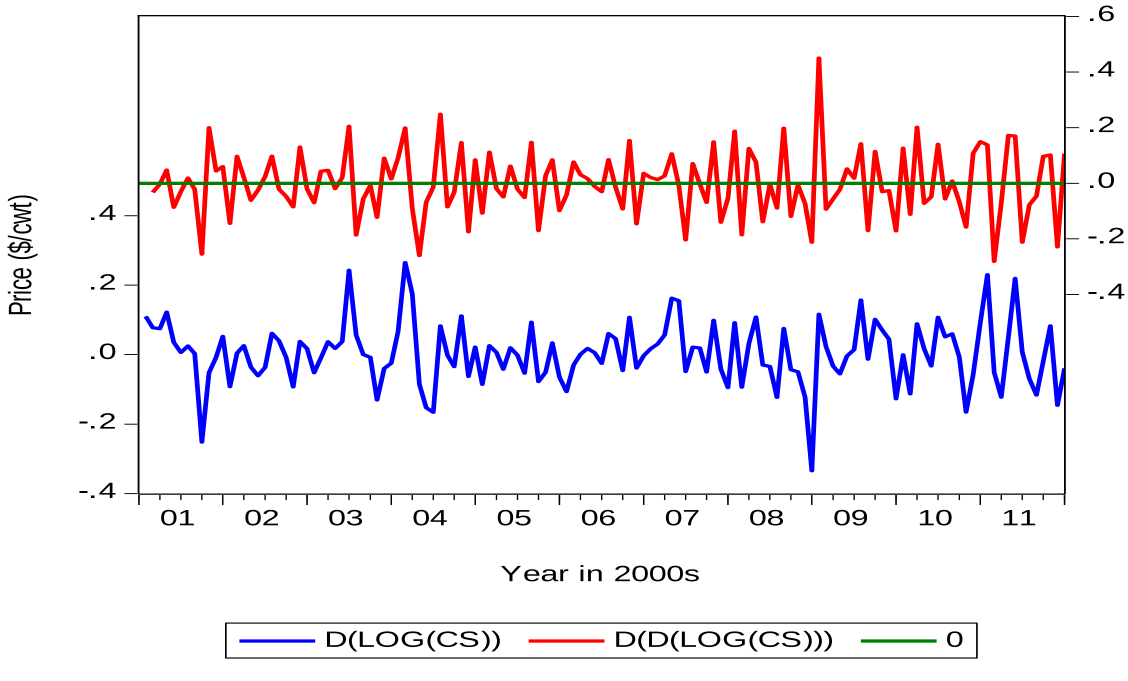

Figure 4.3 First difference (the blue line) and second difference (the red line) of the CME block cheddar cheese spot price in natural logarithms

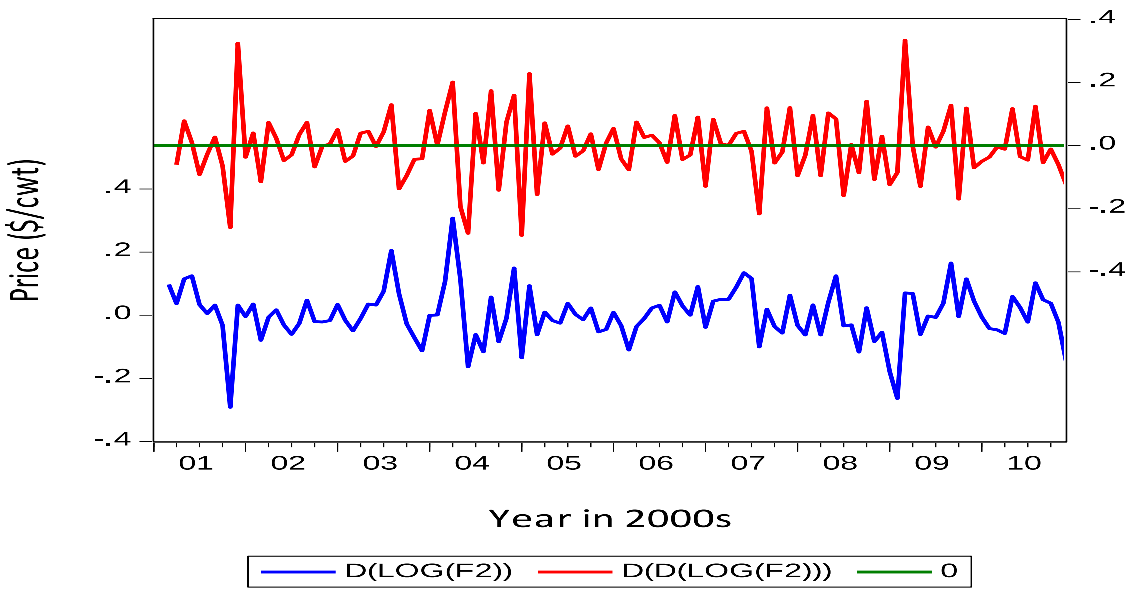

Figure 4.4 First difference (the blue line) and second difference (the red line) of the futures prices for the nearby futures contract of the CME Milk Class III in natural logarithms in the penultimate month before delivery

In order to find out whether the spot price series for CME spot block cheddar cheese and the futures price series for the nearby futures contracts of CME Milk Class III are co-integrated, we run the following regression

$$\mathrm{LOG}(CS_{t-1}) = a + b\mathrm{LOG}(F2_t) + \varepsilon_t \tag{12}$$

The regression results are shown in Table 4.3, where the Durbin-Watson statistic is around 0.55 which is lower than 0.6, therefore, the null hypothesis of no co-integration cannot be rejected and the time series of $\mathrm{LOG}(CS_{t-1})$ and $\mathrm{LOG}(F2_t)$ are not co-integrated. As we already concluded that $\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)$ is stationary, $\mathrm{LOG}(CS_t)$ and $\mathrm{LOG}(F_t)$ cannot be co-integrated either. Therefore, no error correction term is needed in the spot-futures price relationship as presented by equation (11).

Table 4.3 Regression statistics for $\mathbf{LOG}(\boldsymbol{CS_{t-1}}) = \boldsymbol{a} + \boldsymbol{b}\mathbf{LOG}(\boldsymbol{F2_t}) + \boldsymbol{\varepsilon_t}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.853795	0.057816	-32.06381	0.0000
LOG(F2)	0.856004	0.021990	38.92713	0.0000

R-squared	0.920988	Mean dependent var	0.389577
Adjusted R-squared	0.920380	S.D. dependent var	0.188559
S.E. of regression	0.053206	Akaike info criterion	-3.014274
Sum squared resid	0.368007	Schwarz criterion	-2.970596
Log likelihood	200.9421	Hannan-Quinn criter.	-2.996525
F-statistic	1515.322	Durbin-Watson stat	0.547566
Prob(F-statistic)	0.000000		

Nevertheless, Table 4.2 shows that the Durbin-Watson statistic is around 1.48 which is in the acceptable range for stationarity but it is still not around 2 as it should be in the absence of autocorrelation. Thus, the model might be further specified and improved by including dynamic terms, i.e. the lagged spot return and futures return, in the model, and seasonality. In order to do so, the number of lags to use needs to be determined first. In this research, the Schwarz Information Criterion and the Hannan-Quinn Criterion are adopted for determining the optimal lag order because they are stricter with the order selection than less parsimonious criteria such as the Akaike Information Criterion (Kilian, 2001). Therefore, lag order one is selected based on the results in Table 4.4. Adding the dynamic terms and seasonal dummies, the spot-futures price regression equation can be written as follows:

$$\begin{aligned}\Delta\mathrm{LOG}(CS_t) = {} & A + B_1[\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)] + B_2[\mathrm{LOG}(F_{t-1}) - \mathrm{LOG}(F2_{t-1})] \\ & + B_3[\Delta\mathrm{LOG}(CS_{t-1})] + B_4 seas(1) + B_5 seas(2) + B_6 seas(3) \\ & + B_7 seas(4) + B_8 seas(5) + B_9 seas(6) + B_{10} seas(7) + B_{11} seas(8) \\ & + B_{12} seas(9) + B_{13} seas(10) + B_{14} seas(11) + \varepsilon_t^*\end{aligned} \tag{13}$$

where *seas*(*i*) are seasonal dummy variables which are equal to one in month *i* (*i* = 1, …, 11) and zero elsewhere.

Table 4.4 Lag selection results for the spot-futures price regression

Lag	LogL	LR	FPE	AIC	SC	HQ
0	371.0450	NA	8.91e-06	-5.952339	-5.906850	-5.933860
1	403.8702	64.06206*	5.60e-06	-6.417261	-6.280796*	-6.361826*
2	408.2680	8.440870	5.56e-06*	-6.423677*	-6.196235	-6.331284
3	408.9149	1.220846	5.87e-06	-6.369595	-6.051176	-6.240246
4	411.0814	4.018414	6.05e-06	-6.340022	-5.930626	-6.173716
5	413.2186	3.895359	6.24e-06	-6.309978	-5.809605	-6.106715
6	418.0674	8.680823	6.16e-06	-6.323667	-5.732318	-6.083447
7	420.1997	3.748702	6.35e-06	-6.293543	-5.611217	-6.016366
8	424.9719	8.235897	6.28e-06	-6.305998	-5.532695	-5.991864

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 4.5 Regression statistics results for equation with lags and seasonality

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.270467	0.053882	5.019621	0.0000
LOG(F)-LOG(F2)	1.769369	0.150303	11.77201	0.0000
LOG(F(-1)-LOG(F2(-1)))	-0.138848	0.021028	-6.603078	0.0000
D(LOG(CS(-1)))	-0.179948	0.065123	-2.763193	0.0067
@SEAS(1)	0.023219	0.025544	0.908965	0.3653
@SEAS(2)	0.064351	0.026204	2.455789	0.0155
@SEAS(3)	0.060283	0.025677	2.347718	0.0206
@SEAS(4)	0.057042	0.025479	2.238830	0.0271
@SEAS(5)	0.079239	0.025610	3.094072	0.0025
@SEAS(6)	0.065634	0.025502	2.573719	0.0113
@SEAS(7)	0.091221	0.025790	3.537096	0.0006
@SEAS(8)	0.089239	0.025504	3.499019	0.0007
@SEAS(9)	0.097829	0.025719	3.803823	0.0002
@SEAS(10)	0.028109	0.025560	1.099716	0.2737
@SEAS(11)	0.025907	0.025474	1.017002	0.3113

R-squared	0.614412	Mean dependent var	0.001860
Adjusted R-squared	0.567876	S.D. dependent var	0.090481
S.E. of regression	0.059479	Akaike info criterion	-2.698992
Sum squared resid	0.410377	Schwarz criterion	-2.369771
Log likelihood	191.7840	Hannan-Quinn criter.	-2.565215
F-statistic	13.20282	Durbin-Watson stat	1.513257
Prob(F-statistic)	0.000000		

Table 4.6 Correlogram Q-statistics test results for equation with lags and seasonality

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.243	0.243	7.8888	0.005
		2	-0.105	-0.174	9.3843	0.009
		3	-0.095	-0.025	10.608	0.014
		4	0.091	0.116	11.732	0.019
		5	0.167	0.104	15.610	0.008
		6	0.088	0.039	16.687	0.011
		7	0.053	0.075	17.087	0.017
		8	0.024	0.019	17.170	0.028
		9	0.112	0.110	18.950	0.026
		10	-0.011	-0.090	18.967	0.041
		11	-0.000	0.033	18.967	0.062
		12	0.084	0.070	20.005	0.067
		13	0.096	0.025	21.366	0.066
		14	0.095	0.067	22.707	0.065
		15	0.112	0.114	24.597	0.056
		16	-0.053	-0.122	25.018	0.070
		17	-0.079	-0.028	25.980	0.075
		18	0.094	0.091	27.349	0.073
		19	0.163	0.061	31.481	0.036
		20	0.099	0.026	33.013	0.034
		21	-0.037	-0.038	33.231	0.044
		22	-0.099	-0.071	34.812	0.041
		23	-0.025	-0.017	34.915	0.053
		24	0.061	-0.019	35.517	0.061
		25	-0.046	-0.100	35.861	0.074
		26	0.041	0.101	36.144	0.089
		27	0.040	-0.044	36.416	0.106
		28	0.044	0.044	36.740	0.125
		29	-0.022	-0.008	36.820	0.151
		30	-0.025	-0.003	36.924	0.179
		31	0.033	0.043	37.115	0.208
		32	0.138	0.121	40.488	0.144
		33	0.089	-0.038	41.889	0.138
		34	-0.029	0.018	42.036	0.162
		35	0.010	0.051	42.056	0.192
		36	-0.103	-0.149	43.987	0.169

As shown in Table 4.5, the DW statistic has been improved to around 1.51. However, it is still not around 2. According to the correlogram of the residuals as presented in Table 4.6 the autocorrelation breaks off after the first autocorrelation while the partial autocorrelations are more or less dying out. Such a pattern in the correlogram suggests an MA(1) model. Therefore, an MA(1) term was incorporated as an independent variable in the regression, the new regression model will then be:

$$
\begin{aligned}
\Delta \mathrm{LOG}(CS_t) = A &+ B_1[LOG(F_t) - LOG(F2_t)] + B_2[\mathrm{LOG}(F_{t-1}) - \mathrm{LOG}(F2_{t-1})] \\
&+ B_3[\Delta\ \mathrm{LOG}(CS_{t-1})] + B_4 seas(1) + B_5 seas(2) + B_6 seas(3) \\
&+ B_7 seas(4) + B_8 seas(5) + B_9 seas(6) + B_{10} seas(7) + B_{11} seas(8) \\
&+ B_{12} seas(9) + B_{13} seas(10) + B_{14} seas(11) + B_{15}\varepsilon_{t-1} + \varepsilon_t \qquad (14)
\end{aligned}
$$

As presented in Table 4.7, the Durbin-Watson statistic is finally around 2 and the noises have become quiet according to the residual correlogram test results in Table 4.8.

The coefficient of $\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)$ is the optimal hedge ratio for the above model. As shown in Table 4.7, under this portfolio, the dairy producer should hedge 173.4649% of his spot position in the futures market in order to minimize the variance of the hedged portfolio returns.

Table 4.7 Regression statistics results for equation with lags, seasonality and MA(1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.272810	0.066797	4.084131	0.0001
LOG(F)-LOG(F2)	1.734649	0.144319	12.01956	0.0000
LOG(F(-1)-LOG(F2(-1)))	-0.139843	0.026390	-5.299008	0.0000
D(LOG(CS(-1)))	-0.290367	0.066953	-4.336903	0.0000
@SEAS(1)	0.019159	0.021478	0.892006	0.3743
@SEAS(2)	0.059918	0.026706	2.243613	0.0268
@SEAS(3)	0.063308	0.026270	2.409906	0.0175
@SEAS(4)	0.058920	0.026034	2.263234	0.0255
@SEAS(5)	0.082896	0.026067	3.180166	0.0019
@SEAS(6)	0.068811	0.025975	2.649102	0.0092
@SEAS(7)	0.092954	0.026145	3.555363	0.0005
@SEAS(8)	0.090050	0.025952	3.469859	0.0007
@SEAS(9)	0.100551	0.026077	3.855909	0.0002
@SEAS(10)	0.030467	0.025985	1.172503	0.2434
@SEAS(11)	0.022243	0.021278	1.045324	0.2981
MA(1)	0.379635	0.107557	3.529607	0.0006

R-squared	0.652848	Mean dependent var	0.001860
Adjusted R-squared	0.607568	S.D. dependent var	0.090481
S.E. of regression	0.056681	Akaike info criterion	-2.788731
Sum squared resid	0.369470	Schwarz criterion	-2.437562
Log likelihood	198.6619	Hannan-Quinn criter.	-2.646035
F-statistic	14.41782	Durbin-Watson stat	1.991067
Prob(F-statistic)	0.000000		

Inverted MA Roots	-.38

Table 4.8 Correlogram Q-statistics test results for equation with lags, seasonality and MA(1)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.004	0.004	0.0023	
		2	-0.048	-0.048	0.3150	0.575
		3	-0.140	-0.140	2.9880	0.224
		4	0.083	0.083	3.9339	0.269
		5	0.102	0.091	5.3828	0.250
		6	0.008	-0.005	5.3917	0.370
		7	0.064	0.098	5.9627	0.427
		8	-0.011	0.009	5.9797	0.542
		9	0.131	0.127	8.4175	0.394
		10	-0.079	-0.071	9.3139	0.409
		11	0.017	0.016	9.3569	0.499
		12	0.041	0.058	9.5977	0.567
		13	0.063	0.022	10.187	0.600
		14	0.038	0.030	10.400	0.661
		15	0.095	0.130	11.753	0.626
		16	-0.043	-0.063	12.035	0.676
		17	-0.067	-0.055	12.727	0.693
		18	0.062	0.061	13.323	0.714
		19	0.130	0.105	15.938	0.597
		20	0.046	0.003	16.277	0.639
		21	-0.036	-0.009	16.486	0.686
		22	-0.066	-0.050	17.188	0.700
		23	-0.051	-0.075	17.603	0.729
		24	0.082	0.027	18.687	0.719
		25	-0.087	-0.107	19.944	0.700
		26	0.046	0.036	20.300	0.731
		27	0.012	-0.002	20.325	0.776
		28	0.061	0.023	20.965	0.788
		29	-0.065	-0.030	21.697	0.795
		30	-0.004	0.017	21.700	0.832
		31	0.021	0.017	21.776	0.862
		32	0.106	0.118	23.769	0.820
		33	0.080	0.035	24.919	0.809
		34	-0.074	-0.038	25.896	0.806
		35	0.062	0.097	26.596	0.813
		36	-0.117	-0.112	29.101	0.748

So far, the hedge ratios are considered to be static since the variance of the futures return and the covariance between the spot and futures returns are assumed to be time invariant. However, if the variances change over time, then the hedge ratio should be allowed to be time varying, which can be approached by using an MGARCH model (Dawson et al., 2000). As mentioned before, in general a GARCH(1, 1) model will be sufficient to capture the volatility existing in the data. In addition, as a rule of thumb, models that contain as less parameters as possible can provide the most accurate prediction. Therefore, the MGARCH(1,1) applied in this scenario will be free from seasonal and MA terms as these terms appeared to hardly contribute to out-of-sample prediction accuracy. The resulting mean and variance equations are presented below:

Mean equations:

$$\Delta \mathrm{LOG}(CS_t) = C(1) * \Delta \mathrm{LOG}(CS_{t-1}) + C(2) * [\mathrm{LOG}(F_{t-1}) - \mathrm{LOG}(F2_{t-1})] + C(3)$$

$$\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t) = C(4) * \Delta \mathrm{LOG}(CS_{t-1}) + C(5) * [\mathrm{LOG}(F_{t-1}) - \mathrm{LOG}(F2_{t-1})] + C(6) \tag{15}$$

Variance equations:

$$\begin{bmatrix} \sigma_{st}^2 \\ \sigma_{sft} \\ \sigma_{ft}^2 \end{bmatrix} = \begin{bmatrix} M(1) \\ 0 \\ M(2) \end{bmatrix} + \begin{bmatrix} A1(1) & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & A1(2) \end{bmatrix} \begin{bmatrix} \varepsilon_{s,t-1}^2 \\ \varepsilon_{s,t-1}\varepsilon_{f,t-1} \\ \varepsilon_{f,t-1}^2 \end{bmatrix} + \begin{bmatrix} B1(1) & 0 & 0 \\ 0 & R(1,2) & 0 \\ 0 & 0 & B1(2) \end{bmatrix} \begin{bmatrix} \sigma_{s,t-1}^2 \\ \sigma_{st}\sigma_{ft} \\ \sigma_{f,t-1}^2 \end{bmatrix} \tag{16}$$

Based on the estimates shown in Table 4.9, the time-varying hedge ratio can be computed. As defined in Section 3.5, equation (2), ρ will be *R*(1,2) which is 0.680415. Based on equation (16) and all information up to and including time t–1, σ_{st}^2 can be computed as follows: $\sigma_{st}^2 = 0.000208 - 0.096007 * \varepsilon_{s,t-1}^2 + 1.065762 * \sigma_{s,t-1}^2$. Similarly, σ_{ft}^2 can be computed as follows: $\sigma_{ft}^2 = 0.000066 - 0.106103 * \varepsilon_{f,t-1}^2 + 1.065195 * \sigma_{f,t-1}^2$. Finally, the time-varying hedge ratio can be computed and shown in Figure 4.5.

Table 4.9 Results of MGARCH (1, 1) variance equations for the sample period Jan 2001 to Jan 2012

Tranformed Variance Coefficients				
	Coefficient	Std. Error	z-Statistic	Prob.
M(1)	0.000208	0.000240	0.867795	0.3855
A1(1)	-0.096007	0.029130	-3.295857	0.0010
B1(1)	1.065762	0.043545	24.47520	0.0000
M(2)	6.66E-05	4.05E-05	1.644834	0.1000
A1(2)	-0.106103	0.033869	-3.132784	0.0017
B1(2)	1.065195	0.031217	34.12179	0.0000
R(1,2)	0.680415	0.042827	15.88742	0.0000

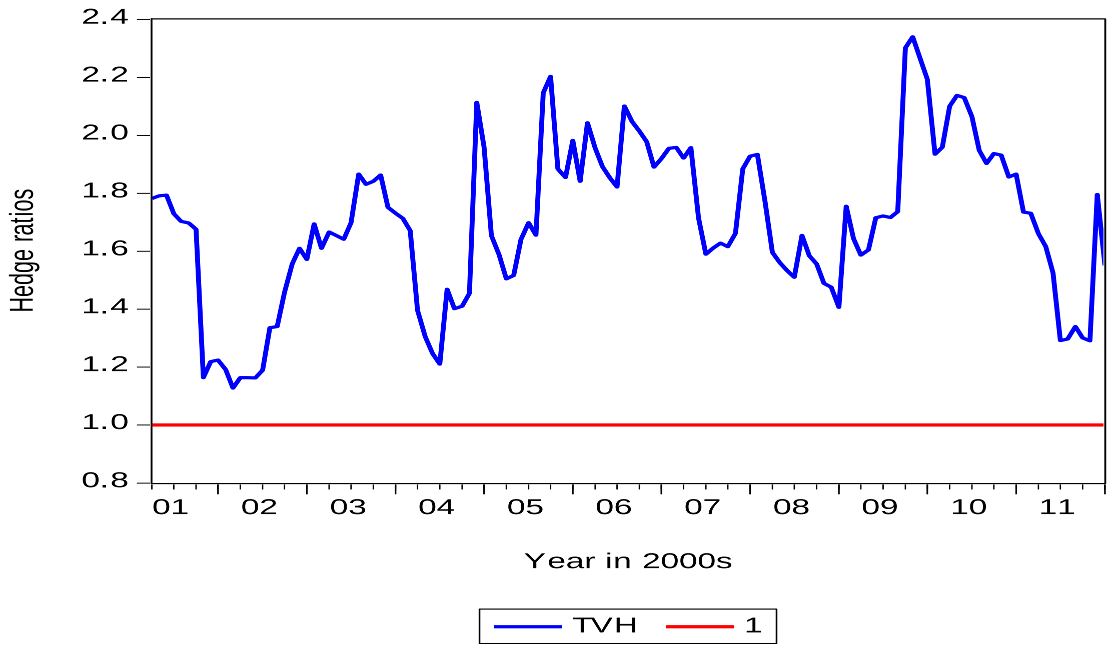

Figure 4.5 Time varying hedge ratios (TVH denotes for the time varying hedge ratios for the period of April 2001 to January 2012)

4.212 Performance evaluation of hedging ratios

In this subsection the effectiveness of different hedge ratios will be compared by investigating both the in-sample and out-of-sample performance of these ratios.

--- In-sample performance comparison

So far, there are five options that can be chosen by the dairy producer. Firstly, the dairy producer can choose not to hedge at all, which means he will directly sell his products to the spot market when the time t comes. Secondly, he can choose the hedge ratio 1.361954 based on the OLS result presented in Table 4.2. Thirdly, he can choose the hedge ratio 1.734649 to construct his hedging portfolio based on the result of the more advanced model with lagged terms, MA (1) and some seasonality terms, which is presented in Table 4.7. Fourthly, he can choose to hedge with a time-varying hedge ratio. Last but not least, he can choose to hedge with a naive hedge ratio which is equal to one.

In order to choose the best strategy out of these five choices with the objective of minimising the variance of the return; the mean of return, variance of return and hedging effectiveness under these five portfolios will be computed and compared for three time horizons: February 2011 to January 2012 (12 months), February 2010 to January 2012 (24 months) and February 2009 to January 2012 (36 months). The results are presented in Table 4.10 to Table 4.12. According to the outcomes, the time-varying hedge ratio is the best one since it has the highest hedging effectiveness for all three horizons.

Table 4.10 Comparison of variance of return of five portfolios (Feb 2011-Jan 2012)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	0.002205	0.014151	0
Hedge (hedge ratio 1.361954)	-0.016914	0.062091	-3.387746
Hedge (hedge ratio 1.734649)	-0.023180	0.086732	-5.129037
Hedge (time varying hedge ratio)	-0.041724	0.006441	0.544838
Hedge (naive hedge ratio 1)	-0.027461	0.008697	0.385414

Table 4.11 Comparison of variance of return of five portfolios (Feb 2010-Jan 2012)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	0.002799	0.010357	0
Hedge (hedge ratio 1.361954)	0.029022	0.065391	-5.313701
Hedge (hedge ratio 1.734649)	0.035697	0.094671	-8.140774
Hedge (time varying hedge ratio)	-0.027486	0.004930	0.5239934
Hedge (naive hedge ratio 1)	-0.016340	0.006586	0.364102

Table 4.12 Comparison of variance of return of five portfolios (Feb 2009-Jan 2012)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	**0.010034**	**0.008936**	**0**
Hedge (hedge ratio 1.361954)	**0.052271**	**0.057066**	**-5.386079**
Hedge (hedge ratio 1.734649)	**0.063443**	**0.082164**	**-8.194718**
Hedge (time varying hedge ratio)	**-0.004842**	**0.005523**	**0.381938**
Hedge (naive hedge ratio 1)	**0.000687**	**0.006312**	**0.293644**

--- Out-of-sample performance comparison

As indicated in Baillie and Myers (1991) as cited by Choudhry (2009), measuring the hedging performance of different methods for out-of-sample periods can provide more reliable results. Two out-of-sample measurements of hedging effectiveness were performed in this research, which are February 2011 to January 2012 (12 months) and February 2010 to January 2012 (24 months). Firstly, different models were estimated for the period of January 2001 to January 2011 and then the estimated parameters were applied to compute the hedge ratios for the period of February 2011 to January 2012. Secondly, the period from January 2001 to January 2010 was used to estimate model parameters and the period from February 2010 to January 2012 was used to calculate the hedge ratios and hedging performance.

Figure 4.6 and Figure 4.7 show the time-varying hedge ratios for the period of February 2011 to January 2012 and February 2010 to January 2012, respectively. Table 4.13 and Table 4.14 present the mean of return, variance of return and hedging effectiveness of the different hedge portfolios for the two out-of-sample evaluations separately. For both out-of-sample periods, the time-varying hedge ratio out-performs the other hedge ratios since it has the lowest variance of return and the highest hedging effectiveness.

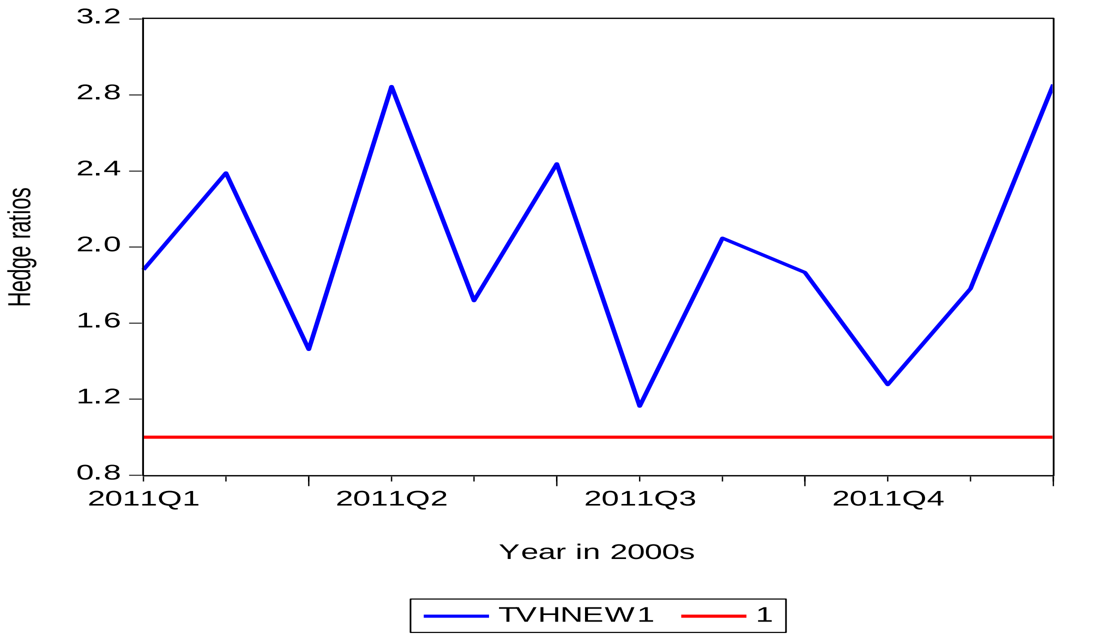

Figure 4.6 Time varying hedge ratios (TVHNEW1 denotes for the time varying hedge ratios for the period of February 2011 to January 2012)

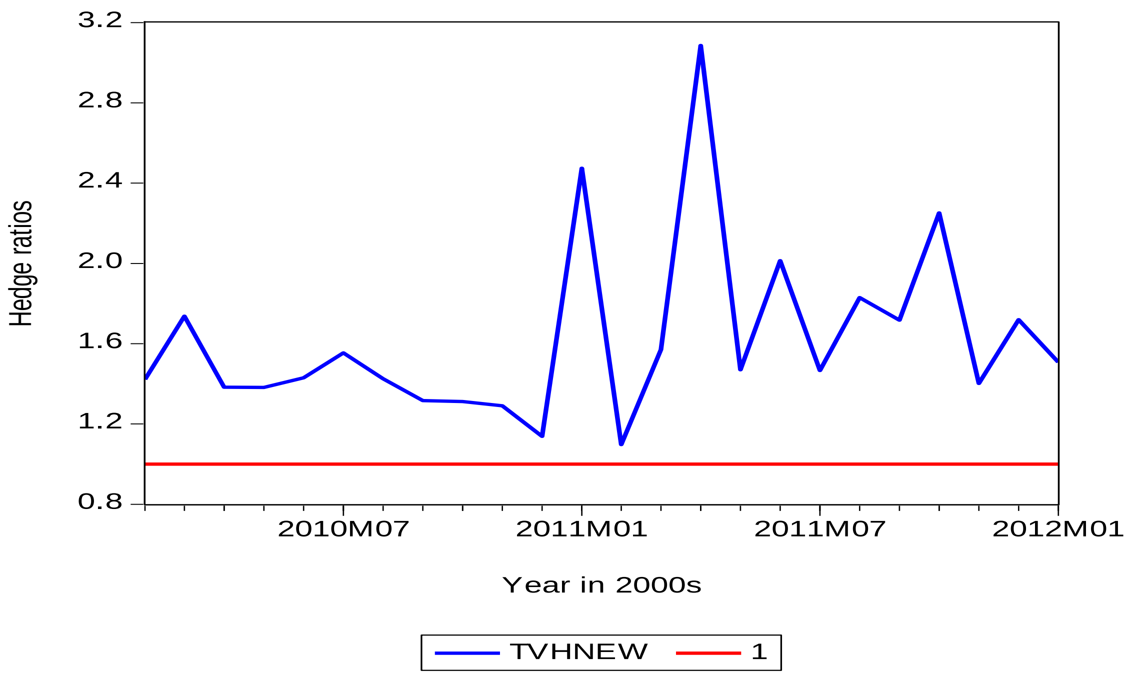

Figure 4.7 Time varying hedge ratios (TVHNEW denotes for the time varying hedge ratios for the period of February 2010 to January 2012)

Table 4.13 Comparison of variance of return of five portfolios (Feb 2011-Jan 2012)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	0.002205	0.014151	0
Hedge (hedge ratio 1.318107)	-0.016177	0.059526	-3.206487
Hedge (hedge ratio 1.674039)	-0.022161	0.082379	-4.821426
Hedge (time varying hedge ratio)	-0.049891	0.006642	0.530634
Hedge (naive hedge ratio 1)	-0.027461	0.008697	0.385414

Table 4.14 Comparison of variance of return of five portfolios (Feb 2010-Jan 2012)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	0.002799	0.010357	0
Hedge (hedge ratio 1.271233)	0.027398	0.059194	-4.715362
Hedge (hedge ratio 1.619783)	0.033640	0.084991	-7.206141
Hedge (time varying hedge ratio)	-0.024643	0.005545	0.464613
Hedge (naive hedge ratio 1)	-0.016340	0.006586	0.364102

4.22 Fluid milk of Wisconsin spot price series vs. CME Milk Class III futures price series

In the second part of our empirical analysis, the data sets considered consist of one time series for the monthly spot prices of fluid grade milk of Wisconsin and two time series of the estimated monthly futures prices for the nearby and next to nearby futures contracts which are composed by taking the average daily price of the CME Milk Class III contract for the period of the delivery month of the maturity contract and for the period of the month before the delivery month, respectively. The whole sample period is from January 2001 to December 2010. Two out-of-sample periods are used which are January 2010 to December 2010 (12 months) and January 2009 to December 2010 (24 months).

4.221 Model selection for computing hedge ratios

In order to get the MV hedge ratio, the conventional OLS technique will firstly be applied by taking the regression of the return of the spot position on the return of the futures position. In this case, the equation can be written as

$$\Delta\,\mathrm{LOG}(SMW_t) = \mathrm{a} + \mathrm{b}[\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)] + \varepsilon_t \qquad (17)$$

where $\Delta\,\mathrm{LOG}(SMW_t) = \mathrm{LOG}(SMW_t) - \mathrm{LOG}(SMW_{t-1})$ denotes the return of the spot position by taking the first difference of the natural logarithm of the spot price of fluid grade milk of Wisconsin. The term $\mathrm{LOG}(F_t)$ is the futures prices for the nearby futures contracts of CME Milk Class III in natural logarithms, and $\mathrm{LOG}(F2_t)$ is the futures prices for next to nearby futures contracts of CME Milk Class III in natural logarithms. Consequently, $\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)$ represents the return in the futures position.

Based on the results displayed in Table 4.15, the coefficient of $\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)$ is significant (prob. < 0.05), thus the optimal hedge ratio in this case is 1.022570, which means the ratio for proportion of futures position taken relative to the proportion of the spot position taken is 1.002570.

Table 4.15 Regression statistics results for $\Delta\,\mathbf{LOG}(\boldsymbol{SMW_t}) = \mathbf{a} + \mathbf{b}[\mathbf{LOG}(\boldsymbol{F_t}) - \mathbf{LOG}(\boldsymbol{F2_t})] + \boldsymbol{\varepsilon_t}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.001187	0.004592	-0.258411	0.7965
LOG(F)-LOG(F2)	1.022570	0.118352	8.640068	0.0000

R-squared	0.389515	Mean dependent var	0.002266
Adjusted R-squared	0.384297	S.D. dependent var	0.063599
S.E. of regression	0.049904	Akaike info criterion	-3.140758
Sum squared resid	0.291381	Schwarz criterion	-3.094050
Log likelihood	188.8751	Hannan-Quinn criter.	-3.121791
F-statistic	74.65078	Durbin-Watson stat	1.042644
Prob(F-statistic)	0.000000		

The OLS technique applied above did not take the possibility of co-integration of those three series into account. If those series are co-integrated, then the OLS regression will be inappropriate; in that case, an error correction term needs to be added to the above regression equation.

The spot price series for fluid grade milk of Wisconsin (SMW) and the futures price series for CME Milk Class III are shown in Figure 4.8. There seems to be a close relationship among the spot price series of the fluid grade milk of Wisconsin and the two futures price series for the nearby and next to nearby futures contracts of CME Milk Class III since they share a similar trend. However, these three series are non-stationary and the order of Integration for these three series data are denoted as $I(1)$ since in Figure 4.9, Figure 4.10 and Figure 4.11, all three price series become stationary around 0 after taking the first difference of their logarithm. Therefore, it is necessary to conduct a co-integration test in order to find out whether these series are co-integrated, that is, sharing a common stochastic trend and hence, a long-term equilibrium relationship.

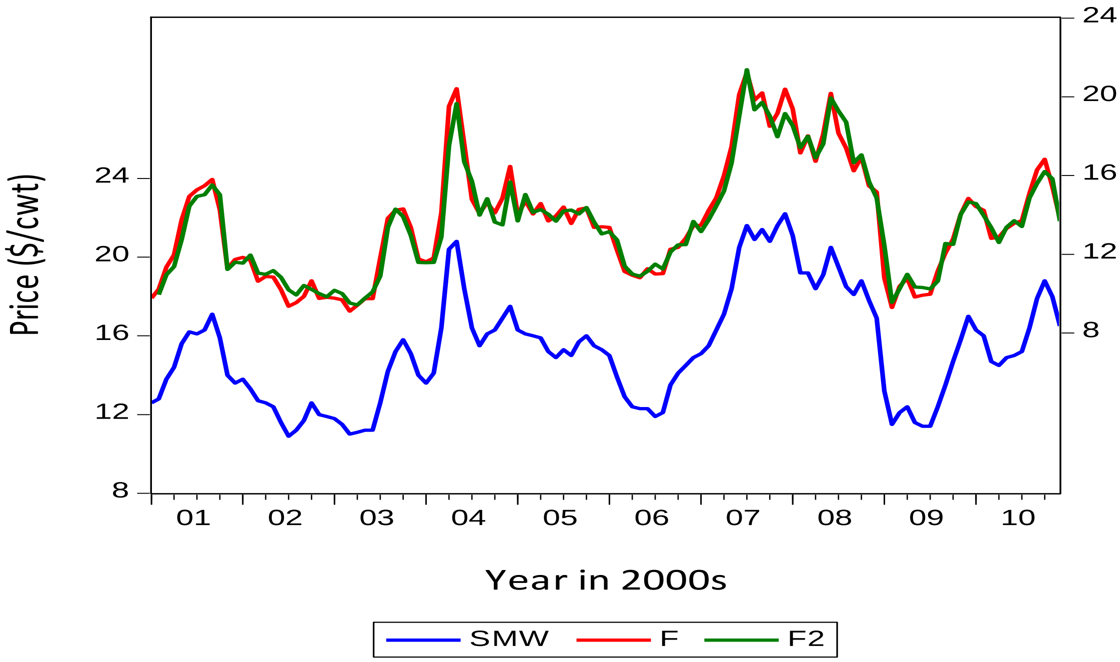

Figure 4.8 Spot prices of fluid grade milk of Wisconsion (the blue line), futures prices of the nearby futures contracts of CME Milk Class III (the red line) and futures prices of the next to nearby futures contracts of CME Milk Class III (the green line)

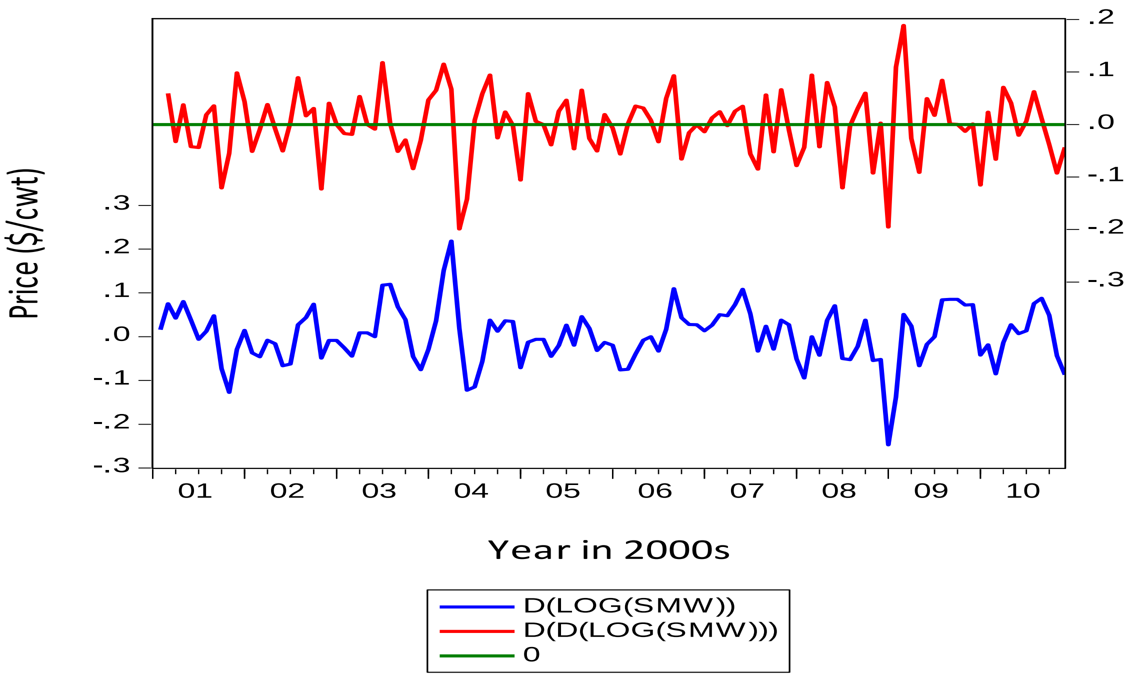

Figure 4.9 First difference (the blue line) and second difference (the red line) of spot prices for fluid grade milk of Wisconsion in logarithm

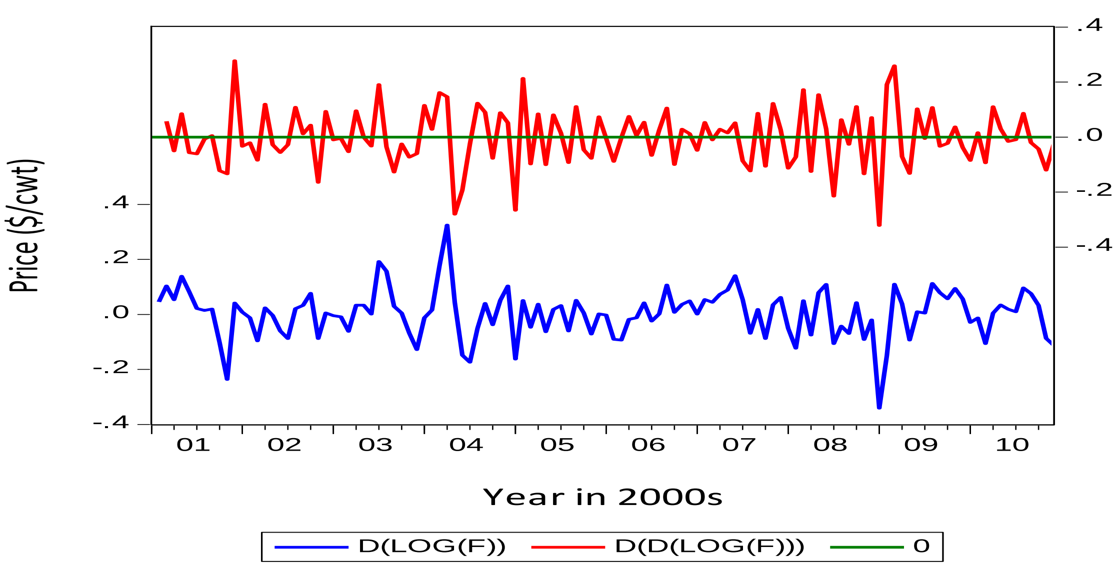

Figure 4.10 First difference (the blue line) and second difference (the red line) of futures prices for nearby futures contract of CME Milk Class III in logarithm

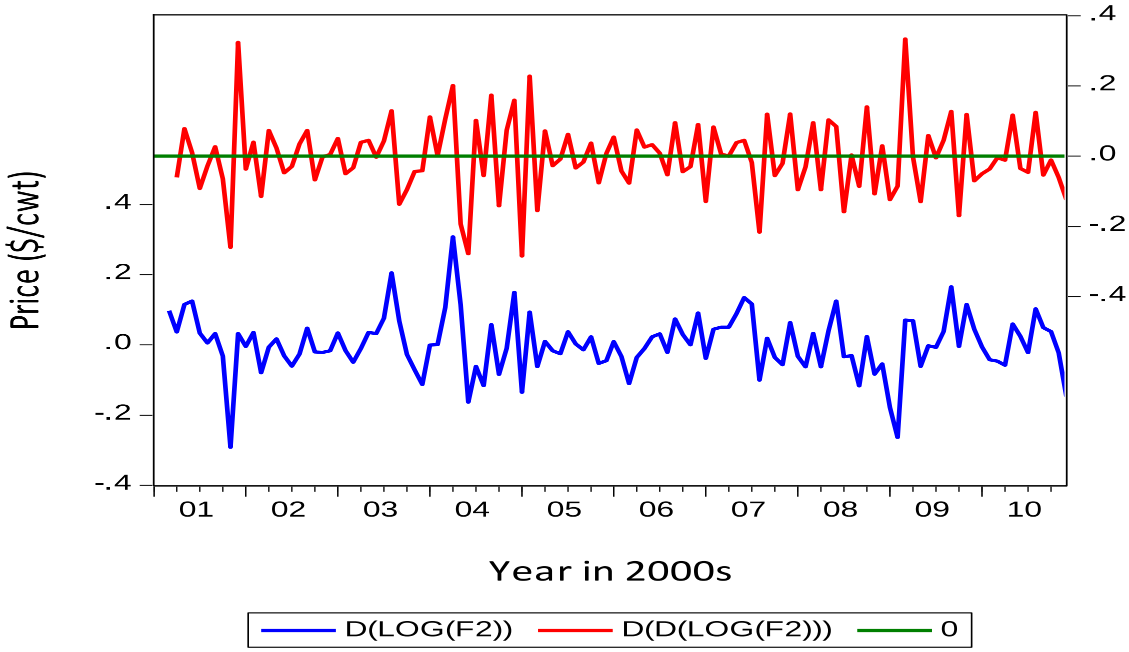

Figure 4.11 First difference (the blue line) and second difference (the red line) of futures prices for next to nearby futures contract of CME Milk Class III in logarithm

As the spot price series and the two futures price series are found to be integrated of order one, i.e. *I*(1), the first step to test for co-integration will be to run a regression as follows:

$$\mathrm{LOG}(SMW_t)=\alpha+\beta\mathrm{LOG}(F_t)+Z_t \tag{18}$$

where Z_t are the co-integration residuals. The regression results are shown in Table 4.16, where the Durbin-Watson statistic is around 0.64 which is higher than 0.6 and therefore, the null hypothesis of no co-integration is rejected and the time series of $\mathrm{LOG}(SMW_t)$ and $\mathrm{LOG}(F_t)$ are concluded to be co-integrated.

Table 4.16 Regression statistics results for $\mathbf{LOG}(\boldsymbol{SMW_t}) = \boldsymbol{\alpha} + \boldsymbol{\beta}\mathbf{LOG}(\boldsymbol{F_t}) + \boldsymbol{Z_t}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.541141	0.034741	15.57636	0.0000
LOG(F)	0.836884	0.013344	62.71840	0.0000

R-squared	0.970876	Mean dependent var	2.712573
Adjusted R-squared	0.970629	S.D. dependent var	0.183835
S.E. of regression	0.031506	Akaike info criterion	-4.060779
Sum squared resid	0.117127	Schwarz criterion	-4.014320
Log likelihood	245.6467	Hannan-Quinn criter.	-4.041912
F-statistic	3933.598	Durbin-Watson stat	0.642133
Prob(F-statistic)	0.000000		

Next, the co-integration relationship between $\mathrm{LOG}(SMW_t)$ and $\mathrm{LOG}(F2_t)$ will be examined by the following regression equation:

$$\mathrm{LOG}(SMW_{t-1}) = \alpha^* + \beta^*\mathrm{LOG}(F2_t) + Z_t^* \qquad (19)$$

where Z_t^* are the co-integration residuals. The regression results are shown in Table 4.17 where the Durbin-Watson statistic appears to be around 0.91 which is higher than 0.6 and hence, falls in the acceptable range for co-integration. Therefore, the time series of $\mathrm{LOG}(SMW_{t-1})$ and $\mathrm{LOG}(F2_t)$ are co-integrated as well. Notice that result complies with the outcome that $\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)$ is stationary as we checked for in Subsection 4.2.1.1.

Table 4.17 Regression statistics results for $\mathbf{LOG}(\boldsymbol{SMW_{t-1}}) = \boldsymbol{\alpha^*} + \boldsymbol{\beta^*}\mathbf{LOG}(\boldsymbol{F2_t}) + \boldsymbol{Z_t^*}$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.512035	0.080740	6.341815	0.0000
LOG(F2)	0.848045	0.031033	27.32729	0.0000

R-squared	0.864549	Mean dependent var	2.711810
Adjusted R-squared	0.863391	S.D. dependent var	0.184421
S.E. of regression	0.068163	Akaike info criterion	-2.517162
Sum squared resid	0.543607	Schwarz criterion	-2.470454
Log likelihood	151.7712	Hannan-Quinn criter.	-2.498196
F-statistic	746.7808	Durbin-Watson stat	0.908721
Prob(F-statistic)	0.000000		

From the above regression (i.e., equation (19) and its results in Table 4.17) the residuals will be collected and denoted as *EC*. The next step, to check for error-correction, is to regress the first differences of the spot price of fluid grade milk of Wisconsin on the difference between the nearby futures price and the next to nearby futures price for CME Milk Class III in logarithm and *EC*. This regression equation can be expressed as follows:

$$\Delta\text{LOG}(SMW_t) = \text{a}_1 + b_1[\text{LOG}(F_t) - \text{LOG}(F2_t)] + b_2 EC + u_t \qquad (20)$$

Table 4.18 Regression statistics results for equation with error correction

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000738	0.001932	-0.381892	0.7032
LOG(F)-LOG(F2)	0.889593	0.050104	17.75480	0.0000
EC	-0.669165	0.028655	-23.35277	0.0000

R-squared	0.892922	Mean dependent var	0.002266
Adjusted R-squared	0.891076	S.D. dependent var	0.063599
S.E. of regression	0.020990	Akaike info criterion	-4.864647
Sum squared resid	0.051108	Schwarz criterion	-4.794585
Log likelihood	292.4465	Hannan-Quinn criter.	-4.836197
F-statistic	483.6606	Durbin-Watson stat	0.844649
Prob(F-statistic)	0.000000		

The regression results are shown in Table 4.18. To begin with, the Durbin-Watson statistic is around 0.845 which is in the acceptable range for stationary but it is still not around 2. After the regression, the correlogram Q-statistics test was performed for testing for the absence of autocorrelation and partial autocorrelation in the residuals as shown in Table 4.19. Since the partial autocorrelation breaks off after the first order while the autocorrelations seem to die out gradually, there exists an AR(1) model in the residuals. Therefore, the regression was corrected for first-order autocorrelation in the residuals by including the AR(1) term as in equation (21):

$$\Delta\text{LOG}(SMW_t) = a_1^* + b_1^*[\text{LOG}(F_t) - \text{LOG}(F2_t)] + b_2^* EC + b_3^* AR(1) + u_t^* \qquad (21)$$

The regression results of equation (21) are shown in Table 4.20. The Durbin-Watson statistic is now around 1.72 which is still not around 2. Nevertheless, Figure 4.12 shows a good fitness of the model although the positive and negative peaks in the residuals slightly reveal a seasonal pattern that is left to be modelled. Therefore, the following regression is performed:

$$\begin{aligned}\Delta\text{LOG}(SMW_t) = A &+ B_1[\text{LOG}(F_t) - \text{LOG}(F2_t)] + B_2 EC + B_3 seas(1) + B_4 seas(2) \\ &+ B_5 seas(3) + B_6 seas(4) + B_7 seas(5) + B_8 seas(6) + B_9 seas(7) \\ &+ B_{10} seas(8) + B_{11} seas(9) + B_{12} seas(10) + B_{13} seas(11) + B_{14} AR(1) \\ &+ U_t \qquad (22)\end{aligned}$$

Table 4.19 Correlogram Q-statistics test results

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.560	0.560	38.287	0.000
		2	0.171	-0.209	41.869	0.000
		3	-0.161	-0.243	45.075	0.000
		4	-0.238	0.009	52.195	0.000
		5	-0.163	0.028	55.540	0.000
		6	-0.020	0.031	55.591	0.000
		7	-0.064	-0.218	56.117	0.000
		8	-0.094	-0.024	57.262	0.000
		9	-0.067	0.083	57.852	0.000
		10	0.111	0.195	59.490	0.000
		11	0.281	0.122	70.025	0.000
		12	0.357	0.076	87.138	0.000
		13	0.281	0.094	97.894	0.000
		14	0.020	-0.138	97.952	0.000
		15	-0.180	-0.041	102.42	0.000
		16	-0.168	0.115	106.37	0.000
		17	-0.071	0.031	107.09	0.000
		18	0.043	0.022	107.35	0.000
		19	0.088	0.022	108.45	0.000
		20	-0.005	-0.061	108.46	0.000
		21	-0.037	0.031	108.66	0.000
		22	0.101	0.176	110.16	0.000
		23	0.233	0.040	118.32	0.000
		24	0.327	0.105	134.53	0.000
		25	0.229	0.005	142.60	0.000
		26	0.024	-0.018	142.69	0.000
		27	-0.238	-0.158	151.52	0.000
		28	-0.293	-0.035	165.08	0.000
		29	-0.229	-0.076	173.44	0.000
		30	-0.087	-0.044	174.68	0.000
		31	-0.089	-0.188	175.98	0.000
		32	-0.053	-0.021	176.45	0.000
		33	-0.049	0.009	176.85	0.000
		34	0.130	0.141	179.69	0.000
		35	0.272	-0.019	192.34	0.000
		36	0.320	-0.006	210.13	0.000

Table 4.20 Regression statistics results for equation with error correction and AR(1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.001132	0.004025	-0.281220	0.7791
LOG(F)-LOG(F2)	0.785847	0.041747	18.82413	0.0000
EC	-0.717891	0.027087	-26.50293	0.0000
AR(1)	0.622270	0.075285	8.265573	0.0000

R-squared	0.934902	Mean dependent var	0.002152
Adjusted R-squared	0.933189	S.D. dependent var	0.063858
S.E. of regression	0.016506	Akaike info criterion	-5.336876
Sum squared resid	0.031059	Schwarz criterion	-5.242955
Log likelihood	318.8757	Hannan-Quinn criter.	-5.298741
F-statistic	545.7327	Durbin-Watson stat	1.715991
Prob(F-statistic)	0.000000		
Inverted AR Roots	.62		

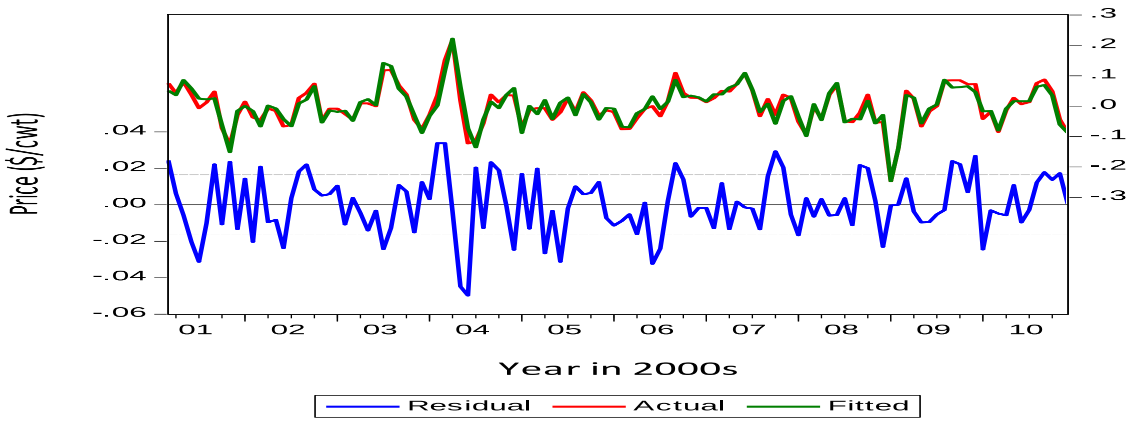

Figure 4.12 Residual (blue line) of u_t^* around 0

Table 4.21 Regression statistics results for equation with error correction, AR(1) and seasonality

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.008798	0.005378	1.635954	0.1049
LOG(F)-LOG(F2)	0.770370	0.035563	21.66221	0.0000
EC	-0.746437	0.025868	-28.85524	0.0000
@SEAS(1)	-0.003996	0.005104	-0.782998	0.4354
@SEAS(2)	-0.009922	0.006302	-1.574453	0.1184
@SEAS(3)	0.001120	0.006775	0.165389	0.8690
@SEAS(4)	-0.010446	0.007055	-1.480755	0.1417
@SEAS(5)	-0.018439	0.007263	-2.538951	0.0126
@SEAS(6)	-0.034351	0.007369	-4.661732	0.0000
@SEAS(7)	-0.032373	0.007496	-4.318733	0.0000
@SEAS(8)	-0.026539	0.007376	-3.598027	0.0005
@SEAS(9)	-0.002601	0.007242	-0.359157	0.7202
@SEAS(10)	0.008755	0.006161	1.421049	0.1583
@SEAS(11)	0.010307	0.004813	2.141436	0.0346
AR(1)	0.573243	0.079596	7.201923	0.0000

R-squared	0.961043	Mean dependent var	0.002152
Adjusted R-squared	0.955748	S.D. dependent var	0.063858
S.E. of regression	0.013433	Akaike info criterion	-5.663869
Sum squared resid	0.018587	Schwarz criterion	-5.311663
Log likelihood	349.1683	Hannan-Quinn criter.	-5.520863
F-statistic	181.4946	Durbin-Watson stat	2.063972
Prob(F-statistic)	0.000000		

Inverted AR Roots	.57

The results of the regression are shown in the Table 4.21. The Durbin-Watson statistic is now around 2.06, which means that the residuals do not exhibit first-order autocorrelation anymore. The coefficient of $\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t)$ is the optimal hedge ratio for the above model. As shown in Table 4.21, under this portfolio, the dairy producer should hedge 77.037% of the value of the spot position in order to minimise the variance of the portfolio return.

So far, hedge ratios have been considered to be static since the variance of the futures return and the covariance between spot and futures return are assumed to be time invariant, however, if the variances change over time, then the hedge ratio should be time varying, which can be approached by using an MGARCH model (Dawson, et al., 2000). As mentioned before, in general a GARCH(1, 1) model will be sufficient to capture the volatility existing in the data. In addition, as a rule of thumb, models that contain as less parameters as possible can provide the most accurate prediction. Therefore, the following MGARCH (1, 1) is applied to compute the time-varying hedge ratio:

Mean equation:

$$\Delta\,\mathrm{LOG}(SMW_t) = C(1) + C(2) * [\mathrm{LOG}(SMW_{t-1}) - C(3) * \mathrm{LOG}(F2_t)]$$

$$\mathrm{LOG}(F_t) - \mathrm{LOG}(F2_t) = C(4) + C(5) * [\mathrm{LOG}(SMW_{t-1}) - C(3) * \mathrm{LOG}(F2_t)] \tag{23}$$

Variance equation:

$$\begin{bmatrix} \sigma_{st}^2 \\ \sigma_{sft} \\ \sigma_{ft}^2 \end{bmatrix} = \begin{bmatrix} M(1) \\ 0 \\ M(2) \end{bmatrix} + \begin{bmatrix} A1(1) & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & A1(2) \end{bmatrix} \begin{bmatrix} \varepsilon_{s,t-1}^2 \\ \varepsilon_{s,t-1}\varepsilon_{f,t-1} \\ \varepsilon_{f,t-1}^2 \end{bmatrix} + \begin{bmatrix} B1(1) & 0 & 0 \\ 0 & R(1,2) & 0 \\ 0 & 0 & B1(2) \end{bmatrix} \begin{bmatrix} \sigma_{s,t-1}^2 \\ \sigma_{st}\sigma_{ft} \\ \sigma_{f,t-1}^2 \end{bmatrix} \tag{24}$$

Based on the estimation results in Table 4.22, the time-varying hedge ratio can be computed. As defined in Section 3.5, equation (2), ρ will be $R(1,2)$ which is 0.879591. Based on equation (24), σ_{st}^2 can be computed as $\sigma_{st}^2 = 0.000465 + 0.120666 * \varepsilon_{s,t-1}^2 + 0.572039 * \sigma_{s,t-1}^2$, while σ_{ft}^2 can be computed as $\sigma_{ft}^2 = 0.000107 + 0.214234 * \varepsilon_{f,t-1}^2 + 0.744116 * \sigma_{f,t-1}^2$. Finally, the time-varying hedge ratio can be calculated and is presented in Figure 4.13.

Table 4.22 Results of MGARCH(1, 1) with the sample period of Jan 2001 to Dec 2010

Tranformed Variance Coefficients				
	Coefficient	Std. Error	z-Statistic	Prob.
M(1)	0.000465	0.000298	1.560152	0.1187
A1(1)	0.120666	0.088793	1.358957	0.1742
B1(1)	0.572039	0.241208	2.371557	0.0177
M(2)	0.000107	0.000158	0.678664	0.4974
A1(2)	0.214234	0.099747	2.147781	0.0317
B1(2)	0.744116	0.120468	6.176889	0.0000
R(1,2)	0.879591	0.020127	43.70160	0.0000

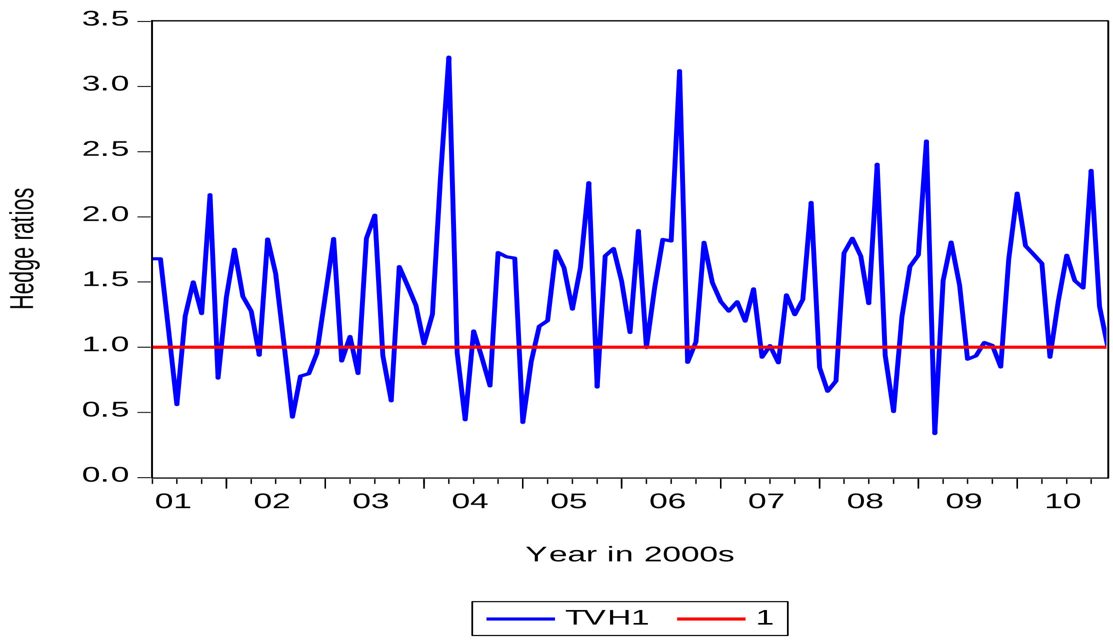

Figure 4.13 Time varying hedge ratios (TVH1 denotes for the time varying hedge ratios for the period of April 2001 to December 2010)

4.222 Performance evaluation of hedging ratios

--- In-sample performance comparison

So far, there are five alternatives of which the dairy producer can choose one. Firstly, the dairy producer can choose not to hedge at all. Secondly, he can choose the hedge ratio 1.02257 based on the OLS result presented in Table 4.15. Thirdly, he can choose the hedge ratio 0.77037 to construct hedging portfolio based on the result of more advance model with error correction term, AR(1) and seasonal dummies which is presented in Table 4.21. Fourthly, he can choose to hedge with a time-varying hedge ratio. Last but not least, he can choose to hedge with a naive hedge ratio which is 1.

In order to choose the best strategy out of these five choices with the objective of minimising the variance of the return; the mean of return, variance of return and hedging effectiveness under these five portfolios will be computed and compared for different time periods as presented in Table 4.23 to Table 4.25. For the two year period (Jan 2009-Dec 2010) and the three year period (Jan 2008-Dec 2009), the naive hedge ratio performs best in minimising the variance of the return. However, for the one year period (Jan 2010-Dec 2010), the time-varying hedge ratio is the best one since it has the highest hedging effectiveness.

Table 4.23 Comparison of variance of return of five portfolios (Jan 2010-Dec2010)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	**-0.002488**	**0.002973**	**0**
Hedge (hedge ratio 1.02257)	**0.006382**	**0.020560**	**-5.915573**
Hedge (hedge ratio 0.77037)	**0.004194**	**0.010739**	**-2.612176**
Hedge (time varying hedge ratio)	**-0.009344**	**0.001677**	**0.4359233**
Hedge (naive hedge ratio 1)	**-0.008650**	**0.001746**	**0.4127144**

Table 4.24 Comparison of variance of return of five portfolios (Jan 2009-Dec2010)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	**-0.000998**	**0.006493**	**0**
Hedge (hedge ratio 1.02257)	**0.033957**	**0.020560**	**-2.166487**
Hedge (hedge ratio 0.77037)	**0.025336**	**0.014587**	**-1.246573**
Hedge (time varying hedge ratio)	**0.003710**	**0.003579**	**0.448791**
Hedge (naive hedge ratio 1)	**0.006492**	**0.003278**	**0.495149**

Table 4.25 Comparison of variance of return of five portfolios (Jan 2008-Dec2010)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	**-0.008243**	**0.005166**	**0**
Hedge (hedge ratio 1.02257)	**-0.018966**	**0.030487**	**-4.901471**
Hedge (hedge ratio 0.77037)	**-0.016321**	**0.019956**	**-2.862950**
Hedge (time varying hedge ratio)	**-0.002798**	**0.003169**	**0.386566**
Hedge (naive hedge ratio 1)	**-0.000468**	**0.003026**	**0.414247**

-- *Out-of-sample performance comparison*

In this part, two out-of-sample analyses were performed. Firstly, the different models were estimated for the period January 2001 to December 2009 and then the estimated parameters were applied to compute the hedge ratios for January 2010 to December 2010. Secondly, January 2001 to December 2008 was used to estimate model parameters and the period from January 2009 to December 2010 was used to calculate the hedge ratios.

Figure 4.14 and Figure 4.15 show the time-varying hedge ratios for the period January 2010 to December 2010 and January 2009 to December 2010, respectively. Table 4.26 and Table 4.27 present the mean of return, variance of return and hedging effectiveness of the different hedge portfolios for the two out-of-sample evaluations. For both out-of-sample periods, the time-varying hedge ratio outperforms the other hedge ratios since it has lowest variance of return and highest hedging effectiveness.

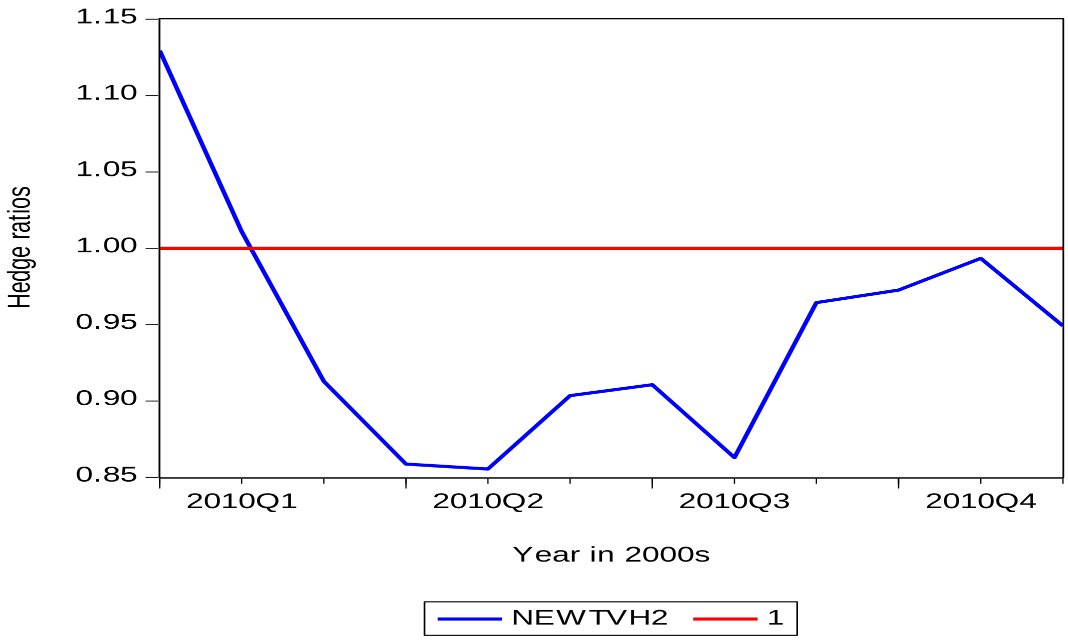

Figure 4.14 Time varying hedge ratios (NEWTVH denotes for the time varying hedge ratios for the period of January 2010 to December 2010)

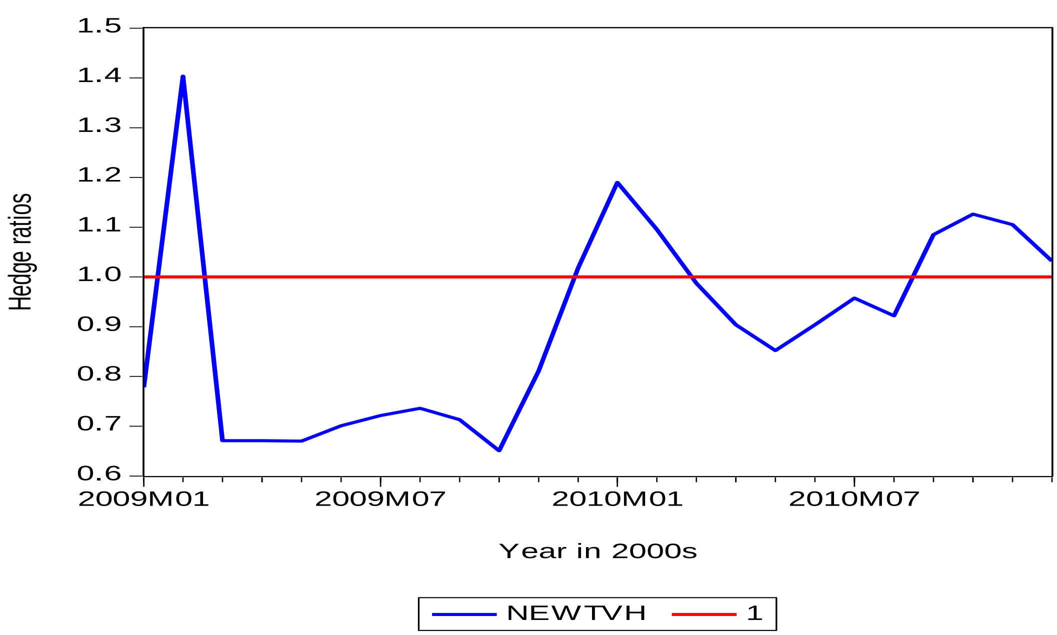

Figure 4.15 Time varying hedge ratios (NEWTVH denotes for the time varying hedge ratios for the period of January 2009 to December 2010)

Table 4.26 Comparison of variance of return of five portfolios (Jan 2010-Dec2010)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	-0.002448	0.002973	0
Hedge (hedge ratio1.002638)	0.006209	0.016692	-4.614531
Hedge (hedge ratio 0.767126)	0.004166	0.010668	-2.588295
Hedge (time varying hedge ratio)	-0.008152	0.001780	0.401278
Hedge (naive hedge ratio 1)	0.006186	0.016615	-4.588631

Table 4.27 Comparison of variance of return of five portfolios (Jan 2009-Dec2010)

Portfolios	Mean of return	Variance of return	Hedging effectiveness
Do Not Hedge	-0.000998	0.006493	0
Hedge (hedge ratio 0.900407)	0.029781	0.017462	-1.689358
Hedge (hedge ratio 0.757374)	0.024892	0.014323	-1.205914
Hedge (time varying hedge ratio)	0.003357	0.003656	0.436932
Hedge (naive hedge ratio 1)	0.033186	0.019959	-2.073926

Chapter 5: Conclusion

In a more liberalised market situation, the EU dairy sector started to face an unprecedented and sustained period of strong price volatility. Therefore, risk management on price volatility has become an important issue in the EU dairy sector since the increasing price volatility can expose its stakeholders to uncertain revenues and expenditures, which makes forecasting and anticipation very difficult. This research investigated how futures can be used as an effective hedging instrument to manage the price risks. Lessons were learned from the CME dairy futures market since it is a worldwide leading dairy futures exchange with the longest history.

5.1 Summary of data analysis results

Results of the data analysis show that futures can be used as an effective hedging instrument since it can reduce the variance of returns compared to the un-hedged portfolio. Among all the portfolios, the time-varying hedge ratio which is estimated by a multivariate GARCH model, outperforms the constant ratios in most of the cases. As shown in Table 5.1, the time-varying hedge ratio is the best for both in-sample and out-of-sample analyses on the data set of the CME block cheddar cheese spot price series and the CME Milk Class III futures price series.

Table 5.1 Best performing hedge ratio selection for the data set of CME block cheddar cheese spot price series vs. CME Milk Class III futures price series

Best perform hedge ratio selection	
In-sample hedging effectiveness comparison (12 months)	**Time varying hedge ratio**
In-sample hedging effectiveness comparison (24 months)	**Time varying hedge ratio**
In-sample hedging effectiveness comparison (36 months)	**Time varying hedge ratio**
Out-of-sample hedging effectiveness comparison (12 months) (Feb 2011-Jan 2012)	**Time varying hedge ratio**
Out-of-sample hedging effectiveness comparison (24 months) (Feb 2010-Jan 2012)	**Time varying hedge ratio**

For the data set of the fluid milk of Wisconsin spot price series vs. the CME Milk Class III futures price series, the results in Table 5.2 show that the time-varying hedge ratio only performs best for both out-of-sample periods and one in-sample period (Jan 2010-Dec 2010). For the other two in-sample periods (Jan 2009-Dec 2010 and Jan 2008-Dec 2010), however, the naive hedge ratio of 1 performs best.

Table 5.2 Best performing hedge ratio selection for the data set of fluid milk of Wisconsin spot price series vs. the CME Milk Class III futures price series

Best perform hedge ratio selection	
In-sample hedging effectiveness comparison (12 months) (Jan 2010-Dec 2010)	**Time varying hedge ratio**
In-sample hedging effectiveness comparison (24 months) (Jan 2009-Dec 2010)	**Naive hedge ratio 1**
In-sample hedging effectiveness comparison (36 months) (Jan 2008-Dec 2010)	**Naive hedge ratio 1**
Out-of-sample hedging effectiveness comparison (12 months)	**Time varying hedge ratio**
Out-of-sample hedging effectiveness comparison (24 months)	**Time varying hedge ratio**

5.2 Recommendations

The data analysis results proved that the U.S. Class III milk futures contract can be used as an effective hedging instrument in managing price volatility risks; therefore, establishing a dairy futures exchange in the EU can facilitate the industry stakeholders to better manage their risks, especially under the situation that the EU dairy industry is facing ongoing liberalisation of the market. However, there are several conditions that are necessary for a successful establishment of a futures market. Based on the work of Carlton (1984), Varangis and Larson (1996), Sarris (1997) (cited in Keane and O'Connor (2009)) and Buckley (2009), the following conditions were identified: (a) substantial price volatility, (b) A large number of potential interested participants, (c) limited government intervention, (d) existence of regulators, (e) reasonable basis risks, (f) reliable and auditable commodity price index, (g) reliable public information and (h) education and information in price risk management.

The EU is the leading supplier to the world cheese market and will remain to be the main cheese producer in the world up to and including 2019 (International Dairy Federation, 2010). However, reduction of import tariffs as part of a WTO agreement transmits world market price fluctuations on the EU internal cheese markets; on the other hand, the abolishment of the export subsidies makes exporting cheese to the world market to be very difficult and vulnerable to price fluctuations (Jongeneel et al., 2010). Therefore, it could be interesting for the EU dairy futures exchange to start with the cheese category first.

5.3 Limitations & Further study

There are some limitations with regard to this research, further studies are suggested based on these limitations.

Firstly, the optimal hedge ratio depends on the objective function to be optimised. In this research, the objective of hedging is minimising the variance of the return; therefore, the minimum variance (MV) hedge ratio was applied. However, further study can be done according to the preference of the decision makers, the objective can also be maximising the expected return or even incorporate both expected return and risks (the variance of the return).

Secondly, the GARCH(1, 1) model with the constant conditional correlation specification was applied in this research. However, the assumption that the conditional correlations are constant may be relaxed. In that case, a dynamic conditional correlation model can be used. In addition to the GARCH(1, 1) model that was considered in this research, there are other more complex and advanced models like Threshold GARCH and Asymmetric GARCH which could be interesting for further research.

Thirdly, due to the fact that futures contracts usually expire periodically, which means that each contract covers a limited time span with a range from weeks to months, the long series of price data were created artificially by simply taking the average prices of the nearby contracts. However, the artificial series might create or remove price jumps which may distort the parameter estimates of the true underlying distributions and as a result the validity of the test statistics may be questioned. Therefore, the price adjustment method can be considered in future studies to eliminate the price gaps resulting from contract rollover.

Fourthly, monthly data sets were used in this research, however, the data frequency can also be altered depending on the specific situation. In addition, although the hedge horizon considered here is one month, future research can consider longer or shorter horizons to evaluate the functioning of the futures market.

Last but not least, the CME class III contract was the only one being investigated in this study in order to measure hedging effectiveness of futures; however, other contracts at the CME as well as other dairy futures exchanges might be of interest for conducting further research.

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Appendices

Appendix 1a. Deviation of minimum variance hedge ratio

The derivation procedure of the static optimal hedge ratio b^* (minimum variance) are well explained by Ederington (1979) as follows:

Consider the expected return and variance of the return regarding the hedged portfolio:

$$E(H) = X_s R_{st} + X_f R_{ft} - K(X_f) \tag{a.1}$$

$$\mathrm{Var}(H) = X_s^2 \sigma_s^2 + X_f^2 \sigma_f^2 + 2X_s X_f \sigma_{sf} \tag{a.2}$$

where $E(H)$ and $\mathrm{Var}(H)$ represent the expected return and the variance of the return for the hedged portfolio, respectively; X_s and X_f represent the spot market holdings and the futures market holdings, respectively; $K(X_f)$ are the brokerage and other costs of participating in futures transactions including the cost of margin call; σ_s^2 and σ_f^2 are the variances of R_{st} and R_{ft}, respectively; and σ_{sf} is the covariance of the possible spot and futures price changes from time 1 to time 2.

Let $b = -\frac{X_f}{X_s}$ which means the proportion of the hedged spot position, since in a hedge, X_s and X_f have opposite signs, b is usually positive.

$$\mathrm{Var}(H) = X_s^2\left(\sigma_s^2 + b^2\sigma_f^2 - 2b\sigma_{sf}\right) \tag{a.3}$$

Holding X_s constant, the effect of a change in *b* on the variance of the return of the hedged portfolio becomes:

$$\frac{\partial \mathrm{Var}(H)}{\partial b} = X_s^2\left(2b\sigma_f^2 - 2\sigma_{sf}\right) \tag{a.4}$$

Since X_s^2 is positive, the risk can be minimized by b^*. Let $2b\sigma_f^2 + 2\sigma_{sf} = 0$ to get b^*, then

$$b^* = \frac{\sigma_{sf}}{\sigma_f^2} \tag{a.5}$$

Given that

$$\sigma_{sf} = \rho\sigma_s\sigma_f \tag{a.6}$$

the optimal hedge ratio can also be written as

$$b^* = \frac{\sigma_{sf}}{\sigma_f^2} = \frac{\rho\sigma_s\sigma_f}{\sigma_f^2} = \rho\frac{\sigma_s}{\sigma_f} \tag{a.7}$$

Appendix 1b. Deviation of hedging effectiveness

In Ederinton (1979), the derivation of hedging effectiveness in case of a minimum variance hedge ratio is illustrated as follows. Let

$$E(U) = X_s R_{st} \tag{b.1}$$

$$E(H) = X_s R_{st} + X_f R_{ft} - K(X_f) \tag{b.2}$$

where $E(U)$ and $E(H)$ are the expected return on the un-hedged and hedged portfolio, respectively, X_s and X_f represent the spot market holdings and the future market holdings, respectively, and $K(X_f)$ are the brokerage and other costs of participating in futures transactions including the cost of margin call.

Likewise, the variance of the un-hedged and hedged portfolio can be written as follows:

$$\mathrm{Var}(U) = X_s^2 \sigma_s^2 \tag{b.3}$$

$$\mathrm{Var}(H) = X_s^2 \sigma_s^2 + X_f^2 \sigma_f^2 + 2 X_s X_f \sigma_{sf} \tag{b.4}$$

Through comparing the variance reduction in the hedge portfolio with the reduction in the un-hedged portfolio, the hedging effectiveness can be defined as follows:

$$e = 1 - \frac{\mathrm{Var}(H^*)}{\mathrm{Var}(U)} \tag{b.5}$$

where H^*denotes the minimum variance on a hedged portfolio. As defined in Appendix 1a, the hedge ratio can be expressed as $= -\frac{X_f}{X_s}$. Bring *b* into equation (b.4) (see also (a.3)), we obtain

$$\mathrm{Var}(H) = X_s^2 \left(\sigma_s^2 + b^2 \sigma_f^2 - 2 b \sigma_{sf} \right) \tag{b.6}$$

Appendix 1a solved b^* (based on the minimum variance objective) as: $b^* = \frac{\sigma_{sf}}{\sigma_f^2}$. Substituting this expression for b^* into equation (b.6) gives

$$\mathrm{Var}(H^*) = X_s^2 \left(\sigma_s^2 - \frac{\sigma_{sf}^2}{\sigma_f^2} \right) \tag{b.7}$$

Bring equation (b.3) and equation (b.7) into equation (b.5), we obtain while using equation (a.6):

$$e = \frac{\sigma_{sf}^2}{\sigma_s^2 \sigma_f^2} = \rho^2 \tag{b.8}$$