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TITLE:
An empirical study of the spot-forward relationship and the hedging efficiency of the Atlantic salmon market.

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Abstract

This thesis investigates well-established theories of the spot-forward relationship in the derivatives market for Atlantic salmon using futures prices collected at a weekly and monthly frequency ranging from January 2008 to December 2015. It also examines the relationship between time to maturity on futures contracts and hedging efficiency.

The spot-forward relationship is first investigated by an unbiasedness test on forecast error following the same method as Movassagh and Modjathedi (2005) used on the gas market. The test found that forecasting error on price changes between spot and forward is close to zero, indicating an unbiased relationship. Secondly, the theory of storage is examined using both a direct and indirect test that originates from Fama and French (1987,1988). The direct test found evidence to support the theory, as inventory levels were highly significant in explaining the difference between spot and futures prices (basis). The indirect test also found evidence to support the theory of storage as the volatility in prices was higher when the inventory levels were low. Thirdly, the thesis extends on previous studies on the risk premium by adjusting a risk premium model that includes risk production factors first introduced by Asche, Misund, and Oglend (2015). The risk premium was found to be negative on average, which indicate a forward curve in normal backwardation. This is evidence to support the hedging pressure hypothesis. Finally, the hedging efficiency on futures contracts ranging from 1-12months to maturity is analyzed to see if time to maturity on futures contracts is correlated with greater hedging efficiency. The evidence support that hedging efficiency is significantly greater on near month maturity futures contracts compared to distant month futures contracts.

Preface

This thesis is written as part of the Master of Science in Business administration program at the University of Stavanger. The thesis marks the end of two interesting years of studies, thanks to the faculty at the UiS Business School.

I would like to especially thank my advisor Bård Misund for the guidance through this master thesis. His knowledge of statistical tests and experience as an author of research papers was very helpful for me through the whole process.

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1 INTRODUCTION

1.1 Background

Over the last decades, Atlantic salmon has grown to become one of the most attractive sources of seafood around the world. The growth in production has increased significantly, yet the demand for Atlantic salmon have increased even more. The production has been limited by government regulations since there are environmental issues associated with the production. The main issues are related to diseases such as salmon lice, and a desire to protect the wild salmon. The industry has responded through big innovations and improvements to increase production to confront the environmental problems and risks.

The spot price of salmon has shown to be very volatile (Oglend 2013), which leads to high risk for the agents involved in buying and selling salmon. In 2006, Fish Pool was established to offer a marketplace for derivatives trading with Atlantic salmon as underlying asset. This gave producers of salmon a tool to hedge against spot price changes to reduce their risk. It also offers a trading opportunity for speculators and arbitrageurs, which is important for a well working derivatives market. Derivatives markets have existed for a long time on other assets and commodities. Therefore several theories about the spot forward relationship have been introduced. Years of studies have shown that the derivatives market work differently on different assets and commodities so one theory can be proven to work in one market, but not proven in another market. Derivatives as hedging instrument against risk of spot price changes has also shown mixed results on different markets. The shrimp market showed to not be very efficient for hedging purposes (Matinez-Garmendia and Anderson, 1999). However, the oil market show significant reduction in price change risk by hedging (Horsnell, Brindle, and Greaves, 1995; Switzer and El-Khoury, 2007). The results often depend on the market maturity and trading volumes.

My interest for derivatives started when I took a course on the subject and was introduced to theories about the spot-forward relationship and learned about the hedging properties of derivatives. At the time I was most familiar with the salmon market as several of my family members work in the industry. Furthermore, the salmon industry was also receiving more attention from the media after the oil price dropped and the activity related to the oil industry decreased substantially. Simultaneously the salmon industry spiked and was going stronger than ever. At some point, several newspapers introduced salmon as the industry who was going to take over for the oil market. This led me to the decision of focusing my thesis on the Atlantic salmon derivatives market.

The timing for investigating salmon derivatives market is good. The market has been active for 8-10years, providing enough data to analyze the market over a long enough time period. Concurrently the data is also recent enough to make contributions, as the scientific community has not investigated the salmon market as thoroughly as more traditional commodities such as oil, gas, iron and wheat. Therefore, I saw an opportunity to make a contribution both by extending on the recent research and performing some tests that has not been done on the salmon industry before. The focus will be on the established theories around the spot-forward relationship and hedging properties of futures contracts. A critical issue of the spot-forward relationship is related to the difference between futures price and expected future spot price. In an efficient futures market the futures price works as an unbiased predictor of the future spot price. This is one of the main areas investigated. Theories regarding this is the rational expectations theory and the hedging pressure hypothesis. Another issue is related to inventory and convenience yield can explain the spot-forward price differences, this is tested through the theory of storage. In addition to this, I will examine hedging efficiency by studying how the maturity of futures contracts affects hedging efficiency. Based on this I developed my thesis statement, which is presented in the next section.

1.2 Thesis statement

My thesis statement is separated into two areas of focus. The first is directed towards well-established theories of the spot-forward price relationship. The theories have been heavily investigated on traditional commodity markets, but less investigated on the Atlantic salmon market. The first research question is defined as the following:

Does price data from the Atlantic salmon market coincide with well-established theories regarding the spot-forward price relationship?

The second focus area is also related to the derivatives market on Atlantic salmon. It is directed towards the hedging efficiency of futures contracts. More precisely, it investigates the role of maturity on futures contracts in regards to hedging efficiency. The second research question investigates the following:

How does time to maturity on futures contracts relate to hedging efficiency of Atlantic salmon futures?

Briefly described researches questions will be investigated by looking into three main theories of the spot-forward relationship. The first are the unbiasedness hypothesis, which builds the assumptions of rational expectations, and that the futures price is an unbiased predictor of the futures spot price. A different view is that the futures price is unbiased because it is set to a discount. This view is called the hedging pressure hypothesis or the theory of normal backwardation. Hedgers are assumed to pay a premium to the speculators to transfer the risk and therefore the futures price should be lower than the expected future spot price. The last theory describing the spot-forward relationship is the theory of storage, which uses inventory levels, storage costs, interest rates and the convenience yield to explain the difference in spot and futures prices. The hedging efficiency`s link to maturity has less established theories, but has been investigated in the oil industry by Ripple and Moosa (2007). The study claims that the covariance between spot and futures is an important determinant of which maturity contracts exhibit the best hedging efficiency. In general hedging efficiency is believed to depend on a high trading volume and volatility on spot price.

1.3 Structure of the thesis

This study is structured as following: Section 2 contains a brief overview of the Atlantic salmon industry. It describes salmon as a commodity, informs about the development of the industry recent decades and explains the connection this has to the pricing mechanics of the derivatives market. Section 3 contains relevant theory that works as a foundation for the thesis. It introduces the spot-forward theories and describes briefly how the theories will be investigated. It also presents some literature and describes my contribution. Section 4 presents the methodology. This section describes the methods and tests used in a more detailed manner. It also explains the theoretical framework behind the tests. Section 5 describes the data used in the tests, then present descriptive data and unit root tests. Section 6 present tests results and discusses the findings. Section 7 contains a conclusion that summarized the findings and explain the importance of this in regards to the thesis statement.

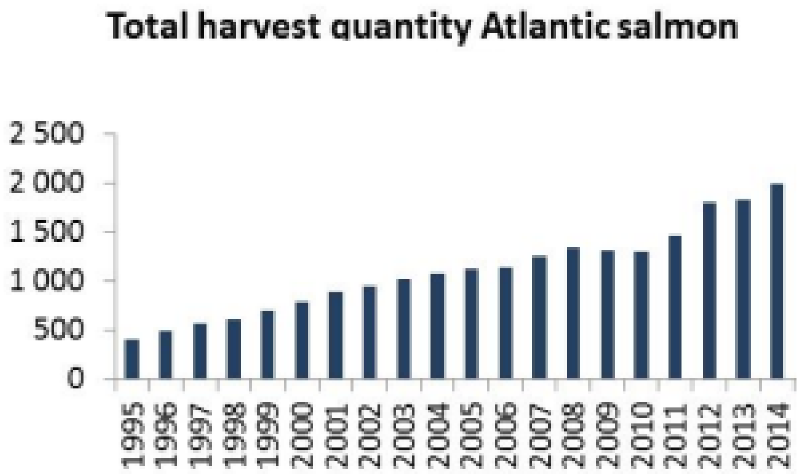
2 OVERVIEW OF THE SALMON MARKET

The spot-forward relationship as well as the hedging efficiency of futures contracts is linked to the characteristics of the underlying asset. Knowledge of the Atlantic salmon market can therefore give valuable insight to why the derivatives market and prices behave as they do. It can also be used to predict if the asset is will have a successful derivatives market as most new futures markets fail within 10years (Carlton 1984). According to Silber (1981) between two-thirds and three quarters of futures markets fail. A derivatives market is dependent on high trade volumes to sustain and there are some characteristics of a commodity market that have been link to having a successful or non-successful derivatives market. These characteristics are showed to be spot-market size, risk-reduction ability, spot price volatility and liquidity costs (Black 1986). A study on agricultural commodities found that the spot price activity on the commodity was the main driver of a successful derivatives market. The same study defined spot price activity as “a large number of market participants quote bids and offers daily”(Brorsen, Fofana, 2001). It is clear the characteristics of a commodity market is affecting the behavior of the derivatives market and therefore an introduction to the Atlantic salmon industry will be presented in this section.

Atlantic salmon as a seafood product has grown popular among the consumers the last decades, but it also have beneficial traits seen from the producer’s perspective. A report by the Ministry of Trade, Industry and Fisheries the salmon has described some of its beneficial traits. The salmon energy effective to produce compared to domesticated animals. The feeding factor is low compared to chicken, pig, sheep and cow, which are competing food items. The salmon grows fast for a fish and handles being domesticated in fish farms well. The salmon is cold blooded and does not have to expend energy to stay warm and does not have to expend energy to stand against gravity like farm animals. It also has a high proportion of eatable meat. This makes it an economically attractive commodity to produce and profit margins have been high in recent years. (Meld. St. 16, 2015). The beneficial traits of the salmon have contributed to the high growth in production the last decades.

The main producers of Atlantic salmon are Norway, Chile, Great Britain, and Canada. According to the Norwegian directorate of fisheries (Meld. St. 16, 2015), “Norway is the world’s biggest producer and exporter of Atlantic salmon. In 2013 Norway produced 60% of all Atlantic salmon on the world market and Norway has accounted for 72% of the growth in salmon production between 2005-2013". Although the growth has been very high recent years, the production capacity today is limited through government regulations such as licenses to produce. Therefore, growth must happen through increased production on current licenses or allocation of new licenses. In June 2015, the Norwegian government announced a 5% growth opportunity for all existing licenses. It is important for the supply of salmon that the Norwegian government has committed to let the industry grow in the future as Norway accounts for over half of the production. Some of the concerns related to growth are the biological and environmental boundaries of producing high amount of salmon by the coastline. This comes with strict conditions related to environment, as Marine harvest points out the maximum sea lice level is set to average 0,2 sea lice per fish. (Marine harvest, 2015) Some current ideas are to move production away from the coast either on land or further away from the coast.

Figure 1: Shows the total amount of harvested Atlantic salmon on world basis from 1995-2014



Note: The numbers are in thousand tons. Source: Marine Harvest (2015)

Figure 1 shows that the growth has been substantial and steady over the last two decades. As the market grows the foundation for an efficient derivatives market improves. As explained in the beginning of this section; an efficient derivatives market is dependent on high trading volumes, which is related to spot market size. Another variable Black (1986) proposed to affect trading volume was high spot price volatility. Research has shown that spot price of Atlantic salmon has shown to be highly volatile (Oglend, 2013). One reason for this is that spot transactions are traded in the over-the-counter market instead of an exchange. So the price is known only to the parties involved in the transaction.

Fish pool as a futures market on Atlantic salmon was established in 2006 and has now lasted for 10 years. The trading amount on futures has increased according to Fish Pool`s published yearly reports and seems to be successful. A study by Asche, Misund (2015) investigated the hedging efficiency on Atlantic salmon. They found that several hedging methods using futures contracts decreased volatility in return significantly. This indicates that the risk reduction abilities of salmon futures are high, which was one of the variables in Black`s (1986) theory of why some futures market succeed. The liquidity cost was the last variable and is harder to observe.

The production cycle of Atlantic salmon is the last issue that will be address in this section. The production cycle takes about 3 years. The first year eggs are fertilized, hatched on land in freshwater and are raised at facilities on land until it is large enough to be transported to fish farms in seawater. The next 14-25months the fish is farmed at sea until they are around 4-5 kg. After they have grown at the fish farm they are transported to harvesting facilities by boat, where the salmon are butchered and transported around the world via ships or trucks either fresh to their final destination or to storage facilities where the salmon are frozen. (Marine harvest, 2015) The importance of this information is related to the theory of storage. The futures prices on Atlantic salmon is fresh salmon and the inventory level are more related to the amount of fish in the fish farms than the amount of frozen salmon at storage facilities. Inventory levels will grow if less fish is harvested and a special characteristic of the salmon commodity is that the storage has potential to grow over time. By delaying harvesting of salmon the producers can affect the supply/demand functions and speculate if prices will go up or down in the future.

This section introduced research that suggests trading volume and success of futures markets are dependent four characteristics; Spot market size, risk reduction abilities, spot price volatility and liquidity costs. Then described the salmon industry and looked at how these characteristics relate to the salmon industry. The conclusion is that the salmon futures market has showed signs to be successful. The spot market is growing, the spot price is volatile and the futures contracts are efficient hedging instruments, thereby the salmon industry fulfill many of the required characteristics proposed by Black (1986).

3 THEORY

This section will first present theories that are important for understanding the spot-forward relationship and the futures market. The no-arbitrage argument is used to build a formula of the spot-forward price and will be explained first. Then characteristics of a consumption commodity will be introduced as the spot-forward relationship of consumption commodities differ from investment commodities. One of the main differences is explained by the cost of carry. This is followed by section 3.1 where an introduction of futures contracts, the futures market and the role of expected future spot price in regards to the forward curve are presented. The section ends with a description of the market conditions referred to as normal backwardation and normal contango. The spot-forward relationship determines which type of market condition that exists. Finally the well-established theories of the spot-forward relationship will be described in section 3.2. The theories are explained will be the rational expectation theory, the theory of storage and the hedging pressure hypothesis. This section also explains the purpose of hedging and present some relevant literature done on the different theories.

Theories of the spot-forward relationship are often derived with an assumption of the no-arbitrage argument. This argument implies that investors will take advantage of mispricing in the market. For an arbitrage opportunity to be present the profit must be made risk-free. The idea is that the investors eventually will drive the prices towards equilibrium at a correct level. A foundation for the no-arbitrage argument is the law of one price. This is an economic concept that suggests that the same good must "sell for the same price at all locations" (Mankiw, 2011). In regards to derivatives it means that the price of the physical good must be similar to the price of the futures contract with the physical assets as underlying.

The mathematical condition for the spot forward relationship is often described in equation 1:

$$F(t,T) = S(t)e^{rT} \qquad (1)$$

If the condition in equation 1 does not hold then there is arbitrage opportunities for investors. They can take advantage through the following steps:

If $F(t,T) > S(t)e^{rT}$:

At time t,

1. Borrow S(t) from bank, at interest rate r, and buy underlying asset at price S(t)

2. Take a short forward position on underlying asset, (agreement to sell the underlying asset for F(t,T) at maturity, time T

At time T,

3. Sell underlying asset as agreed, price is F(t,T)
4. Pay back loan amount of $S(t)e^{rt}$

At time T, the arbitrage profit will be F(t,T)-S(t)e^{rt}.

If $F(t,T) < S(t)e^{rT}$:

At time t,

1. Short sell the underlying asset on the spot market at price S(t), and put the money in the bank to earn interest r
2. Take a long forward position on underlying asset (agreement to buy underlying for F(t,T) at time T)

At time T,

3. Buy underlying asset at agreed price F(t,T)
4. Receive income on interest of S(t)e^{rt}

At time T, the arbitrage profit will be S(t)e^{rt} – F(t,T)

In an efficient market with many investors the arbitrage opportunities will be exploited fast so that the market stays in equilibrium and the proposed spot-forward condition hold.

There is a problem with the no-arbitrage condition in relationship to commodity assets. An assumption behind the condition is that the asset can be stored for a long time with unlimited storage capacity. This assumption holds for investment assets, but not for consumption assets, as consumption assets are not easily stored. For consumption assets storage costs and convenience yield will be taken into the spot-forward formula. The formula for consumption commodities is therefore different from equation 1, which describes investment assets. Atlantic salmon is categorized as a consumption commodity rather than an investment commodity. The variables that change the consumption commodities will be explained in the next paragraphs.

Consumption assets differ from investment assets, because they usually provide no income. Income adds value to the commodity over time; for example, when the price of the commodity increases over time. However, the consumption assets often have high storage costs related to them because they can be difficult to store over time. The consumption commodities have a different spot-forward relationship than the condition described in the no-arbitrage section. The spot-forward relationship on consumption commodities are summarized in equation 2:

$$F(t,T) = S(t+U)e^{(r-y)T} \qquad (2)$$

where U is storage costs and y is the convenience yield. These two terms are important to understand as they are big part of the theory of storage which is one of the main theories of the spot-forward relationship.

A few main terms will be explained in the following paragraph. The definitions are consistent with descriptions by Hull (2015)
Convenience yield is defined as benefits of holding the asset. This occurs when the owner of the physical asset attains benefits that the holder of the futures contract does not obtain. “The convenience yield reflects the market’s expectations concerning the future availability of the commodity. The greater the possibility that a shortage will occur the higher the convenience yield is…with little chance of shortages in the near future the commodity yield tends to be low (Hull, 2015).
Storage cost of an asset is the cost the owner has of storing a physical commodity between the futures contract is made and the maturity of the contract. Salmon has a special trait regarding storage because it can be stored fresh in the fish farm and grow until delivery day.
Cost of carry is a term that is used to summarize the relationship between the futures prices and spot prices. It measures the storage costs and interest rate paid to finance the asset, less the income earned on the asset. In the case of consumption commodities the condition is expressed as earlier described in equation 2.

3.1 Futures market

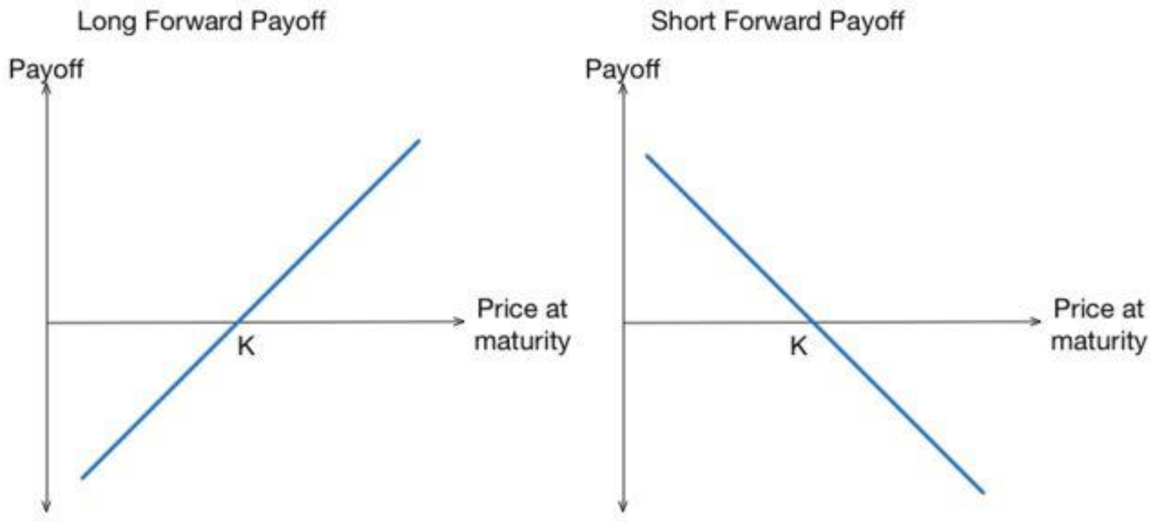
This section will first describe the characteristics of a futures contract and then introduce theory about the futures market that is related to the spot-forward price relationship.

The only derivatives that will be referred to in this thesis are futures contracts and forward contracts. The terms will sometimes be used interchangeably and to avoid any confusion the

section starts by a clarification of the differences and similarities between futures and forward contracts. Both contracts have the same fundamental purpose, it is an agreement between two parties to buy or sell an asset at a certain time in the future for a certain price (Hull, 2015). The purpose of futures contracts is well summarized by French (1986): "Futures markets are often described as having two important social functions. First, they facilitate the transfer of commodity price risk and second, they provide forecast of commodity prices".
There are 3 main differences between futures and forward contracts. First, the futures contracts are traded on an exchange, while forward contracts are traded privately. Therefore the futures contract have more standardized features and specifications. It also have less credit risk as a creditor guarantees for the contract to be held. Specification in a futures contract is normally contract size, delivery agreements, delivery month and price. Second, settlement days are different. Futures contracts settle daily, while forward contracts are only settled at the end of maturity. Third, futures contracts have no physical delivery of the asset, the contracts are normally closed out as speculators have no interest in the delivery. Forward contracts are more normal among hedgers who trade the physical asset and therefore the contract is often closed by delivery or cash settlement. Some research uses futures and other forward contracts. Therefore the two contracts will be mixed throughout the paper, but in terms of theory the two contracts are the similar.

A futures contract has two sides, called long position and short position. A salmon farmer that produce salmon has a naturally long position, while someone who is going to buy a commodity is naturally short. A long position is similar to holding the commodity with intentions to sell in the future, while a short position similar to buying in the future time. In a long position the payoff increase as the price at maturity increase, in a short position the payoff decreases as the price at maturity increases. To hedge risk the salmon producer must buy a future with short position so the payoff works in the opposite direction. This makes the payoff less prone to changes in spot price. A perfect hedge towards price changes is when the payoff is completely independent of the spot price. The relationship between the price at maturity and payoff on forward contracts are described in figure 2:

Figure 2: Describes payoff on forward contracts in short and long positions

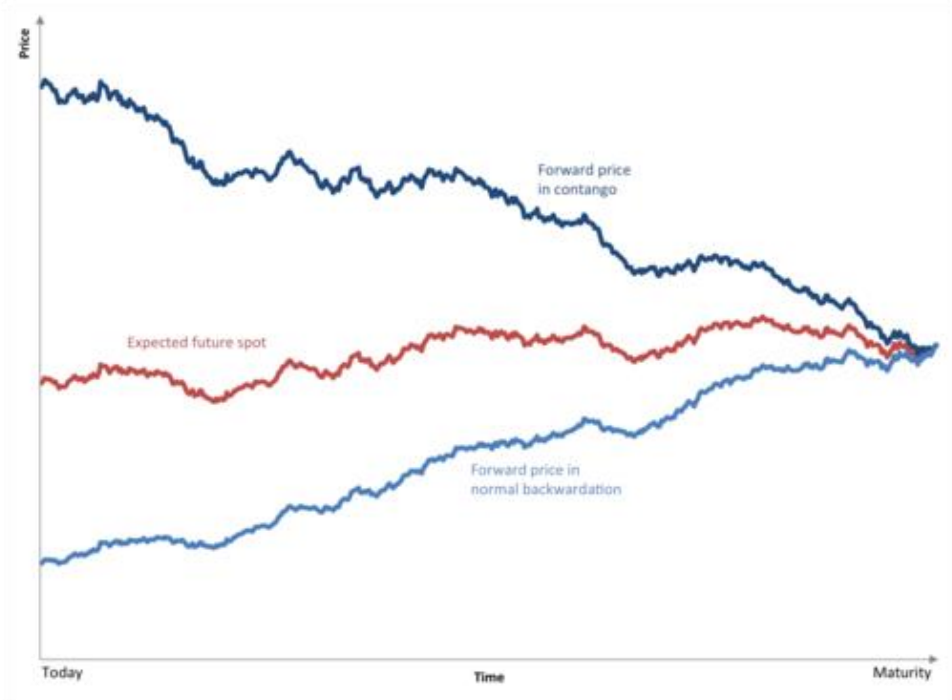


There are 3 main types of traders that are referred to in literature: Hedgers, speculators, and arbitragers. All three have an important role in a well working derivatives market. Hedgers use the futures market as a risk transfer mechanism. These are agents within the industry who are exposed to price change risk in the spot market. Agents that sell assets in the future want to reduce risk by taking short positions in the futures market, while agents who buy assets in the future want to reduce risk by taking long positions in the futures market. Speculators are investors who use the future markets to speculate on future price changes. They take long positions if they expect the future spot price will increase more than the expected future spot price suggest. They also take short positions if they think that the future spot price will be lower than the expected future spot price suggests. Speculators profit if their anticipation of the future spot prices is correct and their positions in the market rise in value. Arbitragers are investors who take advantage of mispricing in the market. They profit if the market prices of spot and futures is break the spot-forward condition explained in the beginning of the theory section.

The expected future spot price has an important role in understanding the futures market. It acts as the market´s average opinion of what the spot price will be in the future. As a futures contract gets close to maturity the futures price move closer towards the expected spot price. This is referred to as the convergence of futures price to spot price. As the delivery period for a futures contract is approached, the futures price converges to the spot price of the underlying asset. At delivery date, the futures price is equal or very close to the spot price

(Hull, 2015). If this is not the case then there would exist arbitrage opportunities for traders. If the futures price is above the spot at delivery then the traders can make a profit by short selling a future contract, buying the asset and make the delivery.
This relationship is showed in figure 3.

Figure 3: Convergence of forward price to expected spot price



Note: As time approaches maturity the forward prices approaches the expected futures spot price.

The characteristics of the futures market can be found by analyzing how the forward curve related to the expected future spot price. This relationship is captured in figure 3 and will tell if the market is in normal backwardation or normal contango. If expected future spot price is higher than the futures price then the market is in normal backwardation. If the futures price is higher than the expected future spot price then the market is in normal contango. Different commodities markets behave differently and same market can change over time. A method to test the behavior of a futures market is to look at the risk premium. The risk premium is originally looked at as the premium hedgers give to speculators for the risk of taking on short futures contract. According to Keynes`s (1930) original theory, the risk premium is negative, indicating that the futures price is below the spot price. This theory will be explained together with other theories of the spot-forward relationship in the next subsection.

3.2 Main theories and literature

This section will present main theories that are used to explain the research questions together with related literature. The first theory of the spot-forward relationship is the *hedging pressure hypothesis*, which origins from Keynes`s theory of normal backwardation. It was first introduced by Keynes (1930) to explain the risk premium in the futures market. The theory looks at the futures markets mainly as a risk transfer mechanism where long (risk-averse) investors earn a risk premium for bearing future spot risk that commodity producers want to hedge. This theory builds on the view that the basis consists of two components: a risk premium and the expected appreciation or depreciation of the future spot price. The risk premium is described by the condition in equation 3:

$$E_t(P_{t,T}) = F_{t,T} - E_t(S_t) \qquad (3)$$

where $E_t(.)$ is the expectations operator at time t, $P_{t,T}$ is the risk premium, $F_{t,T}$ is the futures price observed at time t for maturity T, and S_T is the spot price at time T.
According to Keynes, the risk premium is set to a discount, which makes it attractive for speculators to take the other side of the contract. Keynes and Hicks (1939) view the risk premium as the outcome of the supply and demand for long and short positions in the futures markets. The risk premium has recently been investigated in the salmon market and found slightly negative by (Asche, Misund, Oglend, 2015). In general the hedging pressure hypothesis has received less support than the hedging pressure theory in explaining the spot-forward relationship.

The theory of storage is one of the main theories used to explain the spot-forward relationship. The theory aims to describe the spot-forwards relationship through the convenience yield, storage costs and interest rate. The theory makes two predictions involving inventory levels, which is important for proving the theory. When inventory is low spot prices will exceed futures prices and spot price volatility will exceed futures price volatility (Geman and Smith, 2013). The theory of storage originates from the work of Kaldor (1939) and Working (1949). Kaldor introduced convenience yield and Working (1949) developed the theoretical framework of the theory of storage. Later, studies by Brennan (1958) and Tesler (1958) provided evidence that proved the theory by investigated the relationship between the conveniences yield and inventory levels for several agricultural commodities. Fama and French (1987,1988) also contributed to the theory by investigating several commodities and introducing tests indirect tests to measure find evidence of the theory of storage. An indirect test proposed by French (1988) will be used in this thesis. The theory of storage has been heavily researched and has provided strong evidence to support the theory. In recent years studies by (Modjahedi and Movassagh, 2005; Serletis and Shahmorandi, 2006; and Haff et al., 2008) have provided evidence on the gas market. The theory of storage has been supported by stronger evidence than any other theory of the spot-forward relationship. However, studies on the salmon market have not been researched as heavily.

The *rational expectation theory* is also referred to as the unbiasedness theory in the futures market. This theory suggests that the forward prices are unbiased predictors for the future spot prices. The unbiasedness can be found by looking at the forecasting error between futures prices and expected future spot prices. When testing this theory the null hypothesis is that the mean forecast error is zero, and a rejection of the null hypothesis translates into a risk premium. This relationship is described in the formula 4:

$$E_{t-k}\,(S_t) \;=\; {}_{t-k}F_{t} \qquad (4)$$

where t-kFt is the forward price at time t-k for delivery time t, and Et-k (St) is the expected future spot price at time t-k.

If the future price is below the expected spot price, the market is in normal backwardation. If the futures price is above the expected future spot price, the futures market is normal contango (Hull, 2015). If the expected spot price is estimated correctly, the forecast error will be zero. However, if it expected spot is underestimated (overestimated), the forecast error will be negative (positive).

Theory and literature behind the hedging part of the thesis will be presented in this paragraph. Hedging efficiency using derivatives has been studied for a long time in different markets. Most of the studies conclude that derivatives such as futures contract can be used to hedge against risk and exposure to in the spot price changes. Empirical results conclude that derivatives reduce risk (Guay, 1999; Jin and Jorin, 2006). The risk reduction is the main purpose of hedging and has shown to work in the salmon market as the recent study by Asche and Misund (2015) concluded that the Atlantic salmon reduce risk exposure on spot price changes by 27-38%. On the oil market there also has been studies showing risk reduction such as Ripple and Moosa (2005) who also investigated the relationship between hedging efficiency and maturity on futures contracts. This relationship has not been tested on Atlantic salmon and will be a new contribution that this thesis will make current literature.

Furthermore, it has not been clear if the hedging actually matter in regards profit and the value of the firm. As described by Guay and Kothari (2003)"The effect on overall firm value has been unclear". When assuming that futures are fairly priced the

Studies have proposed that the benefits of hedging is related to the financial constraints of a firm, based on the notion that futures are fairly priced:

> "For a financially unconstrained firm there is no advantage to hedging. Since all hedges are fairly priced a hedge can only change stochastic pattern of the firms future cash flow, not the firms value. However, this is not the case for the financially constrained firm" (Mello 2000)

Mello`s study shows hedging adds financial flexibility. Reduces the cost of financial distress and allows the firm to take advantage of future investment opportunities. These are clear benefits since the investment costs in the salmon industry investment are very high and profits are made at the end of a long production cycle. Another study by Disatnik, Duchin and Schmidt (2014) suggests that the hedging reduce likelihood of violating the financial covenant, and therefore allows the firm to rely more on lines of credit instead of cash as creditors are more willing to lend to companies with small chances of violating the financial covenant. The issue of hedging and firm value has not been investigated in the salmon industry and will not be investigated in this thesis. However, it would be an interesting topic for further research.

Section three has explained the theoretical foundation for the spot-forward relationship and introduced the characteristics of futures contracts and markets. The role of expected futures spot price has been discussed and linked to which type of market condition that exists. The main spot-forward theories that will be investigated in this thesis have also been described together with the purpose of hedging and relevant literature. The theories discussed are important to understand before the methodology section, which presents the methods and tests used to investigate the research questions. The methodology section is more detailed and advanced that the theory section, which was more brief and introductory.

3.3 Contribution

My contribution will be to test the storage theory and unbiasedness theory with tests that have not been tested on the Atlantic salmon before (Movassagh and Modjahedi, 2005). However, the tests have been used in other studies before, such as the oil and gas market. Using tests from other markets can give valuable insight to the Atlantic salmon market, as the theories about the spot-forward relationship are the same. A disadvantage can be that the properties in the salmon industry are different from the others and that the test could benefit from adjustments to be more industry specific. I do not think that will be big problem in the tests used. In the risk premium test my contribution will be to extend on the previous research of (Asche, et al. 2015) and propose a new adjusted model with different variables to improve the model fit. The last test, which relates hedging efficiency to maturity on futures contracts, is a new contribution on the salmon market, but similar studies has been done other commodities, an example is on oil by Ripple and Moosa (2007).

4 METHODOLOGY

The purpose of this section is to describe the empirical test methods that are used in this study. The section will also relate the test methods to the theory off to the theoretical framework of the test and discuss what to expect from the findings.

4.1 The unbiasedness hypothesis:

According to this hypothesis, forward prices are unbiased predictors for future spot prices. The null hypothesis is that the mean forecasting error is zero, if the null is rejected there is a risk premium. The following paragraphs will explain the theoretical framework before the test method is introduced.

The unbiasedness theory can be described by the condition in equation 5:

$$E_{t-k}(S_t) = {}_{t-k}F_t \qquad (5)$$

Where t − kFt is forward price quoted at time t-k for delivery t and $E_{t-k}(S_t)$ is expectation on the future spot price at time t-k.

When this condition is true then the unbiasedness theory hold. When the futures price is below the expected future spot price, the situation is known as normal backwardation, and when the futures prices is above expected future spot price the situation is known as normal contango. (Hull, 2012)

To test is the condition holds an analysis on the forecasting error will be used. The forecasting error is derived based on the payoff of a long futures position. In a long position in a futures contract, the payoff from one unit is calculated in equation 6:

$$Payoff = S_t - F \qquad (6)$$

Where F is the futures contract price and S_T is the spot price of the asset at maturity of the contract. Trough transformation this will be the same as described in equation 7:

$$Forecast\ error = S_t - {}_{t-k}F_t \qquad (7)$$

Where ${}_{t-k}F_t$ is futures price quoted at time t-k for delivery time t, S_t is spot price at time t, and S_t - ${}_{t-k}F_t$ is the k-month-ahead market forecast error in month t.

As suggested by Divot and Wang (2003) the forecasting error is assumed to follow a moving average process of order k-1. To test this relationship an autoregressive moving average model (ARMA) will be applied. The expression used is described in equation 8:

$$S_t - {}_{t-k}F_t = \alpha + u_t + \sum_{i=1}^{k-1} \theta_i \ u_{t-1} \tag{8}$$

Where the left side of the equation is the forecasting error, α is a constant, $u_t$is a white noise process with E(u_t)=0 for all t.

The test is performed using an ARMA model in the statistical software R. Since the model is following a moving average process only the moving average (MA) term of the ARMA model was used. The model assumes that the residuals are white noise, which means that they are uncorrelated, have zero mean and a constant variance. This might not be the case and can create bias in the results. To address the autocorrelation issues and to fit the correct model the autocorrelation function (ACF) plots will be analyzed. These plots can be used to choose the correct amount of lags in the model to avoid the autocorrelation bias in the results.

The null hypothesis is that the forecasting error is zero. To reject this hypothesis the mean forecasting error must be significantly away from zero. If it is not then the null hypothesis hold which is evidence supporting the unbiasedness theory.

4.2 The theory of storage

The theory of storage aims to explain the spot-forward relationship through the convenience yield, storage costs and interest rate. The convenience yield is benefits the owner of the physical good attains and is assumed to be negatively correlated to the inventory level. The method used to test this relationship is explained in this section together with the theoretical framework that the tests are derived from.

The theory of storage assumes that the relationship between spot and forward prices quoted on the same day can be described in equation 9:

$$ {}_tF_{t+k} - S_t = {}_tR_{t+k} + {}_tM_{t+k} - {}_tY_{t+k} \quad (9) $$

Where ${}_tF_{t+k} - S_t$ is basis (log scale), ${}_tR_{t+k}$ is the k-month nominal interest rate at time t, ${}_tM_{t+k}$ is the marginal cost of storing the commodity from t to time t-k and ${}_tY_{t+k}$is the marginal convenience yield accumulated from time t to time t+k.

The convenience yield is hard to observe directly and a standard approach to deal with this is to assume that the net storage cost is a linear function of the level of inventories at time t. This relationship is described in equation 10:

$$ {}_tM_{t+k} - {}_tY_{t+k} = \beta_0 + \beta_1 I_t \quad (10) $$

Where I_t is the inventory level

By substituting equation 9 into equation10, we derive the linear relationship that will be tested through OLS regression analysis. The equation used in the storage test is described in equation 11:

$$ {}_tF_{t+k} - S_t = \beta_0 + \beta_1 I_t + \beta_2({}_tR_{t+k}) + \varepsilon_t \quad (11) $$

Where ε_t is an error term and the β is an estimate that tells us about the magnitude and direction of the variable and its relationship to the basis.

To find evidence of the theory of storage the Beta estimates should according to Fama and French (1987) be the following: β_0 equal to zero, β_1 of postitive sign, β_2 equal to one. Another, note to the model is that if the model is complete and fully specified, the intercept of β_0 should not be significant. A complete model is difficult to achieve and omitted variables is an issue that often can occur in this model.

Another model will also be used to investigate the theory of storage. French (1988) introduced an indirect test, which suggest that marginal convenience yield on inventories falls at a decreasing rate as total inventory level increases. This test uses an interest-adjusted basis to find a testable hypothesis about the convenience yield. By offering a solution to the problem of unobservable convenience yield this test has become attractive. “The indirect test of the theory of storage is the preferred approach over a direct test, due to the lack of available data for the convenience yield”(Serletis and Shahmoradi, 2006).

The indirect model suggests that the interest-adjusted basis is equal to the marginal storage costs less the marginal convenience yield. The equation of the indirect tests suggests that the left hand of the equation is the interest-adjusted basis and this is equal to the marginal warehouse costs less marginal convenience yield. The relationship is described in equation 12:

$$\frac{F(t,T) - S(t)}{S(t)} - R(t,T) = \frac{W(t,T) - C(t,T)}{S(t)} \qquad (12)$$

Where F(t,T) is the futures price at rime t for delivery at time T, S(t) is the spot price at t, R(t,T) is the interest relate at which market participants can borrow or lend over a period starting at date t, and ending at date T, W(t,T) is the marginal warehouse cost and C(t,T) is the marginal convenience yield. Similar studies on other industries state that the marginal storage costs is assumed to be constant, which means that the changes are caused by changes in the convenience yield (Brennan, 1958; Tesler, 1958; Serletis and Shahmoradi, 2006). The indirect test is able to get an estimate of how the marginal convenience yield behaves and relate this to changes in inventory levels.

If the theory of storage holds then the following should be true. When inventory levels are low the variance or volatility in prices are higher than when inventory is high. Low inventory levels will create greater volatility in spot price than the futures price, while the volatility is similar when inventory levels are high. The reason is that inventory levels affect the supply and demand shocks. As inventory levels are high there is less likelihood of shortage, when inventory levels are low the likelihood of shortage increases and therefore spikes in the spot price occur more frequently. Evidence of the theory of storage can be found by comparing the volatility of prices when inventory is low compared to when inventory is high.

4.3 The hedging pressure hypothesis

This section will describe the test and theoretical framework used for testing the risk premium on the Atlantic salmon futures market. Unlike the unbiasedness theory the hedging pressure hypothesis suggest that there is a bias between the futures price and the expected spot price.

The hedging pressure hypothesis suggests that the difference between the futures price and the future spot price is the risk premium and that the formula for risk premium can be stated as in equation 13:

$$E_t\left(P_{t,T}\right) = F_{t,T} - E_t(S_T) \tag{13}$$

Where:

E_t (.) is the expectations operator at time t, $P_{t,T}$ is the risk premium, and $F_{t,T}$ is the futures price observed at time t for maturity at time T

The spot future price relationship can also be written as a sum of the expected premium and an expected change in the price of spot as described in equation 14:

$$F_{t,T} - S_t = E_t\left(P_{t,T}\right) + E_t(S_T - S_t) \tag{14}$$

Where $E_t(S_T - S_t)$ is the expected change in spot price

An Empirical Method for testing this relationship is developed by Fama and French (1987) Their approach tests for a time-varying expected premiums by using the following regression of the premium on the basis, presented in equation 15:

$$F_{t,T} - S_T = \alpha_1 + \beta_2 \beta_t + \varepsilon_T \tag{15}$$

βt is the basis, which is calculated as the difference between $F_{t,T}$ and S_T observed at time T, ε_t is the error term.

The hypothesis of the regression test suggests that variation in realized premiums is evidence of time-varying expected premiums. The result will be seen at the $\beta 2$ coefficient, if it is positive and significant there is evidence of the existence of time varying risk premium.

This model has not shown very consistent results in studies and has been claimed to struggle with omitted variable bias. Recently, Asche, Misund, and Oglend (2015) introduced an adjusted risk premium model. Their proposed model adds industry specific variables related to production risk.

Their modified equation (16) is:

$$RP_t = \alpha_1 + \beta_1 \beta_{t-n} + \sum_{i=1}^{i} \beta_i CV_{i,t} + \varepsilon_t^{rp} \tag{16}$$

Where RP_t is realized risk premium in month t, β_{t-n} is the difference between the spot price at time t-n and forward price for time t, observed at time t-n. *CV* is including several additional variables. The extra variables in $CV_{i,t}$ are:

1) ΔBIOt: Growth in biomass, reported monthly
2) ΔPROt: Growth in harvest, reported monthly
3) ΔTempt*: Temprature deviance (shock) measured as the difference between monthly temperature and the historical average temperature that month.

The estimation is performed through a regression analysis using the Ordinary Least Squares (OLS) method.

The results of the modified model have shown significant results for both biomass and harvest, but the temperature variable showed insignificant results. This was somewhat surprising and an issue with the temperature will be addressed in the new adjusted model proposed in this thesis. The old model used temperature deviation away from historical average. An issue with this method is that 2degrees colder than normal in February and august will both be measured as -2. However, the effect on fish production is opposite in February and august. Theory suggests that the optimal temperature for growth in Atlantic salmon production is 8-14 degrees. In august the normal temperature is over 14 degrees and in February it is 2 degrees. The appetite of salmon has shown to change as temperature gets close to 0 and 20 degrees. Therefore 1 degrees lower than normal in February will be negative for production while 1 degree lower than normal in august is positive for production. This relationship is captured better by the new proposed temperature variable in this study. The variable is calculated as deviation away from optimal temperature. If the temperature deviation away from historical average moves towards optimal temperature it is positive, and if the temperature deviation moves away from optimal temperature it gets a negative sign.

In addition to the new temperature variable an extra variable of dead fish reported monthly will be included in the model. This variable is supposed to account for loss in production and reflect the level of diseases and sickness in the salmon farms.

The results will be used to gain information about the spot-forward relationship. The sign and magnitude of the risk premium will indicate which type of futures market exists and if the forward curve is in backwardation or contango. The production risk variables used in the regression will tell how the risk premium is affected by these variables. This will give valuable insight to why the risk premium behaves as it does in the salmon market.

4.4 Test of hedging efficiency and time to maturity

The objective of this analysis is to test the relationship between hedging efficiency and the maturity of futures contracts. First the hedging efficiency will be found by using two hedging methods on futures contracts with different time to maturity. The hedging strategies used will be the naïve hedging method and optimal variance method, while there will be 5 different maturity contracts ranging from 1-12 months. The hedging methods simulate a producer who is naturally long on the spot market and buys a short futures contract to reduce risk. A hedged position does therefore consist of a spot position and a futures position. Secondly, the hedging results on maturities from 1-12months will be summarized. This will give the results and data needed to describe the relationship. The results are compared and analyzed to see if there is a clear correlation between time to maturity on futures contract used and hedging efficiency result.

The results of different hedged positions depend on the size of the futures positions compared to the size of the spot position. This is called the hedge ratio (h). The efficiency of each hedging strategy will be decided by the hedge ratio used. Some methods use constant ratio while other methods use a changing ratio to such as rolling optimal hedge ratio and bivariate GARCH to capture the changing risk over time. Research from the salmon industry show that the constant hedging methods performed equally or better than the methods with changing hedge ratios (Asche and Misund, 2015)

Both naïve hedge and optimal variance hedge are constant methods and should be appropriate to use since the main purpose will be how the efficiency develop with maturity on contracts.

To evaluate this the results of different maturities will be analyzed for trends. The hedging strategies used will be presented in the following paragraphs.

As a benchmark an *unhedged position* is used, this position is sometimes called a naked position this position is fully exposed to changes in spot price.

The *naïve hedging method* can is a position that are being fully hedged and the method uses a hedge ratio of 1. This method is the simplest strategy and easy to understand. Despite being simple it was the most efficient method in the study by Asche and Misund (2015). Normally the more sophisticated methods are expected to outperform the simple naïve hedge method, but this was not the case in the salmon market.

The *optimal variance method* calculates the hedge ratio that minimizes the variance (h*). The optimal hedge ratio is described in equation 17.

$$h^* = \frac{cov\left(r_{s,t}, r_{f,t}\right)}{var(r_{f,t})} \tag{17}$$

where $r_{s,t}$ the return on spot at time t, and $r_{s,t}$ is the return on spot price

This relationship can also be tested empirically, which was done in this thesis. Then the ordinary least squared method is used to calculate the optimal hedge ratio using a regression described in equation 18:

$$r_{S,t} = \gamma_0 + \gamma_1 r_{f,t} + u_t \tag{18}$$

γ_0= constant, γ_1= the optimal hedge ratio, $r_{S,t}$ and $r_{f,t}$are return on spot price and futures prices at time t, u_t = error term

The optimal hedge ratio is calculated based on historical data and is constant over time. This is a weakness since it fails to capture the changing variance as volatility changes over time. The optimal hedge ratio should ideally change over time, which are possible through the GARCH method or rolling OLS method.

To calculate the hedging efficiency of each hedged position the framework from Matinez-Garmendia & Anderson (1999) will be used. The efficiency is calculated by comparing the variance in revenues of an unhedged spot position to the variance in revenues of a hedged position. Revenues of a hedged position is defined in equation 19:

$$r_{p,t} = r_{S,t} - h^* r_{f,t} \tag{19}$$

Where $r_{p,t}$ is the hedging portfolio revenue, $r_{S,t}$ is the return on the spot position and $h^* r_{f,t}$ is the return on the futures position.

The revenue is calculated using first differenced prices or changes in spot/futures price from one time period to the next. For spot price this will be: St – (St-1) and futures: Ft – (Ft-1)

The hypothesis is that hedging efficiency decreases as time to maturity increase. The reason to believe so is that the liquidity and trading volume on short time to maturity contracts is higher. However, there is also a contrary theory. As time to maturity get closer, more information becomes available and volatility increases. The volatility can potentially disturb the covariance between spot return and futures returns. The covariance is important for hedging efficiency and lower covariance lead to decreased the hedging efficiency.

The methodology section has presented tests and methods that will be used to describe the spot-forward relationship. The unbiasedness test will look into the forecast error, which must be zero to claim that the futures price is an unbiased predictor of the future spot price. If forecasting error is not equal to zero then the difference is evidence of a risk premium. The direction of the sign can be used to describe the forward curve. The theory of storage test described two tests, which will describe the relationship between inventory and convenience yield. The findings can be used as evidence to support or reject the theory of storage as an explanatory factor of the spot-forward relationship. The risk premium test will investigate the variables related to the variation in risk premium and tell us if the risk premium is positive or negative. The Fama and French test for time varying premiums with regards to basis combined with improved model using production risk factors will give insights to the spot-forward relationship. The hedging efficiency method will find revenue in the futures positions and compared this to the unhedged position to evaluate the performance on futures contracts with different time to maturity. The results will be analyzed and if a clear trend appears it will indicate that certain time to maturity on futures contracts is more appropriate for hedging than others.

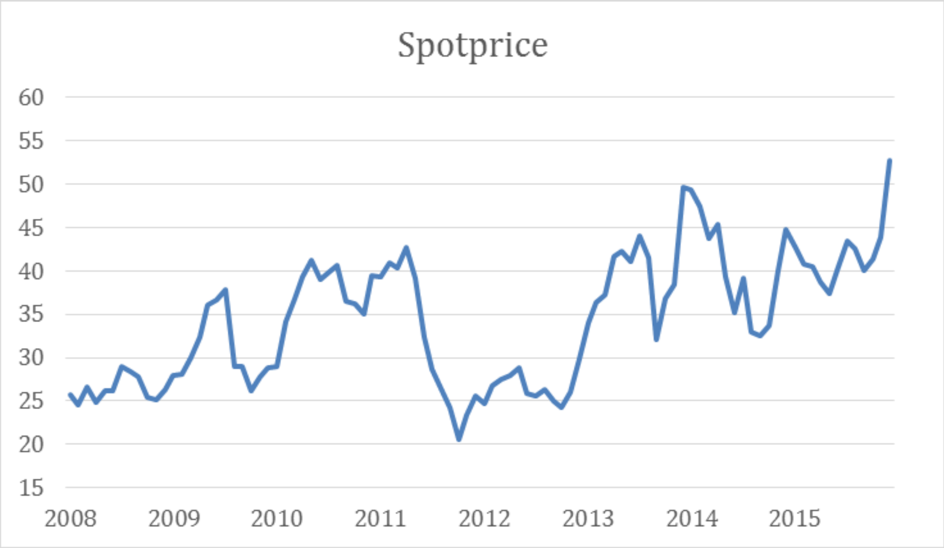
5 DATA

The data section will first discuss the different data variables used in tests and explain how the data has been collected. Then the descriptive data on variables used in tests will be presented together with unit necessary unit root tests and a brief explanation of why time series data must be tested to avoid non-stationary data. When presenting descriptive data and unit root tests each main spot-forward hypothesis will be presented separately.

This thesis performs several tests and uses therefore several data sets. Common for all tests is the spot and futures price on athletic salmon, which are collected from the fish pool index. This source was chosen because of its appropriate abilities as a price index. *Fish pool* was established in 2006, they do not trade physical fish, but has established a synthetic market price as reference point to traders in order to settle financial contracts. They keep track of historical prices on both spot and futures contracts. Their goal is to give a correct reflection of the market price, be able to verify, ensure inability to manipulate, be transparent and available, and remain neutral to all parties. All tests uses data collected from January 2008 to December 2015. For most tests the weekly data is transformed into average monthly data. The monthly data is made up of 4-5 weeks; following fish pools recommendation, such that spot prices are matched to the same time as the monthly future contracts.

All tests use log scale data. This addresses problems that often occur with time series data. Log scale data responds to skewness towards large values and work as a deflator over time. With log numbers, a percent change from 50 is similar to a percent change from 20, which is different from nominal numbers who would weight the change from 50 more than the change from 20. Using log scale numbers also makes it possible to compare results with other studies as most studies on relevant topics use log scale numbers.

Figure 4: Original spot prices January 2008 to December 2015



Note: Price is measured in NOK.

On all tests the spot and futures price are converted into first differentiated prices. This is the same as return on spot price from one period to the next. The reason for this is to address the problem of non-stationary data and be explained in an own paragraph later in this section.

The return on spot is calculated as: St – St-1

where St is spot price at current time t, and St-1 is the spot price at last period. The return on futures prices is calculated using the same method.

The futures prices are collected the 1st day in the month. If this is not a trading day, the first trading day prior to the 1st is used. The futures contracts are collected with different time to maturity. A one-month contract is collected the month prior to maturity and a three-month contract is collected three months prior to maturity. As an example, a futures contract with maturity in February is collected the 1st of January for the one-month contract and 1st of November for the three-month contract.

Descriptive data of the spot and futures prices are presented in Table 1 followed by a short analyzed of the findings:

Table 1: Descriptive data on original spot and futures prices, in NOK

	Spot Prices	Futures 1month	Futures 2month	Futures 3month
Min	20,64	23,50	23,50	23,75
1st Qu.	27,67	26,48	26,50	26,45
Median	35,09	34,40	33,50	33,10
Mean	34,37	33,50	33,29	32,92
3rd Qu.	40,43	38,44	38,15	37,52
Max	52,78	47,90	47,30	46,35
Variance	54,21	46,58	45,89	42,54
SD	7,36	6,82	6,77	6,52
Skewness	0,18	0,18	0,22	0,27
Kurtosis	2,00	1,89	1,89	1,93

Note: Descriptive data using monthly average prices

Skewness is a measure of symmetry. As a rule of thumb the negative skewness is when the mean is less than the median, thus the data distribution is left-skewed. Positive skewness indicates that the mean is larger than the median and that the distribution is right-skewed. In the data of spot and future the mean is less than the median, which would indicate that the skewness is negative and that the distribution is left-skewed. However, it does not have to be like this and in this case it is not. The skewness is positive and the mean is lower than the median. Both the skewness and difference between mean and median is close to 0, so it is not a big deviation from the rule of thumb. The volatility in futures prices is declining as time to maturity, which is consistent with the theory of Samuelsson effect. This theory suggests as more information becomes available closer to maturity, the volatility increase (Samuelson, 1965).

In the risk premium test some variables additional to prices was used in the analysis. These variables will be presented in the following paragraph.

Variables in the risk production model was collected as explained in the following paragraph:

The *temperature* data is monthly average temperatures from several locations along the Norwegian coastline. The temperatures are measured at 5m deep. The data is collected from the Norwegian directorate of fisheries (www.fiskdir.no)

The *biomass* is the total amount of fish reported to be in the fish farms at the end of each month. The data is collected from statistic published by the Norwegian directorate of fisheries on their web pages. This variable works as an indicator of total inventory and supply in near future.

The *harvest* data is the amount of fish that have been harvested per month. This data is reported in to the Norwegian directorate of fisheries. The amount of fish being harvested indicates the amount of supplied fish from Norwegian fish farms.

The loss in production is the amount of dead fish reported found in the fish farms. The data is reported to the Norwegian directorate of fisheries. The amount of dead fish indicated if there is much sickness and diseases in the fish farms.

5.1 Descriptive data and unit root testing

A main concern when using time series data in regression analysis is whether the data is stationary or non-stationary. An assumption behind OLS regression analysis is that the data is stationary and a violation of this can cause problems and bias results. As summarized by econometric literature, “If a time series have either a deterministic or stochastic trend it is non-stationary. Standard regression results and time series tools often rely on stationarity, therefore it is important to test for non-stationarity” (Bjørnland, 2014). Non-stationary data contains randomness that can create noise in the analysis. If this problem is ignored; it can cause incorrect results from the regression analysis. A typical bias that can occur is called spurious regression. This is when the regression results are significant due unrelated data because non-stationary series are used in regression analysis. To test if the time series used in this thesis contain non-stationary data, a unit root test will be applied. The most widely used unit root test is the Augmented Dickey-Fuller test. (ADF). “Dickey fuller developed a test on time series that test weather a series is a random walk against the alternative that it is stationary” (Bjørnland, 2014). The ADF test in this thesis has been performed through the statistical software R, using the ur.df function in the “urca” package.

The descriptive data and unit root tests for all data used in the 4main tests of this thesis will now be presented. The time series data used in the unbiasedness test was spot and futures prices, as well as forecasting error. The results from the ADF can test are presented in table 2. A unit root test with and without trend was used. The critical values are listed on the bottom of table 2. The tests were first performed on original log prices, but as table 2 shows the data were non-stationary. When using first differentiated prices the results showed stationary data. All tests used in this thesis use first differentiated prices to deal with this problem.

Table 2: Unit root test on log scale prices

	T-stat (no trend)	T-stat (with trend)
Spot	0,654	-2,802
Future1M	0,415	-2,767
lnFuture2	0,513	-2,770
lnFuture3	0,509	-2,568
Critical value 1%	-2,6	-4,04
Critical value 5%	-1,95	-3,45
Critical value 10%	-1,61	-3,15

Note: Augmented Dickey Fuller test. The lag number is calculated using the Akaike information Criteria on all ADF tests, (Akaike 1979). Significance level is denoted by asterisk: *<0,1 significance level, **<0,05 significance level, ***<0,01 significance level

The test results show that the T-stat is higher than the critical value needed to reject the null hypothesis of unit root. This implies that the data series of spot and futures prices translated into log scale is non-stationary and follow a random walk.

The ADF test on forecasting error rejected the null hypothesis of unit root on all values. This indicates that the data is stationary and appropriate to use in OLS regression analysis.

Table 3: Unit root test on log scale forecast error ($S_t - F_{t-1}$)

Forecasting error	T-stat (no trend)	T-stat (with trend)
$S_t - F_{t-1}$	-3,969***	-4,074***
$S_t - F_{t-2}$	-3,828***	-3,920***
$S_t - F_{t-3}$	-3,473***	-3,596**
Critical value 1%	-2,6	-4,04
Critical value 5%	-1,95	-3,45
Critical value 10%	-1,61	-3,15

Note: F_{t-n}, is futures price using contacts with n months to maturity. St is spot price. Significance level is denoted by asterisks: *<10% significance level, **<5% significance level, ***<1% significance level

The *risk premium test* has several variables and which are shown in table 4. The data have some interesting characteristics. The mean of risk premium is negative, which grows more negative with time to maturity. This indicates a futures market in normal backwardation. The basis also has a negative mean, which means that the futures price is less than the spot. A negative basis is indicating a futures market in backwardation. Note that the difference between a market in normal backwardation and backwardation is that the normal backwardation is based on expected spot price, while backwardation is based current spot price as when calculating basis. The descriptive data is presented in Table 4:

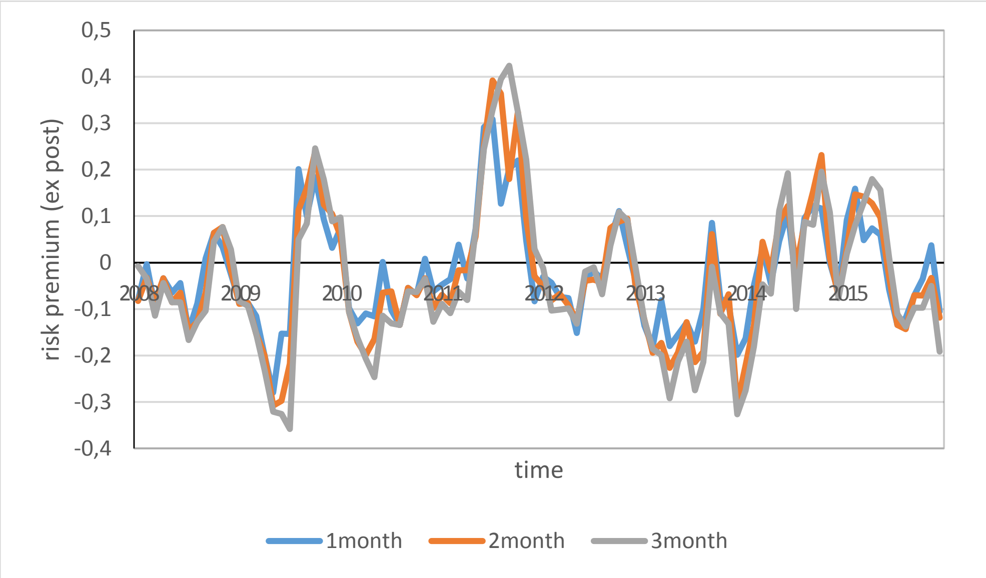
Table 4: Descriptive data of variables used in the risk premium test

	Mean	Standard Deviation	Min	25%	Median	75%	Max
Risk premium							
1M	-0,023	0.111	-0,280	-0,099	-0,044	0,048	0,308
2M	-0,030	0.140	-0,308	-0,123	-0,058	0,066	0,392
3M	-0,039	0.159	-0,358	-0,131	-0,072	0,071	0,424
Spot price changes							
1M	0.005	0.090	-0.267	-0.045	0.015	0.068	0.256
2M	0.011	0.135	-0.320	-0.077	0.027	0.095	0.301
3M	0.018	0.173	-0.399	-0.090	0.021	0.145	0.438
Basis							
1M	-0.018	0.091	-0.229	-0.078	-0.018	0.051	0.184
1M	-0.024	0.120	-0.280	-0.115	-0.038	0.058	0.283
3M	-0.033	0.142	-0.326	-0.127	-0.042	0.059	0.345
Production Variables							
∆Bio 1M	0.004	0.048	-0.075	-0.036	-0.005	0.043	0.043
∆Bio 2M	0.008	0.090	-0.128	-0.069	-0.011	0.074	0.182
∆Bio 3M	0.012	0.125	-0.171	-0.097	-0.005	0.127	0.252
∆Pro 1M	0.006	0.121	-0.243	-0.087	0.015	0.077	0.282
∆Pro 2M	0.010	0.159	-0.331	-0.118	0.010	0.137	0.309
∆Pro 3M	0.015	0.178	-0.442	-0.102	0.035	0.130	0.340
Temp* 1M	0.214	0.824	-2.068	-0.174	0.237	0.718	3.204
Temp* 2M	0.192	0.665	-1.836	-0.224	0.305	0.640	1.752
Temp* 3M	0.203	0.633	-1.521	-0.273	0.280	0.614	1.782
∆Loss1M	0.002	0.264	-0.593	-0.152	-0.023	0.160	0.787
∆Loss2M	0.005	0.395	-1.050	-0.256	0.001	0.291	1.048
∆Loss3M	0.011	0.481	-1.092	-0.369	0.003	0.345	1.002
Temp**	0.187	0,830	-3.204	-0.191	0.187	0.718	2.068

Note: Description of the variables: *Risk premium*=difference in log monthly spot prices observed at time t and futures prices observed at time t-1, *Basis* = difference in log monthly spot and futures prices, *Spot price change* = change in log monthly spot prices from time t-1 to time t, ∆*BIO* = monthly changes in log biomass from time t-1 to t (following time to maturity of futures contract), ∆*PRO* = monthly changes in log quantity of harvested salmon from time t-1 to t, ∆*LOSS*= monthly changes in log quantity of losses in production from time t-1 to t, *Temp** = monthly difference between observed temperature from time t-1 to t and a seasonal normal temperature over the same period. Temp**= monthly difference between observed temperature from time t-1 to t and a seasonal normal temperature over the same period, where the sign of deviation is positive moving towards optimal temperature range of 8-14 and negative moving away from optimal range. 1M, 2M and 3M denotes front month of 1, 2 and 3 months. The number of observations is 96

The risk premium is in figure 5 shows to fluctuate around zero and can be described as mean reverting following. As described earlier the risk premium indicates backwardation when negative and contango when positive.

Figure 5: Shows the variation in risk premium



Note: Risk premium for 1, 2, and 3 month maturity contracts. The risk premium is calculated as difference between log monthly spot at time t and futures observed at time t-1, (Ft-1 – St).

An Augmented Dickey Fuller test was performed on the descriptive data to check for unit root. Two tests were performed; one that check for trend and one that does not. The test results will be summarized in Table 5:

Table 5: Results of Augmented Dickey Fuller test for unit root

	T-stat (no trend)	T-stat (with trend)
Risk premium 1M	-3.969***	-4.074***
Risk premium 2M	-3.828***	-3.920**
Risk premium 3M	-3.472***	-3.596**
Spotprice Δ 1M	-5,751***	-5,703***
Spotprice Δ 2M	-6,457***	-6,424***
Spotprice Δ 3M	-4,972***	-4,932***
Basis 1M	-3.946***	-4.001**
Basis 2M	-4.389***	-4.491***
Basis 3M	-4.108***	-4.231***
ΔBio 1M	-5.424 ***	-5.420 ***
ΔBio 2M	-8.391 ***	-8.391 ***
ΔBio 3M	-11.216 ***	-11.284 ***
ΔPro 1M	-8.619***	-8.577***
ΔPro 2M	-8.150***	-8.114***
ΔPro 3M	-6.896***	-6.889***
LOSSΔ1M	-6.919***	-6.864***
LOSSΔ 2M	-7.950***	-7.8749***
LOSSΔ 3M	-5.875***	-5.819***
Temp* 1M	-3.905***	-4.246***
Temp* 2M	-3,515***	-3,818***
Temp* 3M	-3,399***	-3,721***
Temp**	-5.273***	-5.741***
Critical value 1%	-2,6	-4,04
Critical value 5%	-1,95	-3,45
Critical value 10%	-1,61	-3,15

Note: Description of the variables: *Risk premium*=difference in log monthly spot prices observed at time t and futures prices observed at time t-1, *Basis* = difference in log monthly spot and futures prices, *Spot price change* = change in log monthly spot prices from time t-1 to time t, Δ*BIO* = monthly changes in log biomass from time t-1 to t (following time to maturity of futures contract), Δ*PRO* = monthly changes in log quantity of harvested salmon from time t-1 to t, Δ*LOSS*= monthly changes in log quantity of losses in production from time t-1 to t, *Temp** = monthly difference between observed temperature from time t-1 to t and a seasonal normal temperature over the same period. Temp**= monthly difference between observed temperature from time t-1 to t and a seasonal normal temperature over the same period, where the sign of deviation is positive moving towards optimal temperature range of 8-14 and negative moving away from optimal range. 1M, 2M and 3M denotes front month of 1, 2 and 3 months. The number of observations is 96

All unit root tests show reject unit root and suggests that the time series data used in the analysis is stationary. The Descriptive data looks similar to the study by Asche, Misund, Oglend (2015). Some differences are natural because this study use more recent data input, ranging from January 2008 to December 2015, Compared to June 2006 to June 2014 in their study.

The *hedging efficiency test* use only return on spot and futures prices. These data are time series data and was also tested for stationary. First the descriptive data will be presented before the results from the unit augmented dickey fuller test are presented.

Table 6: Descriptive statistic on spot and futures return ranging from 1-12months.

Return	Mean	St.dev	Min	25%	Median	75%	Max
Spot	0.001	0.062	-0.185	-0.042	0.000	0.048	0.165
F(t-1)	0.002	0.034	-0.144	-0.012	0.000	0.018	0.123
F(t-2)	0.002	0.026	-0.083	-0.010	0,000	0.014	0.115
F(t-3)	0.002	0.024	-0.109	-0.007	0,000	0.014	0.084
F(t-6)	0.002	0.020	-0.118	-0.004	0,000	0.010	0.096
F(t-12)	0.002	0.017	-0.076	-0.002	0,000	0.008	0.072

Note: Return F(t-n): is return on futures contracts with n months to maturity. Return Spot is return on the spot price. All returns are calculated using weekly changes on log scale. As an example Return on Spot is calculated as S(t) – S(t-1).

Since the data is time-series data, the variables are tested for stationary using the ADF with and without trend. Non-stationary data will break an assumption behind OLS and therefore not be appropriate for regression analysis. The results reject unit root and non-stationarity at 0,01 significance level. We can therefore assume that the data is stationary.

Table 7: Unit root test: Augmented Dickey-Fuller

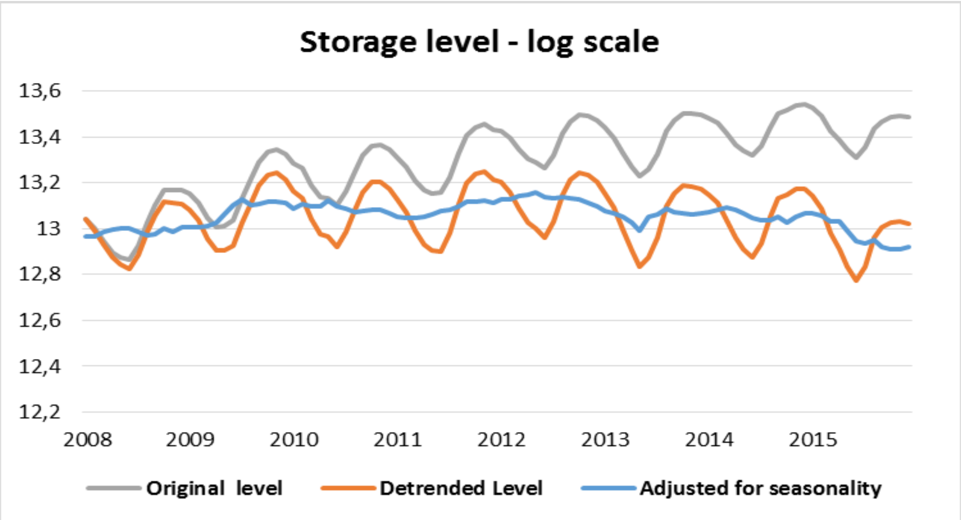
Return	ADF no trend	ADF with trend
spot	-18.522***	-18.509***
F(t-1)	- 14.4939***	-14.5178***
F(t-2)	-13.0319***	-13.096***
F(t-3)	-13.731***	-13.815***
F(t-6)	-13.6687***	-13.754***
F(t-12)	- 14.465***	- 14.6185***

Note: The Augmented Dickey-Fuller test with a null hypothesis that there is a unit root. The significance level is denoted by a asterisk: *:0.1, **:0.05, ***:0.01, The *theory of storage test* use data that that already has been shown such as spot and futures prices, and biomass as indicator for inventory level. The only new variable is the interest rate, which is collect from the Norwegian central bank and the Oslo exchange. The acronym NIBOR stands for Norwegian Inter Bank Offered Rate. This interest rate is important for the money market and Norwegian banks.

To find a suitable measure for inventory I collected data on total biomass of salmon reported to be in the Norwegian fish farms at the end of each month. This data did not make a good fitting model in its original shape, as the R-squared was close to zero and none of the variables significant. The problem was that the production of salmon has been growing rapidly which makes the data include a positive trend. It is easy to see that the data contain seasonal fluctuation. To address this problem the data was first detrended. Then a decomposition model was used to create seasonal factors for each month and adjust the inventory levels for seasonal fluctuations. The reason to adjust for trend and seasonal fluctuation are explained by Cartea and Williams (2007). They propose that the storage level`s effect on the basis is determined by the deviation from the expected seasonal storage level rather than the absolute level.

Using data that was both detrended and adjusted for seasonality showed to be much better for this analysis. The reason is that the trend and seasonal fluctuation created too much noise for the model to capture the relationship it was supposed to. The importance of adjusting the inventory can be understood by looking at Figure 6.

Figure 6: Inventory data, adjusted for trend and seasonality



Note: Storage level data for original data on log scale. Data adjusted for trend and seasonality, from January 2008 - December 2015 in log scale numbers.

The variables in the regression model had to be checked for correlation to avoid an inflated R squared and bias results. The results form the correlation tests are shown below in table 8 and 9.

Table 8: Correlation of variables in risk premium model using 1-3month variables

Correlation on 1month changes

	Basis1m	Changebio1m	Changeprod1m	Temp*
Basis1M	1	-0,008	-0,121	-0,020
ΔBIO1M		1	-0,008	0,005
ΔPRO1M			1	0,082
Temp*				1

Correlation on 2month changes

	Basis1m	Changebio1m	Changeprod1m	Temp*
Basis2M	1	0,123	0,109	0.069
ΔBIO2M		1		0.010
			0,307	
ΔPRO2M			1	0.067
Temp*2M				1

Correlation on 3 month changes

	Basis1m	Changebio1m	Changeprod1m	Temp*
Basis3M	1	0,226	0,232	-0.004
ΔBIO3M		1	0,460	0.072
ΔPRO3M			1	0.126
Temp*				1

Note: *Basis* = difference in log monthly spot and futures prices Δ*BIO* = monthly changes in log biomass from time t-1 to t (following time to maturity of futures contract), Δ*PRO* = monthly changes in log quantity of harvested salmon from time t-1 to t, *Temp** = monthly difference between observed temperature from time t-1 to t and a seasonal normal temperature over the same period. 1M, 2M and 3M denotes front month of 1, 2 and 3 months.

A typical rule of thumb regarding correlation is 0,6. High correlation can lead to negative effects through multicollinearity. There is some correlation in this model, especially in the 3month results. However, with a highest correlation of 0,46 the model does not show an alarming level of correlation.

The same correlation issues are also present in the second model and the same correlation tests have been performed on the adjusted model in Table 9:

Table 9: Correlation on new adjusted model

Correlation on 1 month changes					
	Basis 1M	ΔBIO 1M	ΔPRO 1M	ΔLOSS 1M	Temp**
Basis 1M	1	-0.008	-0.121	-0.278	-0.015
ΔBIO 1M		1	0.137	-0.085	-0.042
ΔPRO 1M			1	0.269	0.006
ΔLOSS 1M				1	-0.010
Temp **					1
Correlation on 2 month changes					
	Basis 2M	ΔBIO 2M	ΔPRO 2M	ΔLOSS 2M	Temp**
Basis 2M	1	0.123	0.109	-0.232	0.0511
ΔBIO 2M		1	0.307	-0.093	-0.056
ΔPRO 2M			1	0.149	0.334
ΔLOSS 2M				1	0.036
Temp **					1
Correlation on 3 month changes					
	Basis 3M	ΔBIO 3M	ΔPRO 3M	ΔLOSS 3M	Temp**
Basis 3M	1	0.226	0.232	-0.249	0.071
ΔBIO 3M		1	0.460	-0.099	-0.044
ΔPRO 3M			1	0.409	0.147
ΔLOSS 3M				1	0.066
Temp **					1

Note: *Basis* = difference in log monthly spot and futures prices, *Spot price change* = change in log monthly spot prices from time t-1 to time t, Δ*BIO* = monthly changes in log biomass from time t-1 to t (following time to maturity of futures contract), Δ*PRO* = monthly changes in log quantity of harvested salmon from time t-1 to t, Δ*LOSS*= monthly changes in log quantity of losses in production from time t-1 to t, Temp**= monthly difference between observed temperature from time t-1 to t and a seasonal normal temperature over the same period, where the sign of deviation is positive moving towards optimal temperature range of 8-14 and negative moving away from optimal range. 1M, 2M and 3M denotes front month of 1, 2 and 3 months.

The same rule of 0,6 for correlation is used. The highest correlation in model 2 is 0,46 between 3-month change in ΔBIO and ΔPRO. The level of correlation between the variables in model 2 is therefore not alarming.

6 EMPIRICAL RESULTS AND DISCUSSION

This section presents the results from the empirical tests. The section is separated into four subsections, one for each main test and focus area. The results in the first three subsections will be discussed in order to explain what the findings tell about the spot-forward relationship. The last subsection will discuss the findings related to how hedging efficiency is connected to time to maturity on futures contracts.

6.1 Unbiasedness hypothesis test

This method tests whether the forecast error of future price and expected future spot price is different from zero. The test is done through a moving average test on the forecasting errors. The results are presented in the Table 10.

Table 10: Results of forecasting error

Market forecast error	Mean error	Standard error	p-value	Median error	Observations
$S_t - {}_{t-1}F_t$	0,026	0,019	0,218	0,016	96
$S_t - {}_{t-2}F_t$	0,030	0,024	0,216	0,004	96
$S_t - {}_{t-3}F_t$	0,041	0,029	0,148	0,007	96

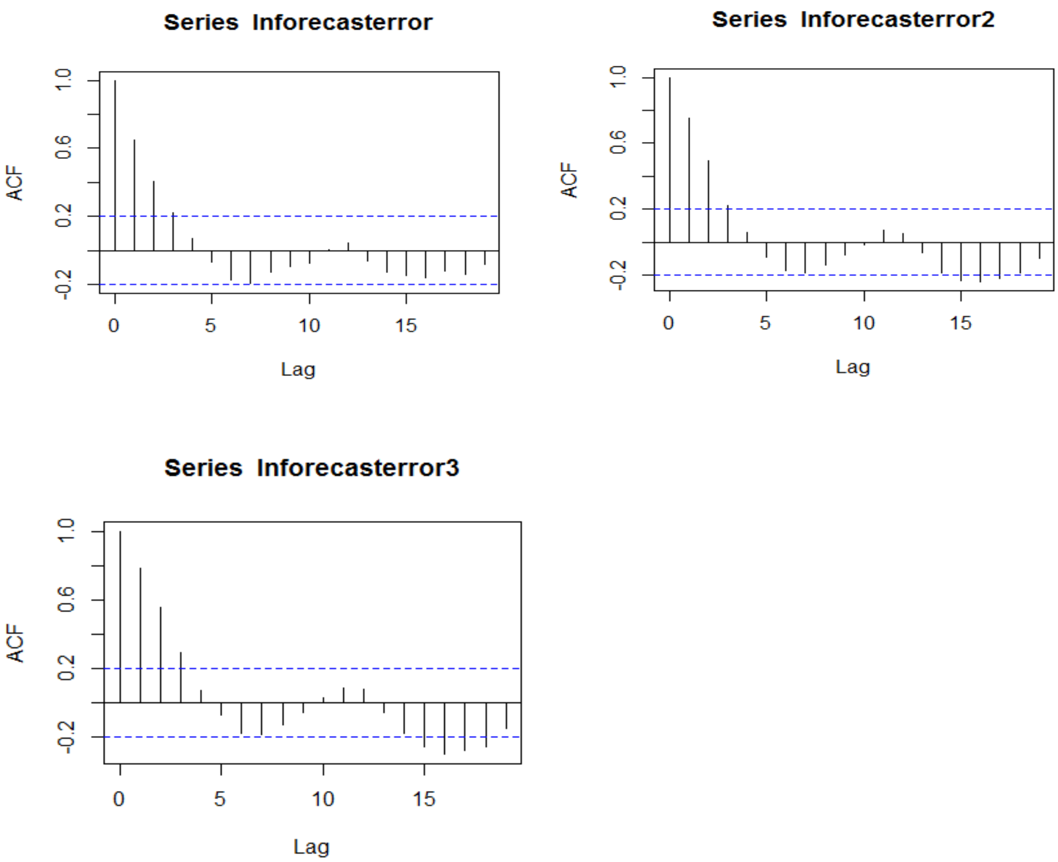
Note: ${}_{t-n}F_t$ is futures price on contract with n month maturity, S_t is spot price

The intercept is positive which is an indicator of a futures market in backwardation. However, the result is not significant so the null hypothesis of the unbiasdness theory is not rejected. Hence, this test does not give empirical evidence to claim that the market is in backwardation. It is worth noticing that the mean error has an increasing trend with time to maturity on the futures contract. This indicate that the forecast error is smaller on futures contracts with short time to maturity compared to contracts with long time to maturity. An explaination can be that availability of relevant information increases as time gets closer to maturity and that longer time to maturity the more unpredicable the price becomes. If the trend continues on 6 and 12 month contracts, it is possible that the results would show significant.

The complexity of fitting the model is a weakness of this test. Since the lagged errors is not observable a non linear fitting method should be used instead of the ordinary least squared method. I followed a suggested guideline for choosing number of lags by looking at the autocorrelation function plots (ACF). The method sugest that the number of lags should be measured by how many lags before the ACF plots are significantly different from zero. By analysing the ACF plots I found 3lags to be the most appropriate for all tests. The ACF plots are shown in Figure 7.

With only one lag the test yielded significant results on the intercept estimate opposite from the results with 3 lags indicating significant results for backwardation. Fitting the model well is therefore very important for the results in this test. Tests where performed in R software using the ARMA function.

Figure 7: Autocorrelation plots of residuals for ARMA models



Note to figure 7:

Series lnforecasterror - ACF plot of residual for ARMA model with 1month ahead forecast errors

Series lnforecasterror2- ACF plot of residual for ARMA model with 2month ahead forecast errors

Series lnforecasterror3- ACF plot of residual for ARMA model with 3month ahead forecast errors

6.2 Storage theory test

To test the theory of storage in the salmon market direct and indirect test has been applied. The direct test used a linear storage model. The model assumed that the net storage costs (marginal storage cost – marginal convenience yield) is a linear function of inventory level. The reason inventory level is used is that the convenience yield is hard to observe and use as an input in models. The model has been used on the gas and oil market in prior studies, but not on the salmon market. (Modjahedi and Movassagh 2005; Cartea and Williams, 2007; Haff, Lindquist, Løland, 2008). If the variables are significant it indicates that, they affect the basis and that, the storage theory explains the variation is spot-forward prices.

The main purpose of the quadratic model is to find information about the net marginal storage costs. The hypothesis by French (1986), suggest that the relationship between net marginal storage cost and inventory is non-linear. The quadratic test is not used on the salmon industry before, but several times in the gas market, in studies by Modjahedi and Movassagh (2005), Falck and Kværner (2010), and Keretsman (2015). The most interesting part about the squared inventory term is that the sign tells us if the relationship is convex or concave. A positive sign suggests a convex model while a negative sign suggest a concave model. It’s also interesting to see if the model is better fitted to explain the relationship as compared to the linear function when looking at the R squared value. The results of the storage model is described in Table 11:

Table 11: Summary results of the direct storage theory test

	Intercept		Storage level		Interest rate		Squared storage level		Model fit
	Estimate	P-value	Estimate	P-value	Estimate	P-value	Estimate	P-value	R²-adj
				Linear Storage Model					
$_tF_{t+1}$ - S_t	-28,49 ***	0,003	2,168 ***	0,003	4,745	0,112	n/a	n/a	0,073
$_tF_{t+2}$ - S_t	-55,151 ***	1,79 -e05	4,198***	1,92 -e05	9,513**	0,013	n/a	n/a	0,174
$_tF_{t+2}$ - S_t	-81,562 ***	3,10 e-08	6,207***	3,46 e-08	14,230 ***	7,8 e-04	n/a	n/a	0,286
				Quadratic Storage Model					
$_tF_{t+1}$ - S_t	-3,954 +e03**	0,023	6,045 +e02**	0,0230	3,505 –e02	0,236	-23,10 **	0,024	0,114
$_tF_{t+1}$ - S_t	-8,637 +e03***	6,76 –e05	1,321 +e03***	7,10 +e05	0,071**	0,046	-50,05 ***	7,45 –e05	0,296
$_tF_{t+1}$ - S_t	-1,351 +e04***	4,04 -e09	2,066 +e03***	4,42 +e09	0,108 ***	0,002	-79,02 ***	4,83 +e09	0,503

Note: The significance level is denoted by ***<0,01 **<0,05 *<0,1

The interpretation of R squared can give us important information about the test. The purpose of is to tell us how well fitted the model is. This regression tells us how much of the variation in Basis (price differences) is explained by the factors in the regression analysis. There is a clear trend in the results that the R squared is larger using futures and interest rates with longer time to maturity.

The storage level is significant for all tests, which indicates that the level of inventory has statistically significant effects on the price differences between Spot and Futures. The sign is positive for all tests. This implies that the futures price strengthens in comparison to the spot price as inventory level increase. This result is as expected and according to what theory discussed earlier implies.

An indirect test proposed by Fama and French (1988) is also applied. Shortly reviewed, this method tests the theory of storage using a different approach. Fama and French (1988) suggest that marginal convenience yield on inventories falls at a decreasing rate as total inventory level increases. This test uses an interest-adjusted basis to find a testable hypothesis about the convenience yield. “The indirect test of the theory of storage is the preferred approach over a direct test, due to the lack of available data for the convenience yield”(Serletis and Shahmoradi, 2006). The indirect test is able to get an estimate of how the marginal convenience yield behaves and relate this to changes in inventory levels.

The indirect method suggests that the interest-adjusted basis is equal to the marginal storage costs less the marginal convenience yield. Similar studies suggest that the marginal storage costs is assumed to be constant which means that the changes are caused by changes in the convenience yield (Brennan 1958; Tesler1958; Serletis and Shahmoradi, 2006). For the model to work appropriately the estimation in equation 12 should yield more positive observations than negative. This condition hold as there are about twice as many positive observations compared to negative.

Table 12: Shows number of positive and negative observations of the indirect storage test

Basis	Positive	Negative	Total
Number of observations			
1month	63	33	95
2month	62	32	94
3month	62	31	93

By looking at the prices and basis on observations when inventory were in the low 25% quartile and the high 25% quartile I found some characteristics that gives insight to the storage theory The findings were that low inventory levels are where associated with negative basis very consistently about 90% of the time while high inventory levels yielded positive basis around 70% of the time. Another finding was that the variance or volatility of spot and futures prices was higher when inventory levels are low compared to when inventory levels are high. The findings indicate that the price shocks are larger when inventory levels are low compared to when levels are high. This is according to theory of how supply and demand shocks are affected by the inventory levels. The findings is evidence to support the theory of storage and its ability to explain the spot-forward relationship.

6.3 The Risk Premium Test

The risk premium test will give insight to the risk premium on the salmon futures market. The section first present the test similar to Asche, Misund, and Oglend (2015). Then the adjusted model will be presented to see if the results are comparable and if the second model was able to improve the original one.

Both models provide evidence that basis explains the differences in the risk premium for 1, 2 and 3 month maturities, similar to results of Fama and French (1987). Harvest also has strong significance, and shows that an increase in production is related to an increase in risk premium. This is similar to the findings of Asche et al. (2015). The biomass factor is significant in most contracts, but not all. This is also similar to the findings of Asche at el. (2015).

The Breusch Pagan test is used to check for heteroscedasticity and the Breusch Godfrey test is used to check for serial correlation. Both tests were not found significant at the 5% significance level. This suggests that there is no evidence of heteroscedasticity or serial correlation in the regression.

Risk premium regression used in model 1 is: $RPt = \alpha 1 + \beta 1 \beta t - n + \sum_{i=1}^{i} BiCVi, t + et^{rp}$
The results from the original model of the is presented in Table 13:

Table 13: Results of risk premium original model

	1month	2month(1)	2month(2)	3month(1)	3month(2)	3month(3)
Intercept	-0,013	-0,012	-0,014	-0,012	-0,013	-0,015
Basis	0,777***	0,892***	0,837***	0,929***	0,886***	0,856***
ΔBIO	0,418*	0,428*	0,245*	0,420*	0,238*	0,123
ΔPRO	0,231**	0,243**	0,166**	0,246**	0,164**	0,131*
Temp*	0,002	0,006	0,001	0,002	0,000	0,002
R^2-adj	0,446	0,638	0,641	0,716	0,716	0,699
F-test	20,1***	42,87***	43,38***	60,97***	60,99***	56,11***
N	91	91	91	91	91	
Breusch	8,108	6,747	6,441	6,521	6,197	6,515
Pagan	(0,088)	(0,149)	(0,169)	(0,163)	(0,185)	(0,164)
Breusch	0,754	0,102	1,859	0	0,824	3,043
Godfrey	(0,388)	(0,7501)	(0,176)	(0,999)	(0,367)	(0,084)

Note: The significance level is denoted by ***=0,01 **=0,05 *=0,1

A main issue of the regression analysis with several production risk factors is that model fit can be inflated by high correlation among the variables. This would lead to unnaturally high R-squared and model fit. The variance inflator factor was tested but yielded low results that were far from alarming. In addition to the VIF test, the correlation among factors where tested and presented as table 11,12 and 13 in the data section.

The second adjusted model includes a variable for loss in production, it also includes a different temperature variable. The main difference is that it captures if the deviation away from average is toward the optimal or away from optimal production temperature (defined as 8-14 degrees Celsius).

The results form the adjusted model is similar to the results from model 1 in many ways, but have some interesting differences that will be discussed in this paragraph. The new variable LOSS, which measure amount of dead fish, is insignificant in all tests except on the 3month(3M). There are some weaknesses in the reliability of this variable as it has been in the media that some companies report false numbers to avoid sanctions. The variable also shows a clear trend of decreasing p-value with more time to maturity. It is possible that the variable captures the producer’s ability to fight diseases and sickness and that one-month is too short to capture this. Another possible explanation is that 3 months capture a whole seasonal change in the aqua cultural environment.

The new temp variable (temp**) is insignificant for all maturities, however the p-value is much lower than temp*. The conclusion is that the new variable strengthens the fit of the model slightly and therefore helps to explain more of the variation in the risk premium. The results of the adjusted model is presented in Table 14:

Table 14: Results of adjusted risk premium test

	1month	2month	2month(2)	3month	3month(2)	3month(3)
Intercept	-0.015*	-0.014	-0.015	-0.0135	-0.014	-0.015
Basis	0.445***	0.906***	0.858***	0.943***	0.908***	0.897***
ΔBIO	0.445**	0.459**	0.279***	0.454**	0.274***	0.182**
ΔPRO	0.215***	0.222***	0.127**	0.223***	0.123*	0.053
ΔLoss	0.028	0.035	0.029	0.037	0.030	0.041*
Temp**	0.012	0.013	0.010	0.013	0.010	0.010
R^2-adj	0,451	0,644	0,646	0,721	0,720	0,708
F-test	20,7	35,3	35,6	50,15	94,92	47,11
N	91	90	90	90	90	90
Breusch Pagan	0.382	0,768	0,646	0,793	0,716	0,513
Breusch Godfrey	0.382	0,730	0,215	0,987	0,442	0,179

Note: *Basis* = difference in log monthly spot and futures prices, *Spot price change* = change in log monthly spot prices from time t-1 to time t, Δ*BIO* = monthly changes in log biomass from time t-1 to t (following time to maturity of futures contract), Δ*PRO* = monthly changes in log quantity of harvested salmon from time t-1 to t, Δ*LOSS*= monthly changes in log quantity of losses in production from time t-1 to t, Temp**= monthly difference between observed temperature from time t-1 to t and a seasonal normal temperature over the same period, where the sign of deviation is positive moving towards optimal temperature range of 8-14 and negative moving away from optimal range. 1M, 2M and 3M denotes front month of 1, 2 and 3 months. Significance is denoted by asterisks: ***<0,1 **<0,5 *<0,1

6.4 Test of Hedging Efficiency and Time to Maturity

The purpose of this test is to investigate the relationship between time to maturity on futures contracts and the hedging efficiency. Two methods where used with 1, 2, 3, 6, and 12month maturity of futures contract to be able to compare the efficiency with different maturity contracts. The results are presented in table 18:

Table 15: Describes hedging method, hedge ratio used and hedging effectiveness

	Hedge ratio	Effectiveness
Unhedged position	0	0
Naïve hedge 1 month	1	16,6 %
Naïve hedge 2 month	1	8,8 %
Naïve hedge 3 month	1	9,9 %
Naïve hedge 6 month	1	1,5 %
Naïve hedge 12 month	1	1,4 %
Optimal hedge 1 month	0,787	18 %
Optimal hedge 2 month	0,765	9,7 %
Optimal hedge 3 month	0,837	10,3 %
Optimal hedge 6 month	0,580	3,4 %
Optimal hedge 12 month	0,604	2,5 %

Note: the number of month is time to maturity on futures contracts used in hedge.

The optimal hedge ratios showed to be between 0,837 and 0,580. This is lower than the fully hedge method with a hedge ratio of 1. The two methods showed fairly similar results, but the optimal variance method was slightly more efficient than the naïve hedging method. The most efficient hedge was using optimal variance method on futures with 1month maturity, which decreased variance in returns by almost 18%. The second best was naïve hedge also using futures with 1-month maturity decreasing returns by 16.6%. The worst result was 1%, using naïve hedge on 12-month futures. The results seem to depend more on maturity on futures contract than the choice of method. The efficiency of hedging was modest and lower than in the study of Asche and Misund (2015). It is possible that the more recent data set influence this. The yearly hedge ratios showed a clear trend of being higher in recent years, and lower in the first years. This indicates that the volatility is changing and is different in the first years compared to the last years of the data set. This is not captured using a constant hedge ratio and it is possible that more advanced methods that allows hedge ratios to change would have outperformed the constant method.

The results show a clear correlation between hedging efficiency and time to maturity on futures contracts for both hedging methods. Futures with near month to maturity are significantly more efficient as hedging instruments than futures with distant time to maturity. The result is according to the proposed hypothesis, which suggested that the hedging efficient become worse as maturity of futures contracts used increases. The result is also comparable to evidence on the oil price from a similar study by Ripple & Moosa (2007).

An explanation to why near month contract perform better at hedging is proposed by Ripple and Moosa (2007). They suggest that the covariance between spot and futures is higher at near month contracts and that this leads to improved hedging efficiency. They compared the results in horizon matching contracts and to see if the expected lower volatility in long-term contracts gives better hedging efficiency. They found that the effect of higher covariance in near month contracts outweighs the effect of decreased volatility in distant month contracts. This is due the small improvement in covariance that has a large effect on the hedging efficiency. The improved covariance can be related to trading volume and how mature the futures market is. In a mature market futures prices adjusts faster and more frequently to match the “correct” spot price. The trading volume on 6 and 12-month futures contracts are lower than on near month contracts and be a reason to why the 6 and 12 month contracts performed worst.

7 CONCLUSION

This thesis has investigated the relationship between spot and forward prices of Atlantic salmon. It also looked into how maturity of futures contracts relate to hedging efficiency. Several tests have been used to attain empirical evidence. The results and implications of the four main tests will be summarized in this section. All tests used price data ranging from January 2008 to December 2015.

All tests also included time series data sets; therefore, the Augmented Dickey Fuller test was used to test for unit root. To deal with non-stationary data some variables needed to be changed into first-difference numbers and most data was transformed into log scale numbers. All variables used in the regression analysis showed significant results indicating stationary data, rejecting the random walk.

Three basic theories of the spot-forward relationship were tested in this thesis. The rational expectation theory (unbiasedness theory), the theory of storage, and the hedging pressure hypothesis (risk premium theory).

The unbiasedness test used an ARMA model to analyze forecasting errors to see if the futures price is an unbiased predictor of the expected future spot price. The results showed positive forecast error on 1,2 and 3-month maturity futures contracts, meaning that the spot was higher than the futures. A positive forecast error would imply that the risk premium is negative and that the market is in normal backwardation. However, the estimates were very close to zero and did not yield significant results away from zero. Therefore, the results cannot be used as empirical evidence for a market in normal backwardation, but rather to explain that the futures price is an unbiased predictor of the future spot price. Another explanation for the unbiasedness can be that the salmon market is still immature and that the spot leads the futures price as found by Asche, Misund and Oglend (2016). The results showing an unbiased relationship, is a key finding of this thesis and gives insight to the spot-forward relationship.

The test of the storage theory used a linear and a quadratic model in a regression analysis to investigate how the storage level relate to price differences between spot and futures. The models used 1,2 and 3-month maturity on futures contracts. All tests showed a significant and positive relationship, which indicates that the inventory levels affect increases the basis. The logic behind this is that higher inventory levels is correlated negatively with convenience yield and therefore leads the spot price to decrease more than futures price. The test also showed positive significant results on the squared storage level variable. A positive sign in the quadratic model is evidence of a convex relationship. The interest variable was showed positive sign and was significant on 2 and 3 month futures, but not on 1 month futures. This suggests that the cost of capital is affects the basis for contracts of 2months or longer. The interest results is according to theory, which suggest that the cost of capital becomes more important on long term contracts than short term contracts. The storage model fit is not very high and it is therefore likely that other variables can help explain more of the changes in the basis. Spot price volatility is most likely an important omitted variable in this model. When price volatility is high the value of holding the asset also becomes higher and basis will most likely decrease.

The risk premium test helps to explain the futures market and will give evidence of the hedging pressure hypothesis. The risk premium was on average negative, which indicates backwardation a necessary condition for the hedging pressure hypothesis to hold. The regression analysis showed that the basis has a positive and significant relationship to the risk premium for all tests and maturities on futures contracts similar results of Fama and French (1987). A model that included several industry specific production risk factors was used and showed that these variables improved the fit of the model and helped explain the variation in risk premium. These findings were similar to Asche, Misund, and Oglend (2015). Biomass and harvesting showed positive significant results, while temperature showed insignificant results. In addition to this, I run an adjusted model including loss of fish in production and a temperature that captured deviations away from optimal growth temperature, instead of only deviations away from monthly average. The model showed to help explain the variation in risk premium as the R-squared increased slightly. However the variables showed to not be significant except for loss in production using 3-month futures and 3-month changes in variables. The temperature variable showed lower p-values in the adjusted model, but was not significant. With further improvement such as limiting the optimal temperature to a smaller range, it might show to be significant.

The last test was aimed to test the relationship between hedging efficiency and maturity on futures contracts. The findings of this test were that there is a clear trend of decreasing hedging efficiency as maturity on futures contracts increased. The higher trading on near month contracts seems to help adjust the prices to a “correct” level, which improve the covariance between spot and futures. The evidence is strong enough to claim that near month futures is better as hedging tools than distant futures contracts on the Atlantic salmon market.

REFERENCES

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control IEEE Trans. Automat*. Contr., 19(6), 716-723.

Asche, F., Misund, B.. (2015). Hedging Efficiency of Atlantic Salmon Futures. *University of Stavanger Working Papers in Economics and Finance.* <Available from: https://ideas.repec.org/p/hhs/stavef/2015_012.html> (Assessed: 2nd February)

Asche, F., Misund, B., & Oglend, A. (2015). Production Risk and the Futures Price Risk Premium?. *University of Stavanger working papers in Economics and Finance.*

<Available from: https://ideas.repec.org/p/hhs/stavef/2015_013.html > (Accessed: 2th February)

Asche, F., Misund, B., & Oglend, A. (2016). The spot-forward relationship in the Atlantic salmon market. *Aquaculture Economics & Management, 20(2),* 222-234.

Bjørnland, Hilde Christiane, and Leif Anders Thorsrud. *Applied Time Series for Macroeconomics*. Oslo: Gyldendal Akademisk, 2014. Print.

Black, D.G. (1986) *Success and Failure of futures contracts: Theory and Empirical Evidence*. Monograph No. 1986-1, Monograph Series in Financial and Economics, Salomon Brothers Center for the Study of Financial Institutions, Graduate School of Business Administration, New York University

Brennan, M, J. (1958). The supply of storage, American Economic Review, 48, 50-72.

Breusch, T. S. (1978). Testing For Autocorrelation In Dynamic Linear

Models*.*Australian Economic Papers Aust Econ Papers*, *17*(31), 334-355.

Breusch, T. S., & Pagan, A. R. (1979). A Simple Test for Heteroscedasticity and Random Coefficient Variation. *Econometrica*, *47*(5), 1287. doi:10.2307/1911963

Brorsen, B. Wade and N`Zue F. Fofana (2001). Success and Failure of Agricultural Futures Contracts, *Journal of Agribusiness 19*, 2: 129-145.

Carlton, D.W. (1984). Futures markets: Their purpose, their history, their growth, their successes and failures. *Journal of Futures Markets 4*, 237-271

Cartea, A. (2008). UK Gas Markets: The Market Price of Risk and Applications to Multiple interruptible Supply Contracts. *Energy Economics*, 30(3), 829-846.

Disatnik. D., Duchin. R., Schmidt. B.. (2014). Cash Flow Hedging and Liquidity Choices. Review of Finance 18(2). 715-748.

Ederington, L.H. (1979). The hedging Performance of the New Futures Markets. *The Journal of Finance*, 34(1)

Falck, J. C., Kværner, J.S. (2010) *The forward-spot spread in the natural gas market: an empirical investigation of Henry Hub and NBP.* Available from: < http://hdl.handle.net/11250/168806 > (Accessed 10 April 2016)

Fama, E. F., & French, K. R. (1987). Commodity Futures Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage. *The Journal of Business JBUS, 60(1), 55.*

Fama, E. F., & French, K. R. (1988). Business cycles and the behavior of metal prices, *Journal of Finance,* 63, 1075-1093

French, K. R. (1986). Detecting Spot Price Forecasts In Futures Prices. *The Journal of Business J BUS, 59*(S2). doi:10.1086/296338

Geman, H., Smith,W.O. (2012) Theory of storage, inventory and volatility in the LME base metals, *Resources Policy. 38(1),* 18-28. <Available from: http://dx.doi.org/10.1016/j.resourpol.2012.06.014> (Accessed: 15march)

Guay, W.R. (1999). The impact of derivatives on firm risk: An empirical examination of new derivatives users. *Journal of Accounting and Economics* 26. 319-351<Available from: http://down.cenet.org.cn/upfile/36/200592817309196.pdf> (Accessed: March 18th)

Guay, W., Kothari, S.P. (2003). How much do firms hedge risk with derivatives? *Journal of Financial Economics 80,* 423-46 <Available from: http://www1.american.edu/academic.depts/ksb/finance_realestate/mrobe/Library/how much.pdf > (Accessed:20th February)

Haff, I. H., Lindqvist, O., & Løland, A. (2008). Risk premium in the UK natural gas forward market. *Energy Economics*, 30(5), 24200-2440.

Hull, John C. *Options, Futures, and Other Derivatives*. 9th ed. Upper Saddle River: Pearson Education, 2015. Print.

Horsnell, P., Brindle, A., and Greaves, B. (1995). The Hedging Efficiency of Crude Oil Markets, *Oxford Institute of Energy Studies*.

Jin, T. Jorion, P., 2006. Firm value and hedging: Evidence from U.S. oil and gas producers. *Journal of Finance 61,* 893-919 <Available from: http://jsmith.cox.smu.edu/fina6224/Readings/Jin%20and%20Jorion.pdf> (Accessed: 15th February)

Kaldor, N. (1939). Speculation and Economic Stability. *The Review of Economic Studies, 7*(1), 1. doi:10.2307/2967593

Keretsman, O. (2015) An empirical study of the spot-forward relationship for natural gas and crude oil markets. Print.

Mankiw, N.G. (2011). *Principles of Economics (6th ed.).* Mason, OH: South-Western Cengage Learning. Page 686

Matinez-Garmendia, J., & Anderson, J.L. (1999). Hedging performance of shrimp futures contracts with multiple deriverable grades. J.Fut. Mark. *Journal of Futures Markets*, 19(8).

Mello, A., Parsons,J.E. (1999). Hedging and Liquidity. Review of Financial Studies 13(1). 127-153. <Available from: http://www.mit.edu/~jparsons/publications/Hedging%20&%20Liquidty.pdf> (Accessed: 3rd March)

Modjathedi, B., & Movassagh,N . (2005). Natural-gas futures: Bias, predictive performance, and the theory of storage. *Energy Economics*, 27(4), 617-637.

Movassagh, N., & Modjahedi, B. (2005). Bias and Backwardation in natural gas futures prices. *J. Fut. Mark. Journal of Futures Markets*, 25(3), 281-308. doi:10.1002/fut.20151

Oglend, A. (2013). Recent Trends In Salmon Price Volatility. *Aquaculture Economics & Management*, *17*(3), 281-299. doi:10.1080/13657305.2013.812155

Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, *75*(2), 335-346. doi:10.1093/biomet/75.2.335

Ripple, R. D., & Moosa, I. A. (2007). Hedging effectiveness and futures contract maturity: The case of NYMEX crude oil futures. *Applied Financial Economics*, 17(9), 683-689.

Said, S. E., & Dickey, D. A. (1984). Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order. *Biometrika,* 71(3),599. doi:10.2307/2336570

Serletis, A. (1991). Rational Expectations, Risk and Efficiency in Energy Futures Markets. *Energy Economics*, 13(2).

Serletis, A., & Shahmoradi, A (2006). Futures trading and the storage of North American natural gas. *OPEC Review*, 30(1), 19-26.

Silber, W. L. (1981). "Innovation, competition, and new contract design in futures markets. "*Journal of Futures Markets 1,* 123-155.

Switzer, L.N., El-Khoury, M., (2007). Extreme volatility, speculative efficiency, and the hedging effectiveness of the oil futures market. *Journal of Futures Markets*

Tesler, L.G. (1958). Futures Trading and the Storage of Cotton and Wheat. *J. Political Economy 66:* 233-255

Working, H. (1948). Theory of the Inverse Carrying Charge in Futures Markets. *Journal of Farm Economics*, 30(1), 1. Doi: 10.2307/1232678

Reports

Marine Harvest. (2015). Salmon Farming Industry Handbook 2015. <Available from: http://www.marineharvest.com/investor/industry-handbook/Z (Accessed: March 19th)

Meld. St. 16 (2015). Forutsigbar og miljømessig bærekraftig vekst i norsk lakse- og ørretoppdrett. Nærings- og fiskeridepartementet < Available from: https://www.regjeringen.no/no/dokumenter/meld.-st.-16-2014-2015/id2401865/> (Accessed: 17th March)