AN ANALYSIS OF THE SAMUELSON HYPOTHESIS IN SOUTH AFRICA

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Abstract

This study empirically investigates the existence of the Samuelson Hypothesis in South African markets. The Samuelson Hypothesis states that the volatility of futures contracts increase as the expiration of the contracts approaches. It is an important phenomenon to account for when setting margins, creating hedging strategies and valuing options on futures. The study utilizes daily closing prices of agricultural and non-agricultural futures contracts for a period varying from 2002 to 2015. In total, eleven contracts were examined over this period, yet only one (White Maize) consistently shows support for the Samuelson Hypothesis. The Negative Covariance and State Variable Hypothesis were tested, but could not provide an alternative explanation for the lack of relationship between the time to maturity and volatility of futures contracts.

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1 INTRODUCTION

The futures instrument has been one of the most notable innovations, comprising high levels of activity (Edwards, 1988). The fundamental idea behind the futures market is that it enhances the liquidity of the underlying stock market (Veljanovski, 1985), enables investors to hold greater positions in the market and have increased risk exposure, with lower transaction costs in comparison to the spot market (Bessembinder & Seguin, 1992), provides arbitrage opportunities and increases the efficiency of the underlying market (Wahab & Lashgari, 1993).

The South African Futures Exchange grew out of an informal market in April 1987, whereby a local merchant bank (Rand Merchant Bank) started an informal financial market (Adelegan, 2009). Subsequently, option contracts were introduced in 1992, agricultural commodity futures in 1995 and a fully automated trading system in 1996. Futures trading on the equity market was introduced on the South African Foreign Exchange (furthermore known as SAFEX) in 1990 and agricultural futures were introduced on the SAFEX in 1995. As a subsection of the derivatives market, the futures market has grown at an increasingly rapid pace in South Africa since inception (Adelegan, 2009). This study will investigate the volatility of the futures contracts by assessing the Samuelson Hypothesis, also referred to as the maturity effect, which proposes that future price volatility increases as the future contract approaches its time of expiration (Samuelson, 1965). Several studies have investigated the Samuelson Hypothesis, however, support for Samuelson (1965)'s theory is conflicting. The main studies that have significantly contributed to investigating the Samuelson Hypothesis are Anderson (1985), Bessembinder, Coughenour, Seguin and Smoller (1996) and Duong and Kalev (2008). A number of researchers find the effect in certain futures contracts such as Rutledge (1976), Anderson (1985) and Milonas (1986). Other authors do not find substantial evidence supporting the Samuelson Hypothesis namely Chen, Duan and Hung (1999) and Floros and Vougas (2006).

Volatility may cause an increase in the risk exposure of investors and have negative effects on their wealth and investments (Edwards, 1988). Edwards (1988) reasons that increased volatility, at the expiration of a futures contract, is the result of market participants unwinding their cash positions. This is a potential explanation of the maturity effect and it causes the elimination of any basis[1] risk. Other possible explanations for the Samuelson Hypothesis range from the Negative Covariance Hypothesis and the State Variable Hypothesis. The first hypothesis states that the presence of the Samuelson Hypothesis is due to the negative covariance that exists between the spot price changes and the change in net carry costs[2] (Bessembinder, Coughenour, Seguin, & Smoller, 1996). Hence, this hypothesis is referred to as the Negative Covariance Hypothesis (Duong & Kalev, 2008). The second hypothesis, the State Variable Hypothesis, emphasises the role of information flow in explaining the time pattern of the futures price volatility (Anderson, 1985).

This study will contribute to the literature by determining whether South African markets future indexes are consistent with the proposed Samuelson Hypothesis. This study will identify if there is more support for the Samuelson Hypothesis in agricultural futures than other futures, as stated by international studies. This study will be unique as it will be the first to examine the Samuelson Hypothesis with special reference to the South African market.

There are three main reasons for the interest in the Samuelson Hypothesis. Firstly, Gurrola and Herrerias (2011) explain that the clearinghouses set margin requirements on the basis of the volatility of future prices. Board and Sutcliffe (1990) convey that the relationship is important to margin setting for future contacts. The desired margin is positively related to the futures contract price volatility. Therefore if the futures price volatility increases as the futures contract approaches maturity, as suggested by the Samuelson Hypothesis, the cash balance held by traders to cover for margin calls should also be increased as the maturity date approaches.

Secondly, the relation between volatility and time to maturity has implications for hedging strategies. If the relationship between volatility and time to maturity is negative or positive, it will have different implications for hedging as hedgers should choose futures contracts with

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[1] Basis refers to the spot price of the underlying asset minus the price for a future contract at any point in time (Brown & Reily,2008).

[2] Net carry costs is the difference between the natural logarithm of futures prices and spot prices, weighted by the time to maturity.

either a short or long time to maturity, such that the price volatility is minimized. When the Samuelson Hypothesis holds, traders might consider switching to contracts further away from expiration day otherwise they will face higher volatility and require a higher risk premium (Duong & Kalev, 2008).

A final reason for the interest in the Samuelson Hypothesis is that since the volatility of the underlying asset is an important input for pricing options, the relation between volatility and maturity should be considered when pricing options on futures. Higher volatility of the underlying asset provides greater potential gains for option buyers. As a result, evidence supporting the Samuelson Hypothesis will suggest a rise in the price of options on futures such that option sellers are compensated for the risks they face (Duong & Kalev 2008).

The delimitations of the paper is that only eleven contracts for a varying time period from 2002 to 2015 were assessed. Another delimitation is that the daily prices are utilised, where according to Duong and Kalev (2008) the intraday prices are more suitable for the estimation of volatility. As the daily prices that are utilised fail to account for all available information and intraday price fluctuations.

The remainder of the study proceeds as follows: Section 2 provides a literature review examining the Samuelson Hypothesis and its empirical evidence. Section 3 outlines the data used, data organisation and sets out the methodology employed to conduct the differing tests. Section 4 is the empirical results and discussion segmented by the test performed; Section 5 concludes the study.

2 LITERATURE REVIEW

2.1 Background

Allen and Cruickshank (2000) explain that there is a general belief that there is an inherent risk in futures markets (primarily attributed to speculative activities), which caused research into the causes of futures price volatility in a number of markets. Factors such as trading volume and time to contract maturity are common explanations. In Samuelson (1965)'s paper called 'Proof that Properly Anticipated Prices Fluctuate Randomly', he affirms that the volatility of future prices will increase as the futures contract approaches its maturity. This hypothesis is referred to as the Samuelson Hypothesis or the maturity effect.

Anderson (1985) explains the Samuelson Hypothesis in more detail and states that assuming the price of the good for immediate delivery follows a stationary first-order autoregressive process and the price of the good for deferred delivery (future price) is an unbiased predictor of the price at delivery date, then the variance of the daily price changes increases as the delivery date approaches. The hypothesis relies on strong assumptions, firstly the assumption of a first-order autoregressive process is very restricting (Anderson, 1985). Samuelson (1976) found that for higher-order stationary autoregressive processes the variance is not commonly monotonically decreasing with the time to maturity. Samuelson (1976) obtains that the weaker result of the futures variance is when delivery is sufficiently distant, compared to the greater variance when the same contract nears maturity. Another assumption is that the result is invalid when the cash price is non-stationary meaning that the assumption is violated if there is a trend to cash prices, as would occur if the first-order autoregressive parameter exceeded unity. Anderson (1985) continues to explain that the assumption will also be violated if the underlying shocks to the cash price exhibited non constant variances. The third and final assumption is that the futures price equals the expected value of the price at the delivery date, which goes against the finding of work on asset pricing such as Cox, Ingersoll, and Koss (1978). Their study illustrated that for a wide class of assets the expectations hypothesis does not generally hold (Anderson, 1985).

Throughout the years of empirical studies there have been mixed results as to whether the Samuelson Hypothesis does truly exist. Moreover, there seems to be more evidence that the Samuelson Hypothesis exists in agricultural futures contracts than in financial futures contracts (Duong & Kalev, 2008). There are two main extensions of the Samuelson Hypothesis, the first one being the Negative Covariance Hypothesis. The Negative Covariance Hypothesis argues that a futures contract exhibiting a negative covariance between its spot price change and the change in the slope of the future term structure would demonstrate support for the Samuelson Hypothesis (Bessembinder et al, 1996). Bessembinder, Coughenour, Seguin and Monroe (1995) explain that the slope of the futures term structure is defined as the change across delivery dates in the futures price observed on a given trading date. An inverse relation between prices and the futures term slope constitutes evidence that investors expect mean reversion in spot prices. Bessembinder et al. (1996) demonstrate that the Samuelson Hypothesis does not require prices to be strictly stationary; and rather the existence of a temporary component in price changes, along with a permanent component introduced by general price level inflation, is sufficient. The analysis predicts that the maturity effect will only hold in markets where the spot price changes include a temporary component, so investors expect a portion of a typical price change to be reversed in the future.

The second extension is referred to as the State Variable Hypothesis and it concludes that the source of volatility of the futures price is the degree of information flow to the market (Anderson & Danthine, 1983). Bessembinder et al. (1996), illustrate that it is possible that a systematic clustering of information flow near the futures delivery dates could cause a corresponding increase in the price change variances, which is consistent with the Samuelson Hypothesis. However, they note the absence of any compelling explanations for why information flows should cluster near futures maturity dates, as in the case for agricultural futures where contracts were not only maturing near harvest dates, but throughout the year. They also assert that time variation in information flow is not a necessary condition for the Samuelson Hypothesis, which is expected to hold in some markets where information flows fail to cluster near the futures delivery date. Thus, explanations that invoke systematic variations with the rates of information flow are unlikely to provide an accurate cross-sectional prediction regarding the validity of the Samuelson Hypothesis. The empirical evidence relating to the Negative Covariance Hypothesis and State Variable Hypothesis is not as robust as the original articulation relating to the Samuelson Hypothesis.

2.2 Empirical Results of the Samuelson Hypothesis

2.2.1 Strong Evidence Supporting the Samuelson Hypothesis

One of the very first authors to investigate the Samuelson Hypothesis was Rutledge (1976). He studied a 1969 wheat contract, a 1970 silver contract, a 1970 cocoa contract and a 1971 soybean oil contract. By using the daily price observation, expressed as logs and taking the absolute value of price differences as a measure of volatility, Rutledge (1976) employed a goodness-of-fit test for a three-way contingency table (Daal, Farhat, & Wei, 2006). His results found support for the Samuelson Hypothesis for the silver and cocoa commodities but failed to find support in the wheat and soybean oil contracts.

Dusak-Miller (1979) follows Rutledge (1976)'s study and investigated the Samuelson Hypothesis with June and December live cattle futures contracts. The study considered the period from 1964 to 1972 and computed the correlation coefficients between the volatility and the time to maturity of the contract (Dusak-Miller, 1979). The study found a significant negative relationship, thus also finding support for the Samuelson Hypothesis.

Castelino and Francis (1982) tested the Samuelson Hypothesis using daily data from 1960 to 1971 for futures listed on the Chicago Board of Trade. The study analysed wheat, corn, soybeans, soybean meal, soybean oil, and copper using the daily spot prices. The authors employed a natural logarithm of the price to examine price variance rather than taking the absolute daily price change. Using the ordinary least squares (furthermore knows as OLS) regression each contract was examined individually using no rollover construction period to create a continual time series, with no mention of excluding data before the maturity month (Castelino & Francis, 1982). Rolling over contracts is a common method followed within the literature, as at any given time it is believed that most trading activities are concentrated in a single contract, usually the contract closest to maturity. Therefore the data for the contract that is closest to maturity is included, but when the contract enters its month of expiration, the price for the next contract nearest maturity is chosen. Castelino and Francis (1982)'s study found that all the commodities tested exhibited the Samuelson Hypothesis and then ranked on which conformed best, with soybean meal ranking first and soybean oil last.

In Anderson (1985)'s study, various statistical techniques were employed, which lead to findings that supported the Samuelson Hypothesis; yet it was recognized in his paper that the seasonal patterns were an important determinant of volatility in future prices. Anderson (1985) assessed the daily data of the Treasury bond futures market from 1977 to 1984 and discovered strong evidence that supported the Samuelson Hypothesis even when the State Variable Hypothesis was applied (Barnhill, Jordan, & Seale, 1987). According to Anderson (1985) the specific form of the State Variable Hypothesis depends upon the nature of the supply and demand uncertainty. He further explains that if the demand uncertainty is dominant and if factors affecting the ultimate demand are subject to progressively greater shocks as the demand date approaches then the futures price variance would increase over time.

As previously discussed, the State Variable Hypothesis is an alternative to the Samuelson Hypothesis, arguing that heterogeneous information flows lead to violations of the Samuelson Hypothesis. The daily data of the Treasury bond future market was investigated from 1977 and 1984 by Barnhill, Jordan and Seale (1987). They found strong evidence to support the maturity effect, even when the State Variable Hypothesis was applied. Allen and Cruickshank (2000) examined commodity contracts on the Sydney, London and Singapore exchanges and found evidence favouring the existence of the Samuelson Hypothesis in the majority of the contracts examined.

Robust evidence for the Samuelson Hypothesis was also found in a study conducted by Milonas (1986), who examined wheat, corn, soybeans, soybean meal, soybean oil, GNMA, T-bonds, copper, gold and silver contracts for the period 1972 to 1983. The study analysed the commodities by calculating the price variance using the natural logarithm of price change, and conducting an OLS regression and then assessing the robustness of the results with an ANOVA test. Milonas (1986) normalised the contracts in order to adjust for a seasonality bias, which is a version of rolling over contracts, but does not exclude data near the maturity date. He found support for the hypothesis in 10 out of the 11 commodities analysed, corn being the exception and he also mentioned that agricultural futures are more consistent compared to metals and financial contracts.

2.2.2 Weak Evidence for the Samuelson Hypothesis

Chen, Duan and Hung (1999) used the Nikkei-225 index spot and futures to examine the Samuelson Hypothesis and focused on the hedging implication under both stochastic volatility and time varying future maturities. The authors employed a bivariate GARCH time series model with the maturity effect in order to model the joint dynamics of the spot index and the futures-spot basis. They found no support for the maturity effect and found that volatility of future prices decreases as contracts tend to maturity, thus their results contradicts the Samuelson Hypothesis. Their results indicate that the two optimal hedge ratios under stochastic volatility differ from the traditional constant hedge ratio. Furthermore, the maturity of the futures contract affects the optimal hedge ratio under the scenario of stochastic volatility. The study also demonstrates that the constant volatility assumption, lack of consideration of the maturity effect, leads to over hedging which induced unnecessary risk exposure.

Pati and Kumar (2007) examine the Samuelson Hypothesis in India, which they refer to as the first paper to investigate this effect in the Indian futures market. They utilise the daily closing price in calculating the natural log returns and ARCH models for the Nifty Index futures. The methodology employed in this study rolls the future contracts into a longer time series, by excluding four days before the contract matures (Pati & Kumar, 2007). Pati and Kumar (2007) find that the Samuelson Hypothesis doesn't exist when looking at the Nifty Index as the time-to-maturity coefficient was statistically insignificant.

Floros & Vougas (2006) examined the Samuelson Hypothesis on index futures contract by using daily data from the Athens Derivatives Exchange. Their research found that from 2003 to 2006 the maturity effect might have been present in some periods, yet overall there is no evidence of the effect when all the contracts are considered. In a later study conducted by Gurrol and Herrerias (2011) in Greece the Samuelson Hypothesis was not found to be present.

2.2.3 Industry Specific Research for the Samuelson Hypothesis

A few authors have specifically focused on the S&P 500 while studying the Samuelson Hypothesis. Park and Sears (1985) studied S&P 500 indices and the NYSE composite indices and found support for the Samuelson Hypothesis. However, Han and Misra (1990) repeated the study five years later and found no support for the hypothesis while using the S&P 500 index. The results found by Han and Misra (1990) were confirmed by Galloway and Kolb (1996). Galloway and Kolb (1996) examined a large data set, comprising of forty five commodities from 1969 to 1992. Their analysis found that the time-to-maturity variable has a significant negative relationship to the monthly return variance for many agricultural commodities, for all energy commodities and for copper.

Akin (2003) analysed 11 commodities on the Chicago Mercantile Exchange focusing on foreign exchange, interest rates on currencies and equity indexes. She used the daily settlement price instead of the closing price and chose to roll over contracts into a continuous time series and exclude the month of maturity. A GARCH model was applied, which account for heteroskedasticity and leptokurtosis that can be present in a financial time series model (Akin, 2003). The study identified several new patterns in the data set. Firstly, a strong time-to-maturity effect is found for currency futures, but there is less evidence found in equity index and interest rate futures. They found their result to be puzzling as they didn't expect an increase in information flows near the maturing of currency futures. Another result from the study saw that markets have become more liquid and larger, thus making the Samuelson Hypothesis increasingly relevant (Akin, 2003). She suggests earlier studies may have failed to find a role for time-to-maturity as the markets did not fulfil the conditions outlined by Samuelson. The third finding in her paper discusses how one policy implication is that if agents fail to incorporate time-to-maturity when making hedging decisions, they may be failing to optimize. The final result found that the empirical modelling of the second moments of futures returns need to incorporate economic and GARCH effects.

In a paper by Duong and Kalev (2008), the authors used intraday data to examine American and international exchanges for 20 commodities such as energies, financial, agriculture and metal futures. Duong and Kalev (2008) tested the Samuelson Hypothesis by creating a 5 minute time interval of transactions per day and taking the natural log of the intraday price variance and then calculating realised volatility. The authors conduct a non-parametric and GARCH test and utilise a 'rollover' method in order to create a continuous time series and exclude the month nearest to maturity. They found support for the Samuelson Hypothesis in agricultural futures but no support is found for the maturity effect in the metals, energy or financial futures.

Verma and Kumar (2010) examined agricultural futures on the Indian Commodity Exchange (NCDEX). They calculated the natural logarithm of daily settlement prices and from this calculated the realised volatility and examined each contract individually, including the maturity month. They found support for the Samuelson Hypothesis in about 45% of wheat and pepper contracts (Verma & Kumar, 2010).

It can be seen from the empirical studies that the support for the Samuelson Hypothesis in the financial industry is not very strong when compared to the agricultural industry. Milonas (1986) investigated the maturity effect for eleven commodities and found general support for ten of these commodities, three of which were financial assets and the rest agricultural commodities. Milonas (1986) found evidence of the Samuelson Hypothesis for the three interest rate futures; however this evidence was somewhat weaker than for the agricultural and metal futures. Bessembinder et al. (1996) demonstrated that futures contracts in the financial industry have no relationship between volatility and time to maturity. Galloway and Kolb (1996) found less support for the Samuelson Hypothesis in financial contracts compared to other commodities. They substantiated minimal support for the Samuelson Hypothesis by concluding that the hypothesis is more prominent in agricultural commodities when they discovered stronger support in agricultural and energy commodities. Grammatikos and Saunders (1986) fail to find supportive evidence for the maturity effect in any of the five currency futures that they examined.

Studies were conducted that examined the financial industry such as Beaulieu (1998) and Chen, Duan and Hung (1999). Beaulieu (1998) examined the behaviour of the basis in stock market index futures contracts. The results indicate that the Samuelson Hypothesis holds, yet the conditional variance of the basis decreases as the delivery approaches (Beaulieu, 1998). This result is consistent with Castelino and Francis (1982). Chen, Duan and Hung (1999) examine the Samuelson Hypothesis and compare hedge ratios under scenarios with and without the maturity effect in equity index futures and test the Nikkei-225. Chen et al. (1999) find that decreasing volatility as maturity approaches contradicts the Samuelson Hypothesis.

In summary, whilst differing results emerge from the above literature, a significant amount of research lends support to the notion of the existence of the Samuelson Hypothesis. The findings of the hypothesis, however, are usually concerning agricultural futures and despite the numerous studies on the topic, there is no overwhelming, conclusive evidence that the Samuelson Hypothesis is true.

2.3 Possible explanations for increasing volatility

2.3.1 Negative Covariance Hypothesis

Bessembinder et al. (1996) discusses that while the mathematics behind the Samuelson Hypothesis model are relatively complex the intuition is clear. Early in a futures contract there is little information known about the underlying commodity but as the contract reaches maturity the rate of information acquisition increases. An example Kolb (1991) puts forward, as cited by Bessembinder et al. (1996), is that as a harvest approaches, the market gets a much better idea of the final price that corn will command. Thus Bessembinder et al. (1996) proposed an expansion of the Samuelson Hypothesis and in doing so proposed a possible reason for its holding in certain markets, while not holding in others. The authors developed a framework for predicting which markets the Samuelson Hypothesis would hold in. They focus their attention on the stationarity of spot prices and show that the Samuelson Hypothesis doesn't require that prices are strictly stationary. The analysis conducted by Bessembinder et al. (1996) predicted that the Samuelson Hypothesis will hold only in the markets where the spot price changes include a temporary component, allowing investors to expect some portion of an ordinary price change to be reversed in the future and empirical examination of this prediction is complicated by the need to identify the markets that meet this criteria. The authors rely on principles of equilibrium to identify these markets. Bessembinder et al. (1996) state that the presence of a temporary component in spot price changes implies expected capital loss or a decrease in expected rates of capital gains, following an unusual price increase or decrease as the spot asset must pay a competitive return in order to induce the holding of inventories and such variation in the expected rates of capital gain must be offset in equilibrium by changes in the economic costs of carrying inventory.

Bessembinder et al. (1996) argue that the most likely reason for substantial time variation inventory carrying costs derives from the variation of real positive covariation between convenience yields service flows or 'convenience yields'. In particular the spot prices lead to mean reverting spot prices in equilibrium and is sufficient in supporting the Samuelson Hypothesis. As financial assets fail to provide service flows, it is predicted that the Samuelson Hypothesis will not hold for financial futures. Bessembinder et al. (1996) explain that the Samuelson Hypothesis requires either systematic increases in spot return volatility near each futures expiration date or negative covariance between the spot returns and the slope of the futures term structure. The authors argue that the former condition is improbable given that futures contracts mature throughout a year. Thus they focus on the second condition and show that it will be met in markets where equilibrium spot prices are mean reverting. This hypothesis should not be predicted to hold in markets where the spot prices follow a random walk or where spot prices contain a mean reverting component attributable to time variation in risk premia. Instead Bessembinder et al. (1996) argue that the conditions are more commonly met in markets for real assets, especially those where the convenience yields display substantial intertemporal variation than in markets for financial assets.

Bessembinder et al. (1996) argue that it could be possible that a clustering of information flow near future delivery date would cause an increase in the price change variance but there is an absence of compelling explanations as to why clustering of information flow would occur near futures maturity dates. Kolb (1991) explains, as cited by Bessembinder et al. (1996), that with an agricultural futures, the contract matures not only near harvest dates, but throughout the calendar year. Illustrating that the clustering of information near future delivery data would fail to cause an increase, as this would occur at every maturity. Bessembinder et al. (1996) assert that the time variation in information flow is not a necessary condition for the Samuelson Hypothesis to hold, as it can be expected to hold in markets where information flow fails to cluster near the delivery date. Thus explanations invoking systematic variation in rates of information flow are unlikely to provide accurate cross-sectional predictions regarding the validity of the maturity effect.

Bessembinder et al. (1996) tested their afore mentioned prediction in 11 futures markets and as they predicted the Samuelson Hypothesis has strong support in markets for agricultural and crude oil, where a strong negative relationship exists between the prices and futures term slopes. This is indicative of a large mean reverting component in spot prices. The Samuelson Hypothesis is supported, although to a lesser extent, in metal markets where the degree of the spot price reversion is less. The financial markets considered were characterised by the absence of a significant relation between prices and the futures term slope and found the Samuelson Hypothesis to not be supported. Bessembinder et al. (1996)'s results are robust to the inclusion of the rate of information flow proxy and then conclude that the Samuelson Hypothesis should hold only in markets where the spot price changes contain a significant temporary component.

The Empirical evidence for the Negative Covariance Hypothesis is mixed, as it is for the Samuelson Hypothesis. Daal, Farhat and Wei (2006) analysed daily settlement prices for sixty one commodities including financial, metals, agricultural and energy markets. They look across multiple exchanges and decided to assess each contract individually and not employ a rollover method, however they did exclude data from the month before maturity. Utilising the natural logarithm of price variance, they calculated the realised volatility and then performed an OLS regression using those results. Their results indicated that the Samuelson Hypothesis exists in 45.7% of agricultural contracts which is a higher proportion than found in the other contracts examines (Daal, Farhat, & Wei, 2006). Daal, Farhat and Wei (2006) also concluded that there was very weak evidence regarding the Negative Covariance Hypothesis. Yet Duong and Kalev (2008) found support for the Negative Covariance Hypothesis when studying intraday data from twelve commodity markets in five future exchanges.

2.3.2 State Variable Hypothesis

Anderson and Danthine (1983) and Anderson (1985) argue that the Samuelson Hypothesis doesn't generally hold unless information flow is incorporated into the model. The authors offered an extension for the time pattern of futures price volatility. Their hypothesis has since been referred to in the literature as the State Variable Hypothesis (Duong & Kalev, 2008). It is argued that the source of volatility of the futures price is the degree of information flow to the market or uncertainty resolution.

Anderson and Danthine (1983) suggest that there is no tendency for the future price volatility to increase as the contract reaches its maturity yet rather it is argued to occur when information resolving uncertainty flows into the markets. The Samuelson Hypothesis is thus viewed, as an unusual case because the resolution of uncertainty or information flow is greater as the maturity of the contract approaches.

The empirical evidence for this explanation, the State Variable Hypothesis, is also mixed. Anderson (1985) studied nine commodities during the period of 1960-1980 and revealed that the seasonal effect was more important than the maturity effect in trying to explain the future price volatility. Kenyon, Kenneth, Jordan, Seale and McCable (1987) studied corn, soybeans and wheat futures and came to a similar conclusion that the seasonal effect was of importance. Duong and Kalev (2008)'s paper examined twelve markets and argued that information flow does not appear to be the main determinant of support with regard to the Samuelson Hypothesis. In their study the empirical evidence remained almost identical regarding the

Samuelson Hypothesis, regardless of the insertion or exclusion of information flow in the regression.

2.3.3 Alternative Explanations

Hong (2000) develops an equilibrium model of a competitive futures market where investors trade to speculate on their private information and to hedge positions. Concluding that in markets where information asymmetry among investors is small, the return volatility of a futures contract decreases with time to maturity.

Akin (2003) asserts that market depth could be another factor affecting the degree of sensitivity of volatility to levels of trading volume. In a theoretical model proposed by Kyle (1985) market depth helps in the creation of more favourable conditions and reduce price pressures when trading provides new information. More precisely, Kyle (1985) suggests that market depth is the order flow that is required to move prices by one unit. As order flow changes, open interest also changes endogenously, thus making it a good measure of market depth (Akin, 2003).

Bessembinder and Seguin (1992) find that market depth (measured by open interest) has an inverse relationship with volatility so as market depth increases volatility decreases. They also find that information flow (which is measured by trading volume) has a positive relationship with volatility meaning as trading volume increases, volatility also increases. This translates into market depth and trading volume have opposite relationships with return volatility. Bessembinder and Seguin (1992) argue that open interest is a good proxy for market depth because it reflects the current willingness of futures investors to risk their capital in future contracts which in turn indicates market depth. The study finds a strong positive contemporaneous relationship between trading volume and return volatility and a new finding that unanticipated volume shocks raise return volatility two to thirteen times more than expected volume shocks. The study also finds, consistent with previous studies, that market depth affects return volatility. Market depth, when constructed by lagged open interest, decreases when actual order flows are differing from anticipated order flows.

Fung and Patterson (2001) integrated two branches of return volatility and trading volume literature to examine the effect of market depth in addition to the relationship between return volatility and trading volume. The authors while examining currency futures and two interest rate futures find that market depth had the strongest relationship with return volatility when the trading volume was high, and this was mainly through the interaction with trading volume. The negative impact of market depth on volatility is relatively marginal and is dependent on its interaction with trading volume.

Grammatikos and Saunders (1986) find evidence of a positive volume and volatility relationship in futures contracts. Wang and Yau (2000) study futures price specifically and find evidence of a positive relation between price volatility and trading volume, and a negative relationship with lagged trading volume. The intuition for their results is that as trading volume increases, there is more opportunity for prices to change. The intuition works the other way also, whereby there is more opportunity for the market to offset the undesirable positions of their inventories and thus reduce the price risk and thus observe lower volatility (Wang & Yau, 2000).

2.4 Background

There are several ways in which the Samuelson Hypothesis has been tested previously with each methodology having their own advantages and disadvantages. In Anderson (1985)'s study, he made use of nonparametric and parametric methods, which led him to find support for the Samuelson Hypothesis, yet he recognized that the seasonal patterns were an important determinant of volatility in future prices. The methodology employed was criticised as no consideration of the contract month effect occurred (Milonas, 1986). If the future price is affected by the month of maturity than no modification for the contract month effect could introduce serious bias, particularly in the agricultural sector. Another constraint of Anderson (1985)'s methodology is that it fails to quantify the maturity effect or examine its behaviour as the contract tends towards maturity. The final constraint for the methodology used, is that it cannot investigate the linearity or lack thereof for the Samuelson Hypothesis, especially when different liquidity in the market exists during the life of the contract (Milonas, 1986). The contribution that the study made was finding seasonal effects to be more important than the maturity effect in explaining futures price volatility.

Khoury and Yourougou (1993) examined the relationship between the variance of futures price changes and the contracts remaining time to maturity and were some of the first authors to do so outside of the USA, analysing the Winnipeg Futures Exchange in Canada. They analysed six agriculutal commodities using daily data containing the open, closing, high and low prices. Khoury and Yourougou (1993) followed Milonas (1986) and employed a rolling over of contracts. Khoury and Yourougou (1993) employ the rollover of contracts which creates a longer time series and disregarded the two week period before a contract was set to expire in order to control for price distortion. They examined their data utilising the natural log of price changes, ANOVA tests and OLS regression and found that the sampled agricultural commodities support the Samuelson Hypothesis where some exhibit stronger maturity effects than others (Khoury & Yourougou, 1993). By following Milonas (1986)'s methodology the variances of the natural logarithm of the futures closing price relatives are calculated first on contract-by-contract basis for non-overlapping monthly periods. These variances are then averaged geometrically and are then normalised. By following this procedure Khoury and Yourougou (1993) ensure that the changes in variances solely reflect the effect of time to maturity.

In Chen, Hung and Duan (1999) a different approach was adopted by which an econometric model focusing on the basis between futures and spot prices were constructed. The rationale for doing this seems apparent as the basis should converge to zero as the contract reaches maturity. Thus it is natural to expect that the volatility of the basis will also approach zero as the maturity is shortened (Chen, Hung & Duan, 1999). The benefit of following this approach is that it became possible to examine the Samuelson Hypothesis as well as to compare the hedge ratios under each scenario with and without the maturity effect. Chen, Hung and Duan (1999) tested the Nikkei-225 stock index as well as index futures and found that the conditional variance of future prices decreases if the maturity of the contract is shortened. In their paper they modelled the basis and spot price jointly utilizing a bivariate GARCH model. The specific model used by Chen, Hung & Duan (1999) includes a maturity variable so the remaining maturity is permitted to play a part in determining the behaviour of the basis. The adoption of the GARCH model was motivated by its empirical success. Many of the financial time series exhibit both leptokurtosis and heteroscedasticity and the GARCH and ARCH processes has become a standard modelling tool for dealing with these features. The justification for the modification from a standard GARCH to a bivariate GARCH model is because of the fact that future contracts have a time varying maturity (Chen, Duan, & Hung, 1999).

Moosa and Bollen (2001)'s study used a measure of volatility that is based on the notion of integrated or realized volatility. This methodology was proposed by Anderson and Danthine (1983) and is calculated as the sum of squared 5-minute returns. They found there was no relationship between time to maturity and volatility. Floros and Vougas (2006) apply linear regression and GARCH models when examining the maturity effect in Greek markets. They made an interesting observation by noting that using GARCH models showed a stronger support for the hypothesis than when linear regressions were used. Duong and Kalev (2008)'s paper tested the Samuelson Hypothesis using three separate methods. A non-parametric test developed by Jonckheere (1954) and Terpsta (1952) was used. Second, they used an OLS regression and finally a GARCH (1,1) model. The squared return is viewed as an unbiased measure of daily volatility yet it is an extremely noisy parameter, whereas the daily squared returns are unable to capture the intraday fluctuations of price, which can be significant.

3 METHODOLOGY

3.1 Sampling and Data Collection

The data utilised in this study are the daily closing prices in the agricultural and financial futures markets during the period ranging from 2002 to 2015. The unstandardized periods were chosen as it was required to obtain as much data as possible on the chosen contracts to create a more robust study and more trustworthy results where possible; thus the data that was able to be retrieved over this period was utilised. It would be preferable to use bid-ask spreads for futures markets, as per Duong and Kalev (2008), however, due to data limitations this information is unavailable for this study. The datasets were obtained through the assistance of iNet BFA. The sample of 11 futures contracts allows for a complete analysis of the South African market over an extended period, extending across all the industries, namely financial, mining, industrial, resources, retailers, property and agriculture. The resulting JSE index futures contracts that will be examined are:

1. FTSE/JSE ALL SHARE INDEX
2. FTSE/JSE FINI 15 INDEX FUTURE
3. FTSE/JSE GOLD MINING INDEX
4. FTSE/JSE INDI 25 INDEX FUTURE
5. FTSE/JSE RESI 20 INDEX FUTURE
6. FTSE/JSE GENERAL RETAILERS INDEX
7. FTSE/JSE SA LISTED PROPERTY INDEX
8. Soybean
9. Wheat
10. White Maize
11. Yellow Maize

The primary reason that these futures contracts were chosen for examination in this study is because the Samuelson Hypothesis needs to be examined with special attention given to the different industries. As a substantial amount of the empirical evidence conducted previously have discovered differing results depending on the industry (Galloway and Kolb, 1996) and Daal, Farhat and Wei, 2006).

Table 1: Outlines basic facts of future contracts assessed in this study.

Contract	Sample Period	Expiration Month	N
All Share	October 2010 – December 2014	3, 6, 9, 12	1008
FINI15	December 2008 – December 2014	3, 6, 9, 12	1651
GoldMining	December 2005 – December 2014	3, 6, 9, 12	2144
Indi25	July 2005 – December 2014	3, 6, 9, 12	2244
Resi20	September 2009 – December 2014	3, 6, 9, 12	1268
Retailers	September 2009 – December 2014	3, 6, 9, 12	1228
Listed Prop	December 2012 – December 2014	3, 6, 9, 12	494
Soybean	December 2010 – Jan 2015	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1081
Wheat	December 2002 – September 2013	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	2670
White Maize	December 2002 – September 2013	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	2791
Yellow Maize	December 2002 – September 2013	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	2763

Notes for Table 1: All the data has been received from INET BFA relating to the JSE (Johannesburg Stock exchange). The table displays the future contract, the sample period of data being utilised, the number of observations within each contract (N), and the expiration month. Expiration month is a numerical representation of the month in which each contracts expires (1= January, 2 = February, 3 = March etc.)

The contracts will be analysed over the period ranging from December 2002 to January 2015, with contracts having differing sample periods, as displayed in Table 1. As explained in Duong and Kalev (2008) several futures contracts with different maturities are normally traded at any given time, this criteria must be specified in order to obtain a continuous future price series. This study will replicate Duong and Kalev (2008), who followed a common method in the literature referred to as rolling over contracts, as earlier explained. This method was utilised for all contracts, except for the agricultural contracts, namely Soybean, Wheat, White Maize and

Yellow Maize. For the agricultural contracts, the rolling over contract could not be applied as it had been with the other contracts, because it had a monthly maturity. Thus, it was decided that for the agricultural contracts, when the contract entered the week of its maturity, the prices from the next contract will be utilised.

3.2 Description of Research Design to Test the Samuelson Hypothesis

The research covers both agricultural and financial contracts for South African contracts in order to have a view if the Samuelson Hypothesis holds in agricultural or financial industries and if this is consistent to international studies. The methodology that will be utilised will be a replication of Duong and Kalev (2008)'s methodology whereby they first conducted a test in their study that was a non-parametric test called the Jonckheere-Terpstra test [3] (furthermore referred to as JT). This test was developed for the purpose of testing ordered differences among classes (Duong & Kalev, 2008). The motivation for using this test is that no assumptions about the data distribution are relied upon for its use. Duong and Kalev (2008) explained how the Samuelson Hypothesis involves testing the order of volatility among different futures with different times to maturity, thus the JT test is particularly suited to assess the Samuelson Hypothesis. The null and alternative hypothesis for this test is as follows:

$$H_0: \sigma_1^2 = \sigma_2^2 = \ldots = \sigma_n^2 \quad (1)$$

$$H_1: \sigma_1^2 > \sigma_2^2 > \ldots > \sigma_n^2 \quad (2)$$

Where n is the number of contracts and $\sigma_1^2$is the volatility of the contract closest to maturity and σ_2^2 is the volatility of the contract second closest to maturity and so on. If H_0 is rejected then the Samuelson Hypothesis holds, meaning that the futures price volatility increases as the future contract approaches its time of expiration (Samuelson, 1965). Several contracts are trading at the same time, with different maturities. In order to obtain a continuous futures price series, the common method followed in the literature is referred to as the rolling over of futures (Duong & Kalev, 2008). Consequently, K different futures time series are constructed for the JT test. The first time series, time series one, is the time series constructed based on the

[3] For more information on this test, which has been proposed to test ordered differences among classes, see Jonckheere(1954) and Terpsta (1954).

prices of the contracts closest to maturity using the rolling over method. The data for the contracts closest to maturity are included. When the contract enters its maturity month, the price for the next nearest-to-maturity contract is selected. Similarly, the second (k^{th}) time series is constructed by rolling over the futures contract second (kth) closest to maturity.

The concern of using a non-parametric test such as the JT test is that it lacks power in comparison to parametric tests (Duong & Kalev, 2008). In order to account for these concerns the second method utilised is the OLS regression of the realised volatility on the time to maturity. This method tests the Samuelson Hypothesis by regressing the daily futures realised volatility on a constant and the number of days until the contract reached maturity. The results for this regression are obtained using Newey and West (1987) Heteroskedasticity Consistent Covariance Procedure (as cited in Duong & Kalev, 2008). The equation for this test is:

$$RV_t = \alpha + \beta TTM_t + \varepsilon_t \tag{3}$$

RV_t Represents the future realised volatility and TTM_t represents the number of days until maturity. For the Samuelson Hypothesis to hold in a given futures contract, β which represents the coefficient of the time to maturity must be negative and statistically significant.

The Samuelson Hypothesis is also going to be tested using a GARCH (1, 1) model. Bollerslev, Chou and Kroner (1992) asserts that GARCH type models are widely used in studies that deal with volatility modelling. Bollerslev (1987), suggests that the GARCH (1, 1) model is the simplest model that captures the dynamics of volatility well. In order to investigate the Samuelson Hypothesis, the time to maturity variable is included as an exogenous variable in the conditional variance equation of the GARCH model. The model is defined as follows:

$$r_t = \mu + \varepsilon_t, \quad \varepsilon_t | \Omega_{t-1} \sim i.i.d.(0, \sigma_t^2), \tag{4}$$

$$\sigma_t^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2 + \delta TTM_t, \tag{5}$$

Where r_t is the futures contracts return for day t, TTM_t is the number of days to maturity, μ is the constant and ε_t is the error term process with mean zero and conditional variance σ_t^2. The GARCH (1,1) model will be estimated where the error term follows Student's t-distribution in order to incorporate the potential leptokurtic distribution of the error term.

3.3 Description of Research Design to Test the Negative Covariance Hypothesis

The methodology that will be utilised in testing the Negative Covariance Hypothesis is illustrated in this section. The Negative Covariance Hypothesis states that the probability of the Samuelson effect holding is higher in a market where changes in spot prices and changes in net carrying costs have a negative covariance (Duong & Kalev, 2008). Following from Bessembinder et al. (1995), the net carry costs (c_t) is the difference between the natural logarithm of futures prices (f_t) and spot prices (s_t), weighted by the time to maturity (TTM_t) as follows:

$$c_t = \frac{(f_t - s_t)}{TTM_t} \tag{6}$$

Duong and Kalev (2008) explain that the covariance between spot prices and changes in net carry costs is then estimated as in the following regression:

$$\Delta c_t = \alpha_0 + \alpha_1 \Delta s_t + \varepsilon_t, \tag{7}$$

Where Δc_t and Δs_t are the changes in net carry costs and changes in spot prices, respectively. If the maturity effect tends to be stronger for markets that have negative covariance (α_1<0), the Bessembinder et al. (1996) hypothesis is supported (Duong & Kalev, 2008).

3.4 Description of Research Design to the State Variable Hypothesis

The information flow will be investigated by first comparing the results obtained when regressing the daily futures realised volatility on days to maturity as done in the OLS regression ,with those obtained when the spot price volatility (VolaSpot) is also included as a control variable in the following regression equation:

$$RV_t = \alpha + \beta TTM_t + \phi VolaSpot_t + \varepsilon_t \tag{8}$$

As explained by Duong and Kalev (2008), if the ‘negative covariance’ condition is the most significant determinant of the Samuelson hypothesis, which is suggested by Bessembinder et al. (1996) then the coefficient of the days to maturity variable (β) should remain negative and significant despite the inclusion of the spot price volatility variable.

4 RESULTS AND DISCUSSION

4.1 Data Description

The manner in which the maturity of each contract is analysed is of utmost importance when investigating the maturity-volatility relationship. A continuous futures price series needs to be established, owing to various contracts with different expiration dates trading at any one time. This is accomplished by using the same method as Duong and Kalev (2008). The closing prices of the contract closest to expiration are used and once the expiry month of the contract is entered into, use is made of the prices of the next contract closest to maturity. The time to maturity is then calculated for every closing price observation. This method was suitable for non – agricultural contracts, as they allow for maturities every three months. However, the agricultural futures mature on a monthly basis, thus in order for the contract to be rolled over efficiently and correctly, it was decided that when the contract entered into the week of its expiration, the closing prices from the next contract closest to maturity will be utilised. The descriptive statistics are presented in Table 2 and Table 3, and are retrieved from the natural-log returns. Table 2 contains financial contracts and Table 3 shows the agricultural contracts.

The mean of the returns of each future contract is close to zero and six out of the eleven contracts are negatively skewed. For data to be classified as normally distributed, the value of skewness would need to be equal to zero. From the results it is evident that the data is rejected for normal distribution. The kurtosis results confirm re-emphasises that the returns don’t follow normal distribution.

When the sample size of the data is greater than 50, the Kolmogorov-Smirnov test is a good test. The null hypothesis states that the data is normally distributed. The probability associated is less than or equal to the level of significance (0.01), thus the null hypothesis is rejected for all contracts when assessing normality using the Kolmogorov-Smirnov test. The results are confirmed by the Cramer-von Mises and the Anderson-Darling tests. It is clear that in each case, the null hypothesis that the returns follow a normal distribution is rejected at all levels of significance, with a p-value that is essentially zero.

Table 2: The Descriptive Stats for non-agricultural futures contracts

	All Share	FINI15	GoldMining	Indi25	Resi20	Retailers	Listed Prop
Mean	0.00051	0.00055	-0.00041	0.00074	-0.00004	0.00083	0.00036
Standard Deviation	0.009157	0.014737	0.026580	0.011766	0.014084	0.012655	0.298035
Skewness	-0.30699	-0.62740	0.68684	-0.16395	0.03896	-0.27881	-0.81714
Kurtosis	1.40771	7.30052	31.91802	2.78337	1.32062	1.19381	246.24064
Median	0.00078	0.00091	-0.00111	0.00117	-0.00003	0.00145	0.00088
Kolmogorov-Smirnov	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cramer-von Mises	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Anderson-Darling	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005

The natural logarithmic returns of the closing prices are calculated and analysed using the formula:

$$R_t = ln(P_t/P_{t-1})$$

The mean, standard deviation, skewness, kurtosis and median are calculated for each contract. To test the if the data is normally distributed 3 tests were employed, namely Kolmogorov – Smirnov, Cramer – von Mises and the Anderson Darling test

Table 3: The Descriptive Stats for the agricultural contracts

	Soybean	Wheat	White Maize	Yellow Maize
Mean	0.00051	0.00029	0.00012	0.00017
Standard Deviation	0.01471	0.01314	0.02025	0.01953
Skewness	3.86629	0.64431	-0.47265	0.79684
Kurtosis	83.08099	17.32125	8.34074	23.45203
Median	0.00000	0.00000	0.00000	0.00000
Kolmogorov-Smirnov	< 0.01	< 0.01	< 0.01	< 0.01
Cramer-von Mises	< 0.005	< 0.005	< 0.005	< 0.005
Anderson-Darling	< 0.005	< 0.005	< 0.005	< 0.005

The natural logarithmic returns of the closing prices are calculated using the formula:

$$R_t = ln(P_t/P_{t-1})$$

The mean, standard deviation, skewness, kurtosis and median are calculated for each contract. To test the if the data is normally distributed 3 tests were employed, namely Kolmogorov – Smirnov, Cramer – von Mises and the Anderson Darling test

4.2 Testing the Samuelson Hypothesis

This section will layer the results of the three tests employed to test the Samuelson Hypothesis. Firstly the non-parametric test, the JT test is applied to investigate the maturity effect. Secondly the OLS regression of the realized volatility on time to maturity and finally the paper uses a GARCH model with time to maturity augmented in the conditional variance equation for examining the Samuelson Hypothesis. Using three tests to test the hypothesis enables more robust conclusions to be drawn and allows for different data to be tested using separate methods.

4.2.1 Jonckheere and Terpstra Method

To test the Samuelson Hypothesis, the non-parametric test developed by Jonkheere (1954) and Terpstra (1952) is utilised. The JT test is applied to examine the null hypothesis which states that the volatility of all futures time series are equal, against the alternative hypothesis, which stipulates that higher volatility is observed in futures time series that are closer to maturing. The null and ordered alternate form is displayed below and the JT test results are found in Table 4:

$$H_0: \sigma_1^2 = \sigma_2^2 = \ldots = \sigma_n^2$$

$$H_1: \sigma_1^2 > \sigma_2^2 > \ldots > \sigma_n^2$$

Table 4: The results for the Samuelson Hypothesis using the JT test of ordered alternatives for non-agricultural contracts

	All Share	FINI15	GoldMining	Indi25	Resi20	Retailers	Listed Prop
JT Stat	247493.5	681110	1134577	129953	399836.5	373161	58958
P Value	**0.32420**	**0.17050**	**0.40870**	**0.29240**	**0.30530**	**0.39390**	**0.27750**

For each commodity, the test is applied to a period when a number of contracts with different maturities exist. To obtain a continuous future price series, the common method followed is referred to as the rolling over of futures (Duong & Kalev, 2008). K different futures time series are constructed for the Jonckheere – Terpstra test. The first time series, time series 1, is the time series constructed based on the prices of the contracts closest to maturity using the rolling over method. The JT test is used to test for the null hypothesis of equal volatility of all contracts against the alternative hypothesis where higher volatility is observed for contracts closer to maturity.

The JT results referenced in Table 4 demonstrate that no contract was significant, and that no contract found support for the Samuelson Hypothesis while assessing the non-agricultural contracts. By contrast, the results in Table 5 assessing the agricultural contracts discovered that there is only one agricultural contract that failed to find support for the hypothesis; Soybean. Wheat, White Maize and Yellow maize contracts show the null hypothesis of equal volatility being rejected, and thus fund support for the Samuelson Hypothesis.

Table 5: The results for the Samuelson Hypothesis using the JT test of ordered alternatives for agricultural contracts

	Soybean	Wheat	White Maize	Yellow Maize
JT Stat	289861.5	1762579.5	1918050.5	1881643
P Value	**0.22320**	**0.01630****	**0.01560****	**0.02300****

For each commodity, the test is applied to a period when a number of contracts with different maturities exist. To obtain a continuous future price series, the common method followed is referred to as the rolling over of futures (Duong & Kalev, 2008). K different futures time series are constructed for Jonckheere – Terpstra test. The first time series, time series 1, is the time series constructed based on the prices of the contracts closest to maturity using the rolling over method.The roll over method is applied slightly differently to agricultural contracts due to the frequency on their expiration. When the contract enters the week of expiration, it will use the closing prices of the next contract closest to maturity.

These results are consistent with previous studies such as Bessembinder et al. (1995), Galloway and Kolb (1996) and Duong and Kalev (2008). Bessembidner et al. (1995) found the degree of mean reversion to be larger for agricultures and relatively small for metals, and non-existent for financials. Galloway and Kolb (1996) find support for the majority of agricultural futures contracts but not when examining precious metals. Duong and Kalev (2008) also provide corroborative evidence that agricultural markets display a significant Samuelson effect and a strong mean reverting tendency, while this is not the case for other markets examined within their study. The first test demonstrates stronger support for the Samuelson Hypothesis in agricultural contracts. However, it is important to understand the limitation of this methodology before any conclusions are drawn as previously stated the JT test is non-parametric. Duong and Kalev (2008) illustrate the JT lacks power in comparison to parametric tests and thus utilise the OLS regression.

In summary three out of the four agricultural contracts display evidence supporting the Samuelson Hypothesis, while no other contract supports the hypothesis. The results are consistent with previous literature as mentioned above, with differing results according to different industries.

4.2.2 Newey – West Method

As indicated, a concern of using the JT non-parametric test is that they lack power compared to parametric tests (Duong & Kalev, 2008). Thus, it is required to provide more robust evidence for the findings of the Samuelson Hypothesis, by testing the Samuelson Hypothesis using a parametric test as they produce more robust evidence. In order for the Samuelson Hypothesis to hold, the coefficient of time to maturity should be negative and statistically significant. The results of the OLS regression are presented in Table 6 and Table 7.

Table 6: Testing the Samuelson Hypothesis using the Newey - West test for non-agricultural contracts

	All Share	FINI15	GoldMining	Indi25	Resi20	Retailers	Listed Prop
Intercept	0.04090	-0.05610	-0.01510	0.03940	-0.10040	0.01910	-0.19410
P Value	**0.48400**	**0.41910**	**0.88620**	**0.30500**	**0.20360**	**0.77810**	**0.93620**
TTM	0.00033	0.00367	-0.00086	0.00102	0.00289	0.00202	0.00732
P Value	**0.85510**	**0.06230**	**0.79130**	**0.27100**	**0.18650**	**0.30080**	**0.95130**
R^2	0.00000	0.00190	0.00000	0.00040	0.01800	0.00090	0.00000

This table demonstrates results using the daily variance. The results are based on the following formula:

$$\sigma^2 = \lambda + \beta TTM + \varepsilon_t$$

The dependent variable, σ^2, is the variance of returns of the time series based on the closest to maturity contracts. The independent variable, TTM, is the time to maturity measured as the number of days until expiration. In addition, the probability values are given to test this variable's significance. R^2 is the adjusted R-squared.

Table 6 and Table 7 present the OLS regressions results for both agricultural and non-agricultural contracts. If a relationship exists between the two variables (variance of returns and time to maturity) then the coefficient of the time to maturity variable will be significant. If the time to maturity variable is also negative, it would then reflect that an inverse relationship exists between volatility and time to maturity, thus finding support for the Samuelson Hypothesis. Only one contract, FINI15, shown in Table 6 has a significant coefficient for time to maturity indicative of there being a relationship between the variables. However, the time to maturity variable is positive, reflecting that the futures volatility in this contract actually decreased as the futures contract approached its maturity.

Table 7 provides evidence that only the white maize contract has a significant coefficient, meaning that a relationship exists between the two variables. This contract's TTM variable has a value of -0.01030, illustrating that the Samuelson Hypothesis is supported for this contract, in addition this contract has the second highest R-squared and the solitary significant intercept.

Table 7: Testing the Samuelson Hypothesis using the Newey - West test for agricultural contracts

	Soybean	Wheat	White Maize	Yellow Maize
Intercept	0.07240	0.04850	0.13450	0.07250
P Value	**0.25320**	**0.33550**	**0.04520**	**0.20050**
TTM	-0.00062	-0.00064	-0.01030	-0.00439
P Value	**0.16770**	**0.67260**	**0.02210**	**0.27750**
R^2	0.00040	0.00010	0.00130	0.00040

This table demonstrates results using the daily variance. The results are based on the following formula:

$$\sigma^2 = \lambda + \beta TTM + \varepsilon_t$$

The dependent variable, σ^2, is the variance of returns of the time series based on the closest to maturity contracts. The independent variable, TTM, is the time to maturity measured as the number of days until expiration. In addition, the probability values are given to test this variable's significance. R^2 is the adjusted R-squared.

In summary, the OLS regression produced near to no support for the Samuelson Hypothesis at a 5% confidence level, and is only supported in one agricultural contract namely White Maize. The results also inferred to the fact that the FINI15 demonstrated support for volatility decreasing as the contract approaches maturity. The results may be compromised due to the OLS regression not being able to fully account for the heteroskedastic variance of these South African futures contracts, this can also be supported by the low R-squared that each of these contracts display.

4.2.3 GARCH (1, 1) Model

A GARCH model is estimated for each contract. Similar to Duong and Kalev (2008), the TTM variable is added as an exogenous variable in the conditional variance equation of the GARCH model. The GARCH model's error term follows a normal distribution with a mean of zero and a constant variance. Subsequent to examining the Akaike Information Criterion values of various lag orders and determining which had the lowest value, a GARCH (1, 1) is chosen to be run for every contract. This is the equivalent specification used by Duong and Kalev (2008) and is, thus useful for relative comparisons.

Table 8: GARCH (1, 1) model presents the results for non-agricultural contracts

	All Share	FINI15	GoldMining	Indi25	Resi20	Retailers	Listed Prop
TTM	0.00185	0.00367	0.00087	0.00083	0.00289	0.00249	0.00732
P-value	**0.20570**	**0.00770**	**0.72910**	**0.34490**	**0.10180**	**0.16380**	**0.99530**
DF	1006	1649	2142	2242	1266	1226	492
σ^2	0.88033	2.16409	23.41998	1.35503	1.97834	1.60951	887.75508

The results are based on the estimates of the following GARCH (1,1) model:

$$Y_t = \propto_0 + \propto_1 X_t + \in_t, \in_t \sim N(0, h_t)$$

$$\sigma_t^2 = \propto_0 + \sum_{i=1}^{p} \propto_i \in_{t-1}^2 + \sum_{j=1}^{q} \beta_j \, \sigma_{t-j}^2 \; + \gamma TTM$$

Yt represents the conditional mean equation and σ_t^2 represents the conditional variance equation. TTM represents the time to maturity. DF illustrates the degrees of freedom of the test and σ^2 is the variance over the period calculated from the returns.

The results of the GARCH model are displayed in tables 8 and 9. Only two out of the eleven contracts are significant, namely White Maize and FINI15. The coefficient of White Maize is negative, illustrating support for the Samuelson Hypothesis within this contract, meaning that as the contract approaches its maturity, the volatility of the contract will increase. The FINI15 contract, however indicates the opposite result. The coefficient here is positive and significant, implying that the futures price volatility actually decreases as the contracts tend towards its expiration.

Table 9: GARCH (1, 1) model presents the results for the agricultural contracts

	Soybean	Wheat	White Maize	Yellow Maize
TTM	0.00062	0.00074	-0.00978	0.00365
P-value	**0.84930**	**0.76320**	**0.03470**	**0.38260**
DF	1079	2668	2789	2763
σ^2	2.16007	2.28123	4.49888	3.93137

The results are based on the estimates of the following GARCH (1,1) model:

$$Y_t = \propto_0 + \propto_1 X_t + \in_t, \in_t \sim N(0, h_t)$$

$$\sigma_t^2 = \propto_0 + \sum_{i=1}^{p} \propto_i \in_{t-1}^2 + \sum_{j=1}^{q} \beta_j \, \sigma_{t-j}^2 \ + \gamma TTM$$

Y_t represents the conditional mean equation and σ_t^2 represents the conditional variance equation. TTM represents the time to maturity. DF illustrates the degrees of freedom of the test and σ^2 is the variance over the period calculated from the returns.

In concluding this section, using three varying methodologies, this study mostly provides no support for the Samuelson Hypothesis in South Africa. An interesting result was found with the FINI15 contract, as it is found to be significant, however the support found is for a decreasing volatility as maturity approached. This contradicts the Samuelson Hypothesis, as it expected volatility to increase as maturity approaches, and not to decrease. The result for the FINI15 contract was found in both the OLS regression and the GARCH (1, 1). Only one contract, White Maize, is supported throughout the use of the three methodologies. The difference in results between the three tests utilised to test the Samuelson Hypothesis were also demonstrated in Duong and Kalev (2008). When they compared the results obtained using the JT test and regression analysis, using the GARCH (1, 1) yields similar results in only six out of the twelve markets.

4.3 Negative Covariance Hypothesis

The Negative Covariance Hypothesis examines the 'negative covariance' theory proposed by Bessembinder et al. (1996). The Negative Covariance Hypothesis states that the Samuelson Hypothesis, (also referred to as the maturity effect) is more likely to be supported in markets that exhibit a negative covariance between the spot prices changes and changes in net carry costs (Duong & Kalev, 2008). As discussed by Duong and Kalev (2008) because spot prices are not generally available, this study will follow Fama and French (1988) in using futures prices in the contract month (or contract week for agricultural futures) as the proxy for the spot prices. If the maturity effect is stronger for markets that have a negative covariance ($\alpha_1 < 0$), then the Negative Covariance Hypothesis is supported. This would mean that for the contract that found support for the Samuelson Hypothesis, namely White Maize, this markets would display a negative covariance between the spot prices changes and changes in net carry costs. While the remaining contracts, which found no support for the Samuelson hypothesis would in contrast not have a negative covariance.

Tables 10 and 11 set the results for agricultural and non-agricultural contracts when assessed according to the Negative Covariance Hypothesis. Only two out of the seven non-agricultural contracts display a negative covariance between spot price changes and changes in net carry costs, those being GoldMining and Listed Prop futures contracts. Yet only the Listed Prop contract has a covariance that is significantly different from zero.

Table 10: Results displayed for testing for the Negative Covariance Hypothesis for non-agricultural futures

	All Share	FINI15	GoldMining	Indi25	Resi20	Retailers	Listed Prop
Intercept	-2.09980	0.34520	0.75160	4.75450	-4.47450	0.28890	133.87810
P-value	**0.16770**	**0.54580**	**0.34400**	**<.0001**	**0.73420**	**0.94540**	**0.02960**
Spot	0.00015	0.00003	-0.00035	0.00006	0.00020	0.00005	-0.02140
P-value	**<.0001**	**0.62180**	**0.56940**	**0.20110**	**0.41800**	**0.51100**	**<.0001**

The results presented for testing for the covariance between spot prices and net carry costs. The results are obtained from the following regression:

$$\Delta c_{j,t} = \alpha_0 + \alpha_1 \Delta S_{j,t} + \varepsilon_t$$

Where Δs_t *is the change is spot prices at time t and* $\Delta c_{j,t}$ *, is the change in net carry costs for contract j at day t. Which is defined as :*

$$c_t = \frac{(f_t - s_t)}{TTM_t}$$

The results are obtained with the Newey-West (1987) Heteroskedasticity Consistent Covariance matrix procedure.

For the agricultural futures contracts, the results indicate all of the contracts (except for yellow maize) have a negative covariance between their spot price changes and changes in net carry costs. All of the contracts displaying a negative covariance, are also significantly different from zero.

Table 11: Results for testing the Negative Covariance Hypothesis for agricultural futures

	Soybean	Wheat	White Maize	Yellow Maize
Intercept	10.73590	1.59540	1.53450	1.81370
P-value	**0.05460**	**0.03170**	**0.01750**	**0.03020**
Spot	-0.00266	-0.00073	-0.00115	0.00069
P-value	**0.04600**	**0.07540**	**0.02560**	**0.08240**

The results presented for testing for the covariance between spot prices and net carry costs. The results are obtained from the following regression:

$$\Delta c_{j,t} = \alpha_0 + \alpha_1 \Delta S_{j,t} + \varepsilon_t$$

Where Δs_t *is the change is spot prices at time t and* $\Delta c_{j,t}$ *, is the change in net carry costs for contract j at day t. Which is defined as :*

$$c_t = \frac{(f_t - s_t)}{TTM_t}$$

The results are obtained with the Newey-West (1987) Heteroskedasticity Consistent Covariance matrix procedure.

Although support was found for Listed Prop, Soybean, Wheat and White Maize, the coefficient is negative but is not economically significant. The largest coefficient is for the Listed Prop contract, however the magnitude of this is minor. Larger estimates of the covariance between net carry costs and spot prices are expected in agricultural futures in comparison to metal futures according to Bessembinder et al. (1995). The results support the Negative Covariance Hypothesis, as no markets had a negative coefficient and were significant, which corresponds to the lack of support for the Samuelson Hypothesis. If there was a negative covariance which was significant, it would then be expected that support was found for the Samuelson Hypothesis.

The results obtained from investigating the Samuelson Hypothesis in Section 4.2 show that the only contract that did consistently show support of the Samuelson Hypothesis is White Maize. According to Bessembidner et al. (1996) the contract with the biggest coefficient, which is Listed Prop should exhibit the greatest support of the Samuelson Hypothesis. This contract found no support for the Samuelson Hypothesis, in any of the three tests utilised throughout this study.

4.4 State Variable Hypothesis

Duong and Kalev (2008) explain that the State Variable Hypothesis infers that information flow is the main determinant of time patterns for the futures price volatility; and the Samuelson Hypothesis is viewed as a special case where the information flow is greater as delivery approaches. There are two steps to provide the correct testing for this hypothesis. Firstly, daily futures realised volatility is regressed on days to maturity and secondly, the spot price volatility is also included as a control variable in the regression equation. If the 'negative covariance' condition is the most important determinant of the maturity effect, as stated by Bessembinder et al. (1996), then the coefficient of TTM should remain negative and significant despite including the spot price volatility variable. The only result here which will be of importance in the White Maize result, the reason being that this is the only contract that found consistent support for the Samuelson Hypothesis. This test serves as a check to identify the cause of the volatility, thus this would only add real value to the White Maize contract, however the test is applied to the other contracts in order to analyse if the results portray any insight. Table 12 and Table 13 display the results before the spot price is included; and Table 14 and Table 15 include the results after the inclusion of the spot price.

Table 12: Testing the State Variable Hypothesis before the inclusion of Spot Price for non-agricultural futures

	All Share	FINI15	GoldMining	Indi25	Resi20	Retailers	Listed Prop
Intercept	-0.18530	1.33530	0.66470	-0.20150	-0.34880	0.62150	-0.28360
P-value	**0.65420**	**0.00720**	**0.44780**	**0.55590**	**0.48420**	**0.25370**	**0.70130**
TTM	0.00381	-0.02260	-0.01410	0.00412	0.00645	-0.00983	0.00568
P-value	**0.61030**	**0.01030**	**0.37140**	**0.50640**	**0.47220**	**0.32150**	**0.67780**

The table examines the effect of information flows as suggested by the "state-variable" hypothesis. In order to examine the information flow effect, daily futures realised volatility is firstly regressed on time to maturity then on time to maturity and spot price. This tables reflect when daily futures realized volatility is regressed on time to maturity. The regression equation used in investigating the effect of information flow is:

$$RV_t = \alpha + \beta TTM_t + \varepsilon_t$$

These regressions are performed on the reduced dataset where futures realized volatility and time to maturity can be matched to spot volatility. The results are obtained with the Newey-West (1987) heteroskedasticity consistent covariance matrix procedure.

The results of this test of the information flow effects are consistent with previous findings whereby the estimated coefficient for the spot price volatility are uniformly positive and all the contracts , excluding soybean have significant coefficients. This translates into the spot price volatility having explanatory power over the futures price volatility.

Table 13: Testing the State Variable Hypothesis before the inclusion of Spot Price for agricultural futures

	Soybean	Wheat	White Maize	Yellow Maize
Intercept	-0.05980	-0.13430	-0.22770	-0.11390
P-value	**0.17860**	**0.02220**	**0.14510**	**0.17940**
TTM	0.00033	0.00599	0.00812	0.00113
P-value	**0.30490**	**0.02060**	**0.27930**	**0.75810**

The table examines the effect of information flows as suggested by the "state-variable" hypothesis. In order to examine the information flow effect, daily futures realised volatility is firstly regressed on time to maturity then on time to maturity and spot price. This tables reflect when daily futures realized volatility is regressed on time to maturity. The regression equation used in investigating the effect of information flow is:

$$RV_t = \alpha + \beta TTM_t + \varepsilon_t$$

These regressions are performed on the reduced dataset where futures realized volatility and time to maturity can be matched to spot volatility. The results are obtained with the Newey-West (1987) heteroskedasticity consistent covariance matrix procedure.

Table 14: Testing the State Variable Hypothesis after the inclusion of Spot Price for non - agricultural futures

	All Share	FINI15	GoldMining	Indi25	Resi20	Retailers	Listed Prop
Intercept	-0.17680	0.05000	-0.07900	-0.05340	-0.29310	-0.14350	-0.13220
P-value	**0.13200**	**0.65960**	**0.32820**	**0.13630**	**0.02850**	**0.31510**	**0.75090**
TTM	0.00301	-0.00087	0.00141	0.00090	0.00498	0.00254	0.00246
P-value	**0.13890**	**0.65840**	**0.28130**	**0.13000**	**0.03380**	**0.30090**	**0.73860**
Spot	1.03310	1.02490	0.98050	1.02160	0.93010	1.02470	0.85390
P-value	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**

The table examines the effect of the State Variable Hypothesis after the inclusion of the Spot Price. The spot price is a control variable utilised in the following regression equation:

$$RV_t = \alpha + \beta TTM_t + \varphi Vola(S_{j,t}) + \varepsilon_t$$

White Mazie and Yellow Maize changed from positive coefficients to negative coefficients with the inclusion of the spot price, while GoldMining and Retailers changed from a negative TTM to positive. The only contract to display the Samuelson Hypothesis consistently is FINI15, as it has a negative coefficient, which is insignificant before and after the inclusion of the spot price.

Table 15: Testing the State Variable Hypothesis after the inclusion of Spot Price for agricultural futures

	Soybean	Wheat	White Maize	Yellow Maize
Intercept	-0.06100	-0.07840	-0.04430	0.00619
P-value	**0.17330**	**0.04840**	**0.61720**	**0.93160**
TTM	0.00033	0.00253	-0.00037	-0.00306
P-value	**0.30020**	**0.11390**	**0.93150**	**0.34450**
Spot	0.64530	0.62100	0.76160	0.57690
P-value	**0.49360**	**<.0001**	**<.0001**	**<.0001**

The table examines the effect of the State Variable Hypothesis after the inclusion of the Spot Price. The spot price is a control variable utilised in the following regression equation:

$$RV_t = \alpha + \beta TTM_t + \varphi Vola(S_{j,t}) + \varepsilon_t$$

It is difficult to reach any robust conclusions for running the State Variable Hypothesis, as it is tested on data that displays little or no consistent evidence on the future contracts, thus making it challenging to determine the source of the volatility of the future price to the degree of information flow to the market.

Table 4 and Table 5 illustrated the results for the non-parametric methodology, namely the JT test which was utilised to test the Samuelsson Hypothesis. None of the non-agricultural contracts were found to be significant, and none of these contracts found support for the Samuelson Hypothesis. The agricultural contracts reveal a different story, whereby only one agricultural contract failed to find support for the hypothesis. Wheat, White Maize and Yellow Maize contracts show the null hypothesis of equal volatility being rejected and thus find support for the maturity effect. The only agricultural contract to find no support for the Samuelson Hypothesis was Soybean.

The next methodology was employed as there was concern over using a non-parametric test. The OLS regression results are presented in Table 6 and Table 7 and illustrate near to no support for the Samuelson Hypothesis at the 5% confidence level. For all contracts examined, support is only found for White Maize. The FINI15 contract demonstrated support for volatility decreasing as the contract approach maturity, instead of increasing as approached maturity. These results may be compromised due to the OLS regression failing to fully account for the heteroskedastic variance of these South African futures contracts, this is compounded by the low R-squared displayed by each of these contracts.

The final method utilised to test the Samuelson Hypothesis is the GARCH (1, 1) model, which is shown in Table 8 and Table 9. Utilising this methodology, only two out of the 11 contracts were significant these being the White Maize and FINI15 contracts. The GARCH (1, 1) results demonstrate that the coefficient of White Maize is negative, illustrating support for the Samuelson Hypothesis within this contract which means that as the contract approaches its maturity, the volatility of the contract will increase. The FINI15 contract, however indicates the opposite result. As the coefficient here is positive even though it is significant, implying that the futures price volatility actually decreases as the contracts tend towards its expiration. This would be plausible as volatility will fall as more certainty could be created.

The data was then tested for the Negative Covariance Hypothesis, which states that the Samuelson Hypothesis, is more likely to be supported in markets that exhibit a negative covariance between the spot price changes and changes in net carry costs (Duong & Kalev, 2008). The results illustrating the Negative Covariance are displayed in Table 10 and Table 11 and find that although support was found for Listed Prop, Soybean, Wheat and White Maize contracts, despite the negative coefficient it is not statistically significant. The largest coefficient is for the Listed Prop contract, however the magnitude of this is minor. Little or no support was found when testing the Negative Covariance Hypothesis.

Table 12 and Table 13 display the results for the State Variable Hypothesis, which states that the source of volatility of the futures price is the degree of information flow to the market or uncertainty resolution (Anderson & Danthine, 1983). However, as little or no support for the Samuelson Hypothesis was found, the State Variable Hypothesis fails to have great significance as its plausibility relies on the existence of the Samuelson Hypothesis.

5 CONCLUSION

The main objective of the study is to examine the Samuelson Hypothesis in the South African futures market. Investigating 12 futures contracts ranging from agricultural, to financial and to metal contracts, this study provides an initial view into the South African market.

Utilising both parametric and non-parametric tests, the Samuelson Hypothesis was examined via three separate methodologies; namely the Jonckheere-Terpstra, OLS regression and GARCH (1, 1) models. When employing the Jonckheere-Terpstra methodology, Wheat, White Maize and Yellow maize contracts found support. FINI15 and White Maize are the contracts displaying support when the OLS regression is employed. The final methodology was a GARCH (1,1) model whereby White Maize and FINI15 find support for the Samuelson Hypothesis.

In summarising the testing for the Samuelson Hypothesis, only the White Maize futures contract supported the Samuelson Hypothesis consistently when testing the Samuelson Hypothesis via the three methodologies. FINI15 found support in two out of three methodologies. The results are consistent with Bessembinder et al. (1995), Galloway and Kolb (1996) and Duong and Kalev (2008) as it finds support for the Samuelson Hypothesis to be greater in agricultural contracts than in other industries. Little evidence was found for the Samuelson Hypothesis, but the one contract that throughout the three methodologies displayed support for the Samuelson Hypothesis was an agricultural contract.

In addition, the study also provides analysis of the Negative Covariance Hypothesis, introduced by Bessembinder et al. (1996). Although support was found for four contracts, namely Listed Prop, Soybean, Wheat and White Maize, the coefficient while negative is very small. The largest coefficient is the Listed Prop contract, however the magnitude of this is minor. According to Bessembidner et al. (1996) the contract with the greatest coefficient, which is Listed Prop should exhibit the greatest support of the Samuelson Hypothesis. This contract found no support for the Samuelson Hypothesis, in any of the three tests utilised throughout this study.

The study also assessed the State Variable Hypothesis and found results of this test to be consistent with previous findings whereby the coefficient for the spot price volatility are uniformly positive and significant for all the contracts, except the Soybean contracts. This translates in to the spot price volatility having explanatory power over the futures price volatility.

This study could be extended by examining other emerging markets, to understand if the lack of support for Samuelson Hypothesis could be related to emerging markets as a whole. Intraday data may be deemed more appropriate than daily data for further studies as it is more robust (Duong & Kalev, 2008). In addition, the study could account for volume traded when analysing volatility as the higher the volume, as this would assist in getting a clearer picture of what is driving the patterns observed in the futures market.

As inferred by previous literature such as Chen, Duan and Hung (1999), Akin (2003) and Duong and Kalev (2008) it is of grave importance that a hedger places emphasis on the contracts volatility and time-to-maturity relationship. Due to the lack of support illustrated in this study for the Samuelson Hypothesis, it is arguable whether this relationship still needs to be focused on for hedging. Instead other factors could be of greater importance.

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