

MIDLANDS STATE UNIVERSITY



FACULTY OF COMMERCE

DEPARTMENT OF BANKING AND FINANCE

**THE APPLICABILITY OF WEATHER DERIVATIVE USAGE ON
TOBACCO FARMING IN ZIMBABWE (1991-2017).**

BY

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*This dissertation is submitted in partial fulfillment of the requirements of the Bachelor of
Commerce Banking and Finance Honors Degree in the Department of Banking and Finance
at Midlands State University, Gweru:*

Zimbabwe 2018

APPROVAL FORM

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FARMING IN ZIMBABWE.

YEAR THIS DEGREE GRANTED:

2018

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ACKNOWLEDGEMENTS

Sir Isaac Newton, the great scientist once said, “If I have been able to see further than others, it is because I have stood on the shoulders of giants”. This research would not be possible without the efforts of the following “giants” whose contributions made and inspired me to continue.

I wish to thank friends, family and school colleagues for tirelessly working with me in carrying out this research. The story of this work is not complete without the wisdom and guidance of these people throughout the compilation process. Their incomparable contribution was of utmost importance. They would make periodic review of the dissertation as it progressed and sacrificed their important time. I owe them a lot and am very grateful.

Above all, I would want to thank God Almighty Creator for being the “strong tower” of my life. In his hands I submit this research.

ABSTRACT

*Financial derivatives are used for hedging and transferring of risks in the financial system, government planning and regulatory systems. Derivatives have been used as a tool to identify risks and develop strategies to address the risks in Agriculture. The study's main aim is to investigate the applicability of weather derivatives on tobacco farming in Zimbabwe and examines its role in production. Thus by studying the issue within the context of Zimbabwe weather patterns and their relation to tobacco prices, the central null hypothesis to be addressed: **Weather derivatives are not applicable in tobacco farming in Zimbabwe.** The hypothesis was formulated to gain a better understanding of weather derivatives feasibility in tobacco farming. Thus, annual data of rainfall patterns, temperature and prices of tobacco for the period 1991 to 2017 was analysed. Time series for annual data was used as the source of data. The Ordinary Least Squares (OLS) was used in the analysis of the econometric model to determine the casual relationship between weather related events and tobacco prices. The study seeks to examine the need to improve regulatory policies in application of the weather derivatives in tobacco farming. The results indicate the need for weather derivatives use in tobacco farming given the fact that preconditions that are conducive for their adoption are satisfied. This include key dimensions namely; financial literacy by agricultural bodies; i.e. Tobacco research board, Tobacco Industry and Marketing Board (TIMB), farmers and government regulators. Given that most of the preconditions were not satisfied, the study does not reject the null hypothesis concluding that weather derivatives are not applicable in Zimbabwe, at the current moment. The study suggested recommendations to financial institutions, farmers and government to develop a framework to adopt weather derivatives as an alternative source of finance and implementing fiscal policies as well as to hedge weather related risks in tobacco farming.*

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LIST OF ACRONYMS

ADF	Augmented Dickey-Fuller
CDD	Cooling Degree Days
GDP	Gross Domestic Product
HDD	Heating Degree Days
IMF	International Monetary Fund
IRD	Interest Rate Derivatives
MM theory	Modigliani-Miller theory
NSE	Nairobi Securities Exchange
OTC	Over-the-Counter
RBZ	Reserve Bank of Zimbabwe
TIMB	Tobacco Industry and Marketing Board
UK	United Kingdom
US	United States
ZIMACE	Zimbabwe Agricultural Commodity Exchange

CHAPTER 1: INTRODUCTION

1.1 Introduction

This study will focus on weather derivatives which act as a hedging tool against weather related events. In this current chapter, the emphasis is to introduce the study to understand the current derivative market, leading to the identification of the problem or opportunity at hand. The chapter will end by a conclusive summary after taking into account the research questions and objectives the study seeks to answer and achieve.

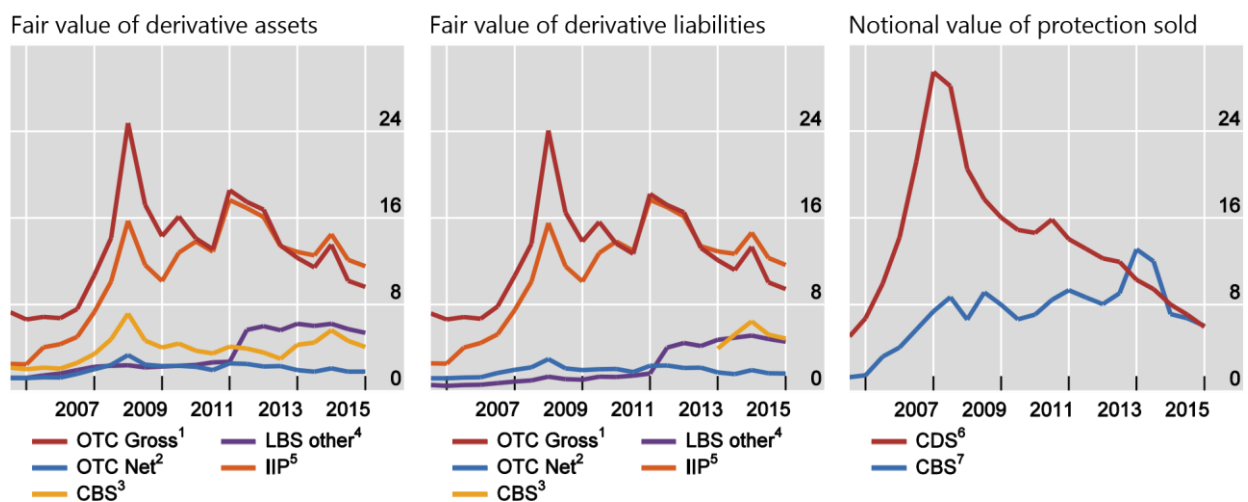
1.2 Background of the Study

Trading of derivatives post the global financial crisis was evidenced by a sharp fall as postulated by (Wooldridge, 2016). The fair value of derivative assets, liabilities and the notional value of protection sold hit a resounding peak between 2007 to 2008 era, followed by a sharp fall approaching 2015. Factors related to consumer skeptics and insufficient market regulation resulted to this trend. This is depicted in the subsequent graphs;

Figure 1: Derivatives statistics (2007-2015)

Derivatives statistics

Outstanding positions, in trillions of US dollars

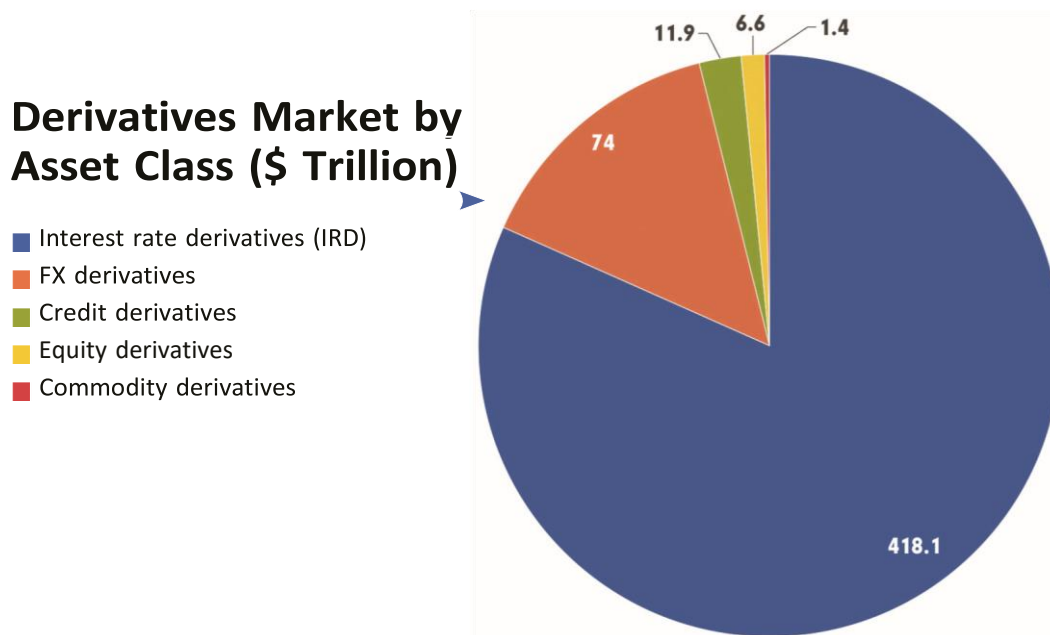


¹ Gross fair value of outstanding OTC derivatives. ² Net fair value of outstanding OTC derivatives. ³ Not adjusted for discontinuities in coverage, notably in 2013–14 when banks started to report derivative assets on counterparties in their home country. ⁴ Other instruments, including derivatives. Not adjusted for discontinuities in coverage, notably in 2012 when banks started to report derivative positions on residents of the reporting country. ⁵ Financial derivatives and employee stock options. Excludes derivative positions of residents on residents. ⁶ Credit default swaps sold. ⁷ Guarantees extended.

Source: Wooldridge, P. (2016) Comparison of BIS derivatives statistics, Bank for International Settlements

According to ISDA (2017) Interest rate derivatives (IRD) constituted about 76% of the total notional outstanding at end June 2016. Forex derivatives constituted about 13% in the same reporting period. Commodity, credit and equity derivatives constituted the remaining share. This signifies a broad stance to prioritize the hedging of interest rate risk as well as currency risk by organizations and of no or insignificant usage of weather derivatives. Varangis (2002) eludes to the fact that the weather derivative market is still new and possibly relatively smaller to the other derivative market, hence its appreciation slightly underscored. This is depicted in the subsequent graph;

Figure 2: Derivatives market by asset class (2016)

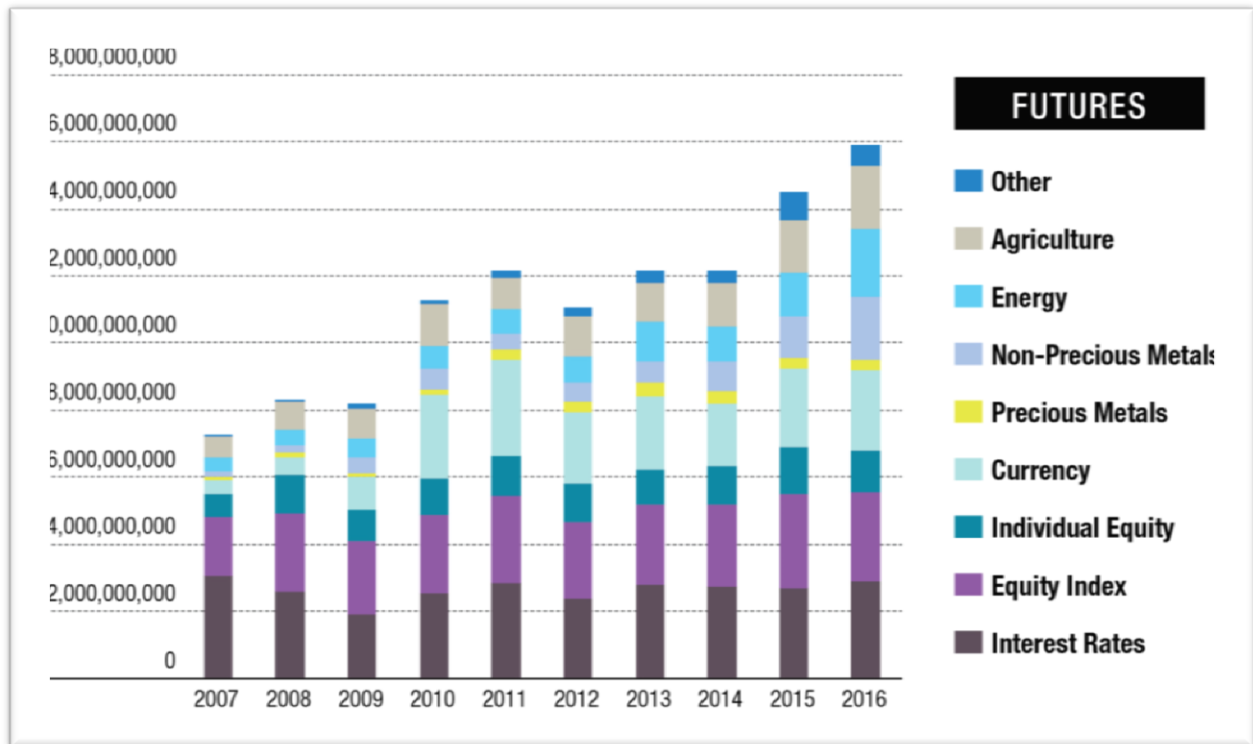


Source: International Swaps and Derivatives Association, Inc. Derivatives facts and figures 2017

According to Geyser (2004) weather risk markets are among the recent of financial innovations and most dynamic markets for financial risk transfers. Participants in this market include the energy sector of prime, tourism, financial institutions as well as agriculture. The market is still

broadly based in the United States, the region of its pioneered inception although its appreciation is spreading across the globe particularly developed economies. Evidence of a relatively insignificant but growing weather derivatives market is depicted in the subsequent graph with weather derivatives being constituted in the ‘other’ category.

Figure 3: Ten year volume trend for global futures (2007-2017)



Source: Bitton, L. (2017) The role and importance of derivative markets, Capacity Building Seminar, Casablanca May 18th 2017

Eganza (2016) postulates that the Kenyan financial market is characterized by the domination of OTC exchange traded financial derivatives instruments like structured and credit derivatives. Evidence also shows that there are still to develop or trade weather derivatives as already been done in developed economies like the United States. Trading of derivatives on the Nairobi Securities Exchange (NSE) was licensed in 2015 according to (Chakri, 2016).

According to the BIS (2017) South Africa has the most developed derivatives exchange in Africa in terms of trading activity. Statistics from the BIS (2017) semiannual survey of OTC derivatives markets, show that only in South Africa were interest rate futures and options traded in 2016 and 2017; classification by currency excluding North America, Europe, Asia and the Pacific.

In Zimbabwe, derivatives trading were once initiated in 1994 when the Zimbabwe Agricultural Commodity Exchange (ZIMACE) was formed which was a private-owned open outcry exchange. According to Chakri (2016), in 2001, ZIMACE was suspended, thus closed as the Zimbabwean government interfered and took control over grain and wheat trading. The lack of weather derivatives could be seen as a missed opportunity in trying to save this market which died at its infancy stage. Geysler (2004) the use of weather derivatives could allow farmers to focus more of their attention on actual farming process. This is so as the major risk categories- yield; event and price risks- would have all been hedged.

According to TIMB (2016) tobacco exports from Zimbabwe rose from 152 million kilograms in 2015 to 164.5 million kilograms in 2016 signifying a growing trend in the production of the “golden leaf” in Zimbabwe over the past couple of years. Total 2016 export proceeds amounted to USD\$933.7 million which was over 5% of the Gross Domestic Product reported for the same period. TIMB (2016) postulate that the 2015 export proceeds in Zimbabwe were USD\$854.9 million signifying a 9.22% increase between 2015 and 2016. This shows how pivotal the “golden leaf” commodity is in generating foreign currency in Zimbabwe and thus a significant reason to adopt weather derivatives to accrue maximum gains from it.

According to ISDA (2017) a comparison of derivative usage in Africa with the rest of the world indicates that the former enjoys a mere 6.4% market share, with the US and UK enjoying 41% and 39% respectively; classification by turnover of interest rate derivatives, BIS triennial survey 2016. According to Gautam and Foster (2000) the usage of weather derivatives in the global economic powerhouses such as the United States, United Kingdom and Japan is largely by energy companies. In light of this, literature gives evidence of a non-existing usage of weather derivatives in Africa.

1.3 Problem Statement

Tobacco is one of the largest agricultural foreign currency earners in Zimbabwe. Since the beginning of the new millennium, there has been a siege in the Gross Domestic Product (GDP) of Zimbabwe mainly attributable to the poor performance of the agricultural sector which was heavily affected by recurrent drought spells coupled with regulation inefficiencies. These varying or erratic weather events threaten the maximum contribution of the agricultural commodity to generate foreign currency receipts. This fluctuating behavior is as a result of varying prices being dictated on the agricultural market, of particular, the tobacco market. Rainfall and temperature are the major determinants of tobacco pricing thus form the source of enquiry to determine their impact on the tobacco prices in Zimbabwe and virtually leading to the applicability of weather derivatives as a hedging tool in tobacco farming in Zimbabwe.

1.4 Objectives of the Study

- The primary objective of the study is to establish the applicability of weather derivatives in tobacco farming in Zimbabwe. This major objective is broken down into the following sub objectives.
- To determine the impact of rainfall on tobacco prices in Zimbabwe.
- To analyze the impact of temperature on tobacco prices in Zimbabwe.
- To establish the effect of tobacco prices to the volume of foreign currency generated in Zimbabwe.

1.5 Statement of Hypothesis

Ho: Weather derivatives are not applicable in tobacco farming in Zimbabwe.

H1: Weather derivatives are applicable in tobacco farming in Zimbabwe.

1.6 Significance of the study

Although the main focus is on the applicability of weather derivatives in tobacco farming in Zimbabwe, a relationship with regards to weather related risks and tobacco prices will be drawn. Financial institutions benefit from weather derivatives as the contracts are secondary sources of finance. Revenue is earned when financial institutions perform the underwriting role for these

contracts, as they will be charging a fee for this service. The government will also benefit from the information on weather derivatives as this would assist them in formulating fiscal policies. Agricultural output's contribution to the Gross Domestic Product (GDP) can be estimated reliably if a weather risk mitigation schemes are in place. Farmers benefit from the use of weather derivatives and the information of them thereof as they will be able to hedge against non-catastrophic weather events in their farming activities. Future scholars will benefit from this study as it enlightens on current literature gaps in the area on derivatives; this, for the purpose of them able to contribute to the existing body of knowledge relating to derivatives.

1.7 Delimitations (Scope) of the study

This study will mainly focus on tobacco farming in Zimbabwe as the commodity is the major foreign currency earner locally. Data sample of two weather events namely rainfall and temperature were chosen to represent the total population study of weather events as they are the major determinants in crop yield, which thus affect crop returns realized. A period stretching from 1991 to 2017 will represent the time frame to be considered under this study so as to mitigate the bias attributable to short time frames.

1.8 Assumptions

- The chosen data sample is expected to represent the factual data relating to the whole data sample.
- The relationship to tobacco prices is assumed to be mainly influenced by temperature and rainfall patterns which thus only constitute the research sample.
- The data collected from the weather portal is error free.

1.9 Limitations of the study

- The results gathered from this study may not be universally applicable.
- The data used for the non-catastrophic weather events has been averaged and thus results are based on these averaged statistics although the deviation from the actual monthly data is low.

- The effect of the weather events is generalized for the whole of Zimbabwe which has however a varying climatic landscape across the country although regions expecting most of the tobacco farming have little deviations between them.

1.10 Definition of terms

Financial derivatives are financial instruments that are linked to a specific financial instrument or indicator or commodity, and through which specific financial risks can be traded in financial markets in their own rights. (IMF, 1998:2)

A weather derivative is a contract between two parties that stipulates how payment will be exchanged between two parties depending on certain meteorological conditions during the contract period. (Geysler, 2004:445)

A heating degree day (HDD) measure the coldness of daily temperature compared to the standard of 65°c degree Fahrenheit. (Tyagi and Shastri, 2016:132)

A cooling degree day (CDD) measures the warmth of daily temperature as compared to the standard of 65°c Fahrenheit. (Tyagi and Shastri, 2016:132)

1.11 Organization of the study

This chapter was introducing the area of study to be covered of the applicability of weather derivatives in agriculture in a developing country. A background surrounding derivatives trading was given which gave birth to the explicit stating of the problem to be addressed in this study. The subsequent chapters will entail the supporting literature in line with this concept, the methods used in evaluating the problem and thus leading to a comprehensive factual conclusion regarding the applicability of weather derivatives in Zimbabwe. An appreciation of literature both theoretical and empirical will be discussed in-depth in the following chapter.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter discusses the theoretical and empirical literature regarding the usage and applicability thereof of weather derivatives. An in depth analysis into the core founding theories formulating this study will be done stretching to the empirical evidence put forward by those theories. An overview of the derivatives usage from a global perspective to a regional scenario will also form the core of this chapter. A conclusive summary in regard to the literature of weather derivatives will close, and enlighten the chapters to follow.

2.2 Theoretical Literature

2.2.1 The Keynesian Income-expenditure model

John Maynard Keynes developed the income-expenditure model which was published in his book, *The General Theory of Interest and Money* in 1935, as postulated by (Mahdjoubi, 1997). The model for national income encompasses consumption, investment, government, and net exports. This is the decomposition of GDP. According to Breido and Tregub (2005), aggregate expenditures on investment, government and net exports are regarded as independent of current income. The only exception from current income is aggregate consumption which Keynes advocates that it is primarily determined by current real national income.

The equation: $\text{aggregate consumption} = C + mpc (Y)$ where C is autonomous consumption, mpc is the marginal propensity to consume and Y is the level of current real income; is one that explains the relationship of current real income and aggregate consumption. Any increase in current real income is signified by the marginal propensity to consume.

According to Breido and Tregub (2005), total aggregate expenditure denoted as AE is the sum of consumption, investment, government expenditure and net exports. The equation for AE can be written as; $AE = A + mpc (Y)$, where A is different levels of autonomous expenditure, mpc is the marginal propensity to consume and Y is real national income.

The level of Gross Domestic Product (GDP) within an economy is a determinant of derivative usage which implies a relationship of GDP to investment. The level of real GDP is the level of Gross Domestic Product adjusted for the effects of inflation. Equilibrium real GDP in the

income-expenditure model is found by setting current real national income equal to current aggregate expenditure represented as; $Y = AE$ as postulated by (Breido and Tregub, 2005).

According to Mahdjoubi (1997:3); if the flow of purchasing power- of aggregate demand is insufficient to sustain a high level of economic growth, and activity, lowering taxes, interest rates and government expenditure in excess of tax receipts will restore consumer and business confidence.

According to Hazlitt (1995), the government cannot go bankrupt if its debt is solely from its citizens, that is, internal debt. This is so because by employing internal debt, the citizens are on both sides of the balance sheet, that is, through debt owed by and tax payable by the government. Altering the tax rate is irrelevant as the same money taken from citizens is used to pay back to them for government debt, as postulated by (Hazlitt, 1995). There is also a setback to the concept of interest rates (monetary policy) as an effective tool for stagnation and unemployment; as postulated by (Mahdjoubi, 1997). During times of recession, lowering interest rates may not reliably contribute to increased consumer expenditure.

Another flaw to the economics of Keynes suggest that, the “real economy” controls, and money is only the “veil of things” and also Keynes was of the view of equilibrium economics, a closed and static economy as criticized by (Drucker, 1986). According to Galbraith (1994), they criticize the Keynesian doctrine which suggests that the government should intervene by running deficits in times of serious unemployment to support the flow of aggregate demand; as this later was evidenced by numerous problems. Figgie and Swanson (1992) advocate in favor of the Keynesian doctrine postulating that the United States Federal budget in the early 1970s had always run on deficit, even during the boom years and thus clearly giving light that the Keynesian doctrine was employed beyond its scope and intention.

Rueff (1947) argues that the postulations of the General Theory of Employment, Interest, and Money by Keynes, are applicable to a specific case only and not to the general case. Moreover, the characteristics of the special case assumed by the classical theory of Keynes happen not to be those of the economic society in which we actually live, as postulated by (Hazlitt, 1995:238).

The Keynesian economics in contributing to the understanding of this study plays a pivotal role and also contributes to the continued debate in literature relating to monetary economics. The

activities of financial markets, that is, derivatives, are affected by the postulations of the Keynesian economics and the critics thereof and henceforth prove to be an influential theory of discussion in giving a solid foundation to this current study.

2.2.2 Monetarist Theory

This theory explains the causes of inflation in the economy. Various economists have different views regarding the source of inflation. Humphrey (1975) postulates that, monetarists are of the view that inflation is purely a monetary phenomenon and an increase in money supply leads to increased prices in the economy. They developed an equation which is; $MV = PQ$. Where **M** is money supply, **V** is the velocity of money circulation, **P** is price level and **Q** is the quantity of money in circulation. The velocity of money circulation and the quantity of money in circulation are regarded constant (Humphrey, 1975). The source or cause of inflation in this regard is the increase in money supply.

Omanukwue (2010) examined the Modern Quantity theory of money in Nigeria for a study period between 1990 and 2008. The study made use of the Eagle-Granger two-stage test for co-integration employing quarterly time series data to establish the long-run relationship between money, prices, output and interest ratio and ratio of demand deposits/time deposits, as postulated by (Omanukwue, 2010). The study showed that the long-run relationship among money, interest rate, prices and financial sector development were in tandem, in Nigeria for the sample period 1990 to 2008. The study also concludes that information relating to consumer prices will still be encompassed in the monetary aggregate, as postulated by (Omanukwue, 2010).

Abiola and Egbuwato (2012) conducted a study to validate the restatement of the Quantity Theory of Money by Milton Friedman using Nigerian data from 1970 to 2008. The study employed a co-integration econometric technique, using time series data. The study results showed conformity to the model of Milton Friedman. Whereas price is positively related to demand for money, the long-run change in price is negatively related to it, according (Abiola and Egbuwato, 2012). The only varying result to the postulations of Friedman shows a contrary relationship of non-human wealth to human wealth as an explanatory variable of demand for money in Nigeria, as postulated by (Abiola and Egbuwato, 2012).

According to Ruffin (1938), empirical evidence from the American economy between 1915 and 1980 nullifies the concept of constants, in the Crude Quantity theory of Money. Real GDP rose to eight times its size and money supply (M1) increased to about 33 times its size, as postulated by (Alam, Mohiuddin and Arif, 2014). This shows that growth in money supply far outstripped the growth of the Real Gross National Product.

Alam, Mohiuddin and Arif (2014) carried out a study to test the postulations of the Crude Quantity theory of Money using data from the Bangladesh economy, both in the short and long run. Time series data of economic variables that explain and form the core of the Quantity theory of Money were used. The results of the study concluded that the price level does not move proportionally with an increase in money supply in the Bangladesh economy, as postulated by (Alam, Mohiuddin and Arif, 2014). The reason for the result prove that constants, that is, velocity of money circulation, gradually falls to an increase in money supply whilst nominal GDP increases, thus nullifying the concept of constants in the Crude Quantity theory of Money. Real GDP also increases due to an increase of investment, use of modern technology in production, increase of the labor productivity and government policies, according to (Alam, Mohiuddin and Arif, 2014:143).

Monetarists reject any non-monetary causes of inflation. Among the list includes government fiscal policies, shifts in autonomous private expenditure, cost-push influences to name but a few, which are supported by the Classical view. The condition basing this assumption or view is on the grounds that an increased stock of money per unit of output is required on all cases and therefore constitutes the time cause of inflation, as is supported by (Humphrey, 1975).

Financial securities are traded in the volatile macro-economic environment. Derivative securities are used mostly to hedge positions taken in the cash market and for speculative purposes that is, taking positions today with future expectations. Inflation is one of the major variables to consider in the macro-economic environment as it affects the future value of money as well as its buying power, hence the relevance of understanding the postulations of the Quantity theory of Money.

2.3 Empirical Literature

Bobrikora (2016) carried out a study on the weather risk management in agriculture with the main focus on weather derivative valuation with payoffs depending on temperature. Historical

weather data of 30 years obtained in Kosice, in Slovakia was used, to design a weather contract that can be used to hedge against suboptimal temperature conditions. The Burn analysis was used to assess the data in this study. According to Bobrikora (2016), the results showed that the farmer establishes the highest payoff when they buy a put or call option in the event of temperature fluctuations, thus suggesting to the use of weather derivatives. These postulations are in tandem to what Pajic and Markovic (2016) postulate, that the highest return per unit of risk is attained when using weather derivatives when hedging against non-catastrophic weather risks.

According to Pajic and Markovic (2016), a study on the possibility of adapting drought risk reduction in corn production was done for Serbia, with rainfall being the explanatory variable. Time series data from 2004 to 2013 of the July-August precipitation, realized corn yield, revenue and realized costs was used in the study. According to Pajic and Markovic (2016), the model included the use of the classical statistical indicators (correlation quotient, variation quotient, and variation interval, mean). The results showed that, the application of the weather option in corn production led to a decreased co-efficient of variation in financial results by 9.64% as opposed to the version where weather derivatives were not applied. The possibility of achieving a negative financial result using weather derivatives was eliminated, which adds to the existing literature of the effect and that which prefers weather derivatives as a risk reduction scheme. Bobrikora (2016) also contributes to the literature which supports the use of weather options as the ideal derivative instruments for hedging weather related risk in agriculture.

According to Tyagi and Shastri (2016), weather derivatives act as a technique of earning profits and also as a substantial risk management mechanism for assuring revenue losses for the industries depending upon weather. A study on the feasibility of weather derivatives in India with reference to the agricultural sector was conducted. The secondary data method was employed as postulated by (Tyagi and Shastri, 2016). The impact of weather on the Indian economy is very compelling as agriculture is the major contributor to Indian's GDP and the sector heavily depends on the Monsoon rains, as postulated by (Tyagi and Shastri, 2016). The study included Heating Degree Days (HDD) and Cooling Degree Days (CDD) as proxies from which the particular weather derivatives are derived. According to Tyagi and Shastri (2016), addition of weather derivatives in the Indian financial market can be a pivotal weather risk mitigation system to agricultural sectors and risks in this sector greatly affect developing countries. This is factual

as maximum developing economies such as India and South Africa massively depend on agriculture and thereby weather. This postulation is more or less the same true for developing countries. Agriculture contributes to the national income of the country through net exports, investment within the sector as well as government expenditures extended in the sector, which thus is what Breido and Tregub (2005) advocates for in their appreciation of the Keynesian economics.

Geyser (2004) conducted a study on the concept and applicability of weather derivatives in South Africa. An analysis of how and the type of rainfall options applicable in mitigating yield risk in South Africa's agricultural sector was done. Data of gross annual crop value for grain and rainfall for the period between January 1990 and December 2003 was used. The correlation coefficient was used to determine the relationship between maize yields and rainfall for the three selected districts in Free State, according to (Geyser, 2004). The study concluded that the use of rainfall derivatives in South Africa had potential to increase. This is so because of the collective organization of the capital markets, financial institutions and insurance companies as well as hedge funds to share and distribute weather risks, according to (Geyser, 2004).

Crop yield directly influences the demand and supply metrics of a particular crop which in turn affect the price dictated on the market according to the "Law of the invisible hand" in price determination in a free economy. According to Humphrey (1975), monetarists regard money supply as an explanatory variable to the price of money in the economy to which factors such as foreign currency reserves and the balance between exports and imports are encompassed in it.

Stulec (2017) carried out a study on the effectiveness of weather derivatives as a risk management tool in Croatia. The study focused on the review of available weather risk management solutions in the retail sector in curbing non-catastrophic weather events such as temperature, sunlight and rainfall. With the aid of a panel regression model, the results showed that weather has a statistically significant effect on beverage sales as well as risk reduction, according to (Stulec, 2017).

According to Anand and Mahadik (2006), agriculture is the major contributor to GDP in India. On the study of pricing and design of weather derivatives in India, weather derivatives can be effectively used to manage agricultural production risk. Rainfall data is considered in this study.

According to Anand and Mahadik (2006), weather derivatives when used as a hedging tool against the agricultural risk, happen to be cheaper and more effective compared to insurance schemes, in agriculture. For developing economies whose income levels are lower, adopting cheaper and effective risk mitigation tools is ideal. This supports the current study postulations of the applicability of weather derivatives in agriculture in a developing economy. Efficient use of resources is the major key to assuming greater returns either in private or public business ventures. This study is supportive of the view of Juarez-Torres, Sanchez-Aragon and Vedenow (2017) of resource optimization.

Juarez-Torres, Sanchez-Aragon and Vedenow (2017) carried out study on the impact of weather based insurance contracts, particularly weather derivatives, in Mexico on water management. A stochastic dynamic optimization model was employed. The results showed significant impact of weather derivatives on the reallocation of water from the wet season to the dry season by water authorities through irrigation. Henceforth, the expected utility of production as well as the farmer's welfare increases, as postulated by (Juarez-Torres, Sanchez-Aragon and Vedenow, 2017). This is possible because weather derivatives act as a hedging tool against yield, basis and price risks. These risks are as a result of non-catastrophic weather events and thus losses accruing to farmers are minimized in the wet season as well as water usage. Stulec (2017) also supports the view of maximization of earnings and reduction of risk attributable to them, the only varying factor between the studies being the underlying resource to which the earnings are derived from. Some resources are financial whereas others are natural, that is, non-financial.

According to Stoppa and Hess (2003), on their study of the use and design of weather derivatives in agricultural policies in Morocco; if weather elements have a dominant and observable causal relationship with the production variable, weather derivatives can be effectively used to manage agricultural production risk. This therefore is evidence that a reliable weather database is essential in the design and henceforth the applicability of weather derivatives. The respective weather element, either rainfall or temperature, has to be a prevalent feature in order to ascertain the weather risk exposure with certainty, as postulated by (Stoppa and Hess, 2003). This points out to the need to collect and observe specific weather data for a considerable time span.

Yang (2010) conducted a study analyzing the applicability of traditional agricultural insurance schemes pertaining to risk transfer, in China. According to Yang (2010), a pricing model for

weather index derivatives of which is deduced with utility-based pricing was adopted. Data computed for Cooling Degree Days (CDD) and Heating Degree Days (HDD) was used. Yang (2010) postulates that the traditional agricultural risk reduction schemes of insurance are to a lesser extent applicable to lower income countries. This is so as they are dominated by a large number of small farms and would be uneconomic to depend solely on those schemes; as also advocated by Anand and Mahadik (2006), in postulating for cheaper and effective risk reduction tools for lower income countries. Many weather events created large losses by impacting a large number of individuals at the same time, according to (Yang, 2010). The result of the study suggests that index based weather insurance can be of great use in facilitating the transfer of this type of correlated risk out of local communities. The adoption of weather derivatives is thus a pivotal need and also their applicability regarding the stated problem is being supported by the conducted research.

Dalhaus, Musshoff and Finger (2018) postulate that weather risks are an essential component in causing agricultural income volatility. The empirical study was carried out in the critical growth phase in winter wheat production in Germany. The independent variable was winter wheat yield, considered as explained by the sum of precipitation within a drought sensitive growth stage. The study results show an effect of phenology reports to contribute to reduce basis risk. This gives evidence of the attractiveness of the weather index insurance s such as weather derivatives, according to (Dalhaus, Musshoff and Finger, 2018). The casual relationship between rainfall and wheat yield is considered positive, but confined within the range obtained from the phenology report's databases.

Mapfumo (2011) conducted a study on the relationship of agricultural production and economic growth in Zimbabwe. The Log linear growth regression model was employed where GDP was the explained variable and tobacco, maize, coffee and cotton production being the independent variables, as postulated by (Mapfumo, 2011). Time series data from 1980 to 2010 was employed. According to Mapfumo (2011), the results from the study suggested that economic growth in Zimbabwe from 1980 to 2010 was positively and significantly affected by the value of agricultural production of tobacco, maize and cotton.

2.4 Summary

Theories, concepts and empirical evidence reviewed in this chapter have pointed out on the need for adopting weather derivatives. The major literature gap was the lack of strong empirical support on the importance of weather derivatives in Africa as well as in Zimbabwe. This could be generally applicable to the weak adoption of derivatives within the African continent of whom most countries are still at their infancy stage of financial development. A major positive point of reference which was highlighted is the linking closely well of the theoretical postulations and the empirical evidence gathered; from both developed and emerging financial economies. Subsequent chapters in this study will look into the data collection, analysis and justification thereof, collected for the purpose of this study. A critical evaluation of the results will be done to give a comprehensive and factual conclusion in view of this study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter will entail the methods utilized in conducting our research, justification of major theoretical participants and basically to give a platform on how the findings will anchor on. An outlay of the model specification, the diagnostic tests to be employed, justification of the research variables as well as a concluding summary will form the core.

3.2 Research Design

An explanatory research design was adopted for this research. The study made use of a sample data of the Zimbabwean rainfall and temperature pattern being the independent variables as well as the Zimbabwean data of flue-cured tobacco prices being the dependent variable. A period from 1991 to 2017 was adopted because of the availability of data within the spectrum range as well as to reduce the bias arising from using short time frames. The explanatory research design is employed when the research is quantitative in nature and has typically tested prior hypothesis by measuring the relationship study.

3.3 Model Specification

The relationship to the price of flue cured tobacco was modeled in the following manner;

$$\text{PRICE}_t = \beta_0 + \beta_1 \text{RAINFALL}_t + \beta_2 \text{TEMPERATURE}_t + \mu_t$$

Where:

PRICE_t – Price is represented by the price of flue-cured tobacco in Zimbabwe denoted in US\$/kg.

RAINFALL_t – Rainfall is represented by the annual rainfall in millimeters, in Zimbabwe.

TEMPERATURE_t – Temperature is represented by averaged annual temperature in degrees Celsius, in Zimbabwe.

Alpha - constant intercept

Beta- sensitivity of flue-cured tobacco prices to explanatory variables

μ - random disturbance or the error term

The model for the study was adapted from (Stulec, 2017). Brooks (2008) postulates that, variable transformation into natural logarithms helps to pull in extreme observation as a way of rescaling. Rainfall and temperature will be transformed into logarithmic form.

3.4. Justification of Variables

3.4.1 Rainfall

Within the Southern African region, inclusive of Zimbabwe, most of the rainfall is seasonal and usually occurs between October and March as postulated by (Geysler, 2004). According to Geysler (2004), the relationship between weather events such as rainfall to crop yield, can be measured by the correlation co-efficient. The relationship of rainfall to crop yield which in turn affects crop prices is not clearly defined as too much or too low amount of rainfall, from the normal, will have the same effects of a poor yield. In light of this however, Geysler (2004) postulates a positive and significant relationship of normal rainfall to maize yield, for a study conducted in South Africa for the period of December 1991 to March 2012.

Pajic and Markovic (2016) also conducted a study on the relationship of a weather event such as rainfall and crop production. Crop production is greatly affected by fluctuations in the amount of precipitation received as the latter is one of the major input in initiating crop germination and growth. Rainfall has a statistically significant and positive relationship to Corn production in Serbia ($r_{xy} = 0.83$), as postulated by (Pajic and Markovic, 2016).

3.4.2 Temperature

Temperature as a weather event, affects the returns in agriculture when suboptimal temperatures are experienced. Temperature is denoted in degrees Celsius for this particular study. Bobrikora (2016) identified the importance of using temperature related weather derivatives in the modeling of an efficient weather risk management scheme. Temperature as a weather event, is considered statistically significant in agriculture although the expected co-efficient is not as clear as would be in the energy or retail sectors.

According to Stoppa and Hess (2003), if weather elements have a prevalent and observable causal relationship, with say crop yield, weather derivatives can be effectively and efficiently

designed. They can be effectively and efficiently designed to manage the risk associated with the non-catastrophic weather event, such as temperature. Stulec (2017) conducted a research on the applicability of weather derivatives, whose value is based on a weather index such as temperature, sunlight and rainfall. The weather events were statistically significant in affecting sales in the beverages retail industry. Temperature is considered to have a positive relationship with sales, of products dependent on temperature such as beverages. In agriculture thus, crops reliant on the consistence in temperatures are greatly affected when temperature fluctuations are experienced.

3.4.6 The Error Term

The stochastic error term captures all the measurement errors, unavailability of data, measurement errors, human error and variable omission.

3.5 Data Type and Sources

Yearly data from 1991 to 2017 was used and it was in the form of secondary data. This was done to match the available data of all considered variables in the same spectrum. The data for the dependent variable was obtained from (TIMB, 2016). That of the independent variables was obtained from (The World Bank Group, 2018).

Time series data was used so as to meet the requirements of ordinary least squares time series regression. The time frame, tobacco prices and number of the weather events chosen represent a sample basis and the researcher considers them appropriate to reduce information bias in the process of carrying out this study.

3.6 Estimated Procedure

3.6.1 Descriptive Statistics and Test for Normality

The descriptive statistics test was conducted, whereby the mean, median and the standard deviation of the data will be analysed. For the purpose of determining if the data is normally distributed, the p-value of the dependent variable has to be below 0.05. If the p-value is greater than 0.05 then the data will not be normally distributed and as such presenting the data in logarithmic form would be ideal, as postulated by (Brooks, 2008).

3.6.2 Unit Root Test

According to Gujarati (2004:798); if a time series is stationary, its mean, variance, and auto covariance (at various lags) remain the same no matter at what point we measure them; that is, they are time invariant. The impact of integrated time series or stationary time series in econometric research has been under consideration from various researchers such as Campell and Perron (1991). Using data with unit roots (non-stationary) will make my data invalid as the results obtained by using data with unit roots or is not stationary will most likely result in spurious regression, as postulated by Gujarati (2004). According to Gujarati (2004:798), if a time series is non-stationary, we can study its behaviour only for the time period under consideration thus making it less valuable for use in other time periods. To test for the presence of unit roots a variety of test are available such as the Augmented Dickey Fuller (ADF), Phillips and Moon, and the Phillips and-Perron test. The study adopted the ADF test for testing the presence of unit root in the time series data.

H0: Time series contains a unit root

H1: Time series does not contain unit root

We reject the null hypothesis when the p-value is less than 0.05. This means the time series does not contain a unit root hence it is stationary. If the time series data is non-stationary we do not reject the null hypothesis signifying the time series data contains a unit root.

3.6.3 Testing for Multicollinearity

According to Gujarati (2003:341), assumption 10 of the Classical Linear Regression Model (CLRM) is that there is no multicollinearity. The existence of a perfect linear relationship among the explanatory variables is what is termed multicollinearity, according to (Gujarati, 2003). The presence of multicollinearity can be identified by employing the correlation matrix. If the correlation coefficient is greater than 0.80, then a problem of multicollinearity exists. According to Gujarati (2003:344); if multicollinearity is perfect, the regression coefficients of the X variables are indeterminate and their standard errors are infinite. If multicollinearity is less than perfect, the regression coefficients, although determinate, possess large standard errors (in relation to the coefficients themselves), which means the coefficients cannot be estimated with great precision or accuracy.

3.6.4 Autocorrelation Test

If residuals appear to be correlated with their own lagged values then existence of serial correlation is evident, as postulated by (Brooks, 2008). The researcher made use of the Breusch-Godfrey serial correlation LM test so as to determine the validity of the explanatory variables.

H₀: There is no autocorrelation

H₁: There is autocorrelation

We reject the null hypothesis if the obtained p-value is less than 0.05. This signifies that autocorrelation is present within the variables otherwise we do not reject null hypothesis as autocorrelation is not present within the variables.

3.6.5 Testing for Heteroskedasticity

It is advised to test if the residuals are correlated, that is, whether they are heteroskedastic or not. This will enable the researcher to determine the appropriate way to proceed so as to avoid having biased results in the regression. To correct for heteroskedasticity for the regression one has to employ robust standard errors in order to produce better results, according to (Brooks, 2008). The study made use of the White test to test for heteroskedasticity in the time series data.

H0: constant variance

We reject the null hypothesis if the p-value is less than 0.05 meaning that the model is heteroskedastic. Otherwise we do not reject the null hypothesis to conclude that the regression is homoscedastic.

3.7 Summary

This chapter has explored the research design and model employed in our study and the justification of the explanatory variables thereof. The diagnostic tests were carried out as a prerequisite and these will form the elementary of our research findings and their meaning. The research methodology was adapted from previous scholars in a bid to produce results that are similar to those of literature and to minimize bias in terms of computational error.

CHAPTER 4: DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter shows the results from the secondary data that was extracted from the respective sources to help in the analysis and interpretation. It also reveals the results obtained after using the EVIEWS (econometric package) to estimate the data. The chapter also presents and discusses the study results and will also look at the consistency of the study results with the model, theoretical and empirical literature.

4.2 Diagnostic tests results

Among the executed tests within this study are descriptive statistics and test for normality, ADF unit root test, heteroskedasticity- white test, correlation test and Breusch-Godfrey Serial Correlation LM test.

4.2.1 Descriptive Statistics and Test for Normality

This section analyses the general trend that exist in the data. The mean, median, maximum and minimum values constitute the descriptive statistics for our dependent variable.

Table 4.1: Descriptive Statistics and test for normality

Variable(s)	Mean	Median	Maximum	Minimum	Standard deviation	Observations	P-value
Price1	1.743481	1.733000	1.880000	1.500000	0.069241	27	0.000002

Source: Own computation using EVIEWS 7

The test results show that 27 observations were used and the dependent variable is price of tobacco in US\$/kg denoted as price1. The mean value of 1.743481 represents the average price for tobacco over the years considered from 1991 to 2017 expressed in US\$/kg. A minimum of 1.500000 and a maximum of 1.880000 are evidenced, postulating that, in the best of the cropping

season, farmers earn US\$1.880000/kg for their yield and unlike wise in the least best of the cropping season, they earn a fair US\$1.500000/kg for their tobacco produce. The price dictated on the market translates to the liquidity which is generated into the country denoted in foreign currency which is supported by the export earnings of the tobacco crop. The standard deviation from the mean is a mere 0.06924 which signify a low variation of tobacco prices from the estimated average. The median of 1.733000 is close to the mean and the minimum value for price and gives the postulation of the maximum being an outlying value. The P-value of 0.000002 is below 0.05 which acts as a rule of thumb and means the data for the prices of tobacco are normally distributed, that is, containing less outlying values.

4.2.2 Augmented Dickey Fuller Unit root test

Gujarati(2003) postulates that it is very important to apply the right sort of stationarity to transform the data, if they are not already stationary. The impact of integrated time series or stationarity in econometric research has been under consideration by various researchers such as (Campell and Perron, 1991). According to Brooks (2008), using data with unit root or that is not stationary will most likely result in spurious regression. Both temperature and rainfall were all stationary. Temperature had a P-value of 0.0053 and rainfall had a P-value of 0.0000. The P-values were below 0.05, which is the rule of thumb; hence we reject the null hypothesis that the explanatory variables contain a unit root. The results of the Unit root tests for the two explanatory variables are presented in Appendix 2.2.1 and Appendix 2.2.2

4.2.3 Correlation test for Multicollinearity

Table 4.2: Summary of the Correlation test results

	Temp	Rain
Temp	1.000000	-0.2055775
Rain	-0.205775	1.000000

Source: Own computation using EVIEWS 7

The results show that there exists a weak and negative correlation between the two explanatory variables, that is, rainfall denoted as rain and temperature denoted as temp. According to Gujarati (2003), multicollinearity means the regression coefficients possess large standard errors in relation to the coefficients themselves. This means that the coefficients cannot be estimated with accuracy and precision, thus unreliable. If the correlation coefficient is greater than 0.80, then a problem of multicollinearity exists which thus is not evident with our explanatory variables.

4.2.4 Testing for Autocorrelation

Table 4.3: Summary of the Breusch-Godfrey Serial correlation LM test for Autocorrelation

Variable	Temp	Rain	F (1,23)	Chi-Square
P-value	0.7800	0.7062	0.4025	0.3629

Source: Own computation using EVIEWS 7

The P-values for temperature, rainfall, F-statistic and the Chi-Square are all above 0.05 which is the rule of thumb. We thus do not reject the null hypothesis that there is no autocorrelation in the data. We thus conclude that the residuals are not correlated with their own lagged values hence no autocorrelation in the explanatory variables.

4.2.5 Testing for Heteroskedasticity

According to Brooks (2008), it is advised to test if the residuals are correlated so as to avoid having biased results in the regression. The P-values for the F-statistic, Chi-Square, temperature and rainfall were all above 0.05, which is the rule of thumb. We thus conclude that the data is not heteroskedastic but rather homoscedastic and henceforth we do not reject the null hypothesis of the presence of constant variance in the data. The results of the White test for Heteroskedasticity are fully represented in Appendix 2.5.

4.3 Results Presentation and Analysis

Table 4: Summary of the regression results

Variable	Coefficient	t-statistic	Prob>t-statistic
Temp	0.219102	0.932180	0.3605
Rain	0.657437	5.409636	0.0000

R-Squared 0.549705

Adjusted R-Squared 0.512180

F- Statistic 14.64910

Probability F- Statistic 0.000069

Source: Own computation using EVIEWS 7

The following regression model can be estimated:

$$\text{PRICE1} = -0.405778 + 0.219102 \text{ TEMP}_t + 0.657437 \text{ RAIN}_t + \mu_t$$

4.3.1 R-squared and Adjusted R-squared

Gujarati (2003) postulates that the R-squared value of 0.998 suggest that there is almost a perfect fit. The regression model has an R-squared of 0.549705 which means that 54.97% of the variations in tobacco prices are explained by the explanatory variables. The remainder may be attributable to the excluded variables in the regression model. The Adjusted R-squared value of 0.512180 gives the true impression of the variations in tobacco prices. Both the R-squared and the Adjusted R-squared are statistically significant as they are both above 0.5, which is the general rule of thumb.

4.3.2 F-statistic

The rule of thumb is that the F-statistic should be greater than five. The regression model has an F-statistic of 14.64910 which is greater than five. The P-value of the F-statistic is 0.000069

which is below 0.05, that which is considered the rule of thumb. This shows the overall significance of the model.

4.3.3 Temperature

The coefficient of temperature denoted as temp is 0.219102 in our regression model, which means a 1% increase in temperature will lead to an increase in tobacco prices by 0.219102; as the data for temperature is given in logarithmic form. The t-statistic is below 2 which according to the rule of thumb should be greater than two. The p-value for the t-statistic is above 0.05 which nullifies the significance of the t-statistic in giving a reliable statistical representation of temperature as an explanatory variable, thus suggesting temperature to be statistically significant in explaining tobacco prices. According to Bobrikra (2016), Stoppa and Hess (2003), temperature is considered statistically significant in affecting returns such as yield and financial gains in agriculture, although the expected coefficient for temperature is not a clear cut consideration. Stulec (2017) postulates a positive and statistically significance of temperature in affecting sales, though in the retail sector. Taking into account that temperature is a statistically significant explanatory variable in agriculture; fluctuations in the variable will have a significant impact on the yield and prices obtained in the agricultural sector. This suggests the need for weather derivatives in the agricultural sector in Zimbabwe. The obtained results are in support of the empirical literature considered thus making them reliable.

4.3.4 Rainfall

The coefficient of rainfall is 0.657437 in our regression model. The t-statistic is 5.409636 and is above 2 generally regarded as the rule of thumb. The p-value for the t-statistic is below 0.05 signifying the significance of rainfall as an explanatory variable for tobacco prices. This is so as the t-statistic is significant and its statistical value is to validate the explanatory variable. According to Geysler (2004); Pajic and Markovic (2016), rainfall is statistically significant and has a positive relationship to crop yield and thus crop prices dictated on the market. Fluctuations in rainfall thus, affect the gains that accrue to the agricultural sector, and in this light is a source of weather related risk in the agricultural sector. This, in support to the literature postulations, signifies the need for weather derivatives in agriculture in Zimbabwe.

4.3.5 Intercept

The coefficient of the regression intercept is -0.405778 in our regression model. This means that assuming temperature and rainfall values are zero, prices of tobacco will be on the negative. This is ideally true as say we consider tobacco contract farming; the absence of normal temperatures and rainfall, examples being the usual drought spells experienced in Zimbabwe, farmers will endure a negative return from their farming. This is so because their produce, if at all is realized, fetches nothing on the market because of poor quality, and because of the costs incurred in production inclusive of them interests paid on debt, their financial return is negative as is suggested by the results shown in our model through the regression intercept.

4.4 Summary

This chapter has explored the relevant diagnostic tests to validate the results that were presented as well the interpretation and analysis of the results. A concrete base has been formulated which determines the impact on weather related events on returns in the agricultural sector. Both rainfall and temperature have been considered as statistically significant in explaining variations in agricultural returns. The subsequent chapter will entail the overview of the whole research and the conclusion that has been reached in tackling the problem statement as has been supported by the regression results as well as literature postulations in this study.

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This is the overleaf of the whole study. Our research study intended to ascertain the applicability of weather derivatives in tobacco farming in Zimbabwe. This chapter will give a summary of the study, the conclusion reached among pointing out areas that future researches might consider in their researches.

5.2 Summary of the study

The study was carried out to ascertain the applicability of weather derivatives in the agricultural sector in Zimbabwe, of particular reference to tobacco farming. Considered literature that gave a background to this study, suggested a weak but improving adoption of weather derivatives globally. Literature gaps were accounted for by the theoretical and empirical evidence in literature. With the appropriate method(s) adopted in this study, reliable research results could be drawn that give light on the possibility of adopting weather derivatives in Zimbabwe. This is on the condition that preconditions such as farmer's willingness, independence of the agricultural market from control of government, financial literacy for end users, and significant impact of weather events on agricultural gains, a proper and efficient regulatory framework, are met; many of which could not be satisfied in Zimbabwe.

5.3 Conclusion

- Prices of tobacco in Zimbabwe, which fuel the need and applicability of weather derivatives in Zimbabwe, are positively influenced by the considered weather events.
- It is feasible, to a lesser extent, to have weather derivatives in tobacco farming in Zimbabwe at present, given that the majority of the preconditions are not yet evident in Zimbabwe.
- The conclusion has thus resulted in the null hypothesis not being rejected.

5.4 Recommendations

- Reliable weather data as well as increasing the level of financial literacy, in particular to weather derivatives should be advocated for and prioritized by the government in assisting in the closing of the knowledge gap in agriculture in Zimbabwe.
- The Ministry of Finance for Zimbabwe in partnership with the Reserve Bank of Zimbabwe (RBZ) should pave way for a conducive environment for the adaption of weather derivatives so as to safeguard gains realized in the agricultural sector; as agriculture is a pivotal sector in contributing to the GDP as well as earning foreign currency through export receipts in the country.
- Financial institutions in Zimbabwe, should consider the growing importance for financial derivatives in order to safeguard their survival in this dynamic and volatile global financial system, were liquidity is a very scarce resource and financing is expensive.

5.5 Suggestions for further study

- This current study focused primarily on the applicability of weather derivatives in tobacco farming in Zimbabwe. Future researchers should consider the contribution of weather derivatives to the financial system as it is the backbone of a prosperous economy and also their effect in promoting financial sector stability.
- The feasibility of other derivative classes such as interest rate swaps, equity forwards and futures, hybrids such as swaptions to name but a few should be also an area of concern in the studies relating to Zimbabwe as these instruments are effective in hedging financial risks that threaten the viability of the Zimbabwean economy.

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APPENDICES

Appendix 1: Data Set

	A	B	C	D	E	F
1	YEAR	price1	rainfall	temperatu	temp	rain
2	1991	1.72	640.7218	23.5463	1.371923	2.80667
3	1992	1.71	513.1605	23	1.361728	2.710253
4	1993	1.77	701.0138	24.0341	1.380828	2.845727
5	1994	1.725	652.384	27.5467	1.44007	2.814503
6	1995	1.7	460.0719	23.3444	1.368183	2.662826
7	1996	1.76	694.7523	27.6399	1.441536	2.84183
8	1997	1.78	791.7431	24	1.380211	2.898584
9	1998	1.755	687.9406	22.2783	1.347882	2.837551
10	1999	1.76	688.0629	22.3456	1.349192	2.837628
11	2000	1.85	891.8292	19.2765	1.285028	2.950282
12	2001	1.83	872.3763	22.5467	1.353083	2.940704
13	2002	1.5	444.4364	24.012	1.380428	2.64781
14	2003	1.713	622.4142	22.9823	1.361393	2.79408
15	2004	1.75	742.1822	21.8997	1.340438	2.870511
16	2005	1.73	571.17	19.0123	1.279035	2.756765
17	2006	1.76	698.7252	23.4533	1.370204	2.844306
18	2007	1.73	674.2351	23.6555	1.373932	2.828811
19	2008	1.724	549.8194	23.9854	1.379947	2.74022
20	2009	1.72	653.3013	23.7	1.374748	2.815114
21	2010	1.73	681.5717	26.0823	1.416346	2.833512
22	2011	1.754	714.567	25.6578	1.409219	2.854043
23	2012	1.733	602.3673	24.9765	1.397532	2.779861
24	2013	1.74	616.9252	25.8471	1.412412	2.790233
25	2014	1.7	655.8	23.7896	1.376387	2.816771
26	2015	1.69	421.3796	27.65	1.441695	2.624673
27	2016	1.88	650.289	27.745	1.443185	2.813106
28	2017	1.86	789.4312	25.7456	1.410703	2.897314

Appendix 2: Diagnostic tests

Appendix 2.1: Descriptive Statistics and Test for normality

	PRICE1
Mean	1.743481
Median	1.733000
Maximum	1.880000
Minimum	1.500000
Std. Dev.	0.069241
Skewness	-1.038926
Kurtosis	7.388277
Jarque-Bera	26.52125
Probability	0.000002
Sum	47.07400
Sum Sq. Dev.	0.124653
Observations	27

Appendix 2.2: Unit Root tests

Appendix 2.2.1: Augmented Dickey-Fuller Unit Root test for Temperature

Null Hypothesis: TEMP has a unit root				
Exogenous: Constant				
Lag Length: 0 (Automatic - based on SIC, maxlag=6)				
			t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic			-3.065216	0.0420
Test critical values:	1% level		-3.711457	
	5% level		-2.981038	
	10% level		-2.629906	
*Mackinnon (1996) one-sided p-values.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(TEMP)				
Method: Least Squares				
Date: 05/09/18 Time: 21:05				
Sample (adjusted): 1992 2017				
Included observations: 26 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
TEMP(-1)	-0.573463	0.187087	-3.065216	0.0053
C	0.791912	0.257980	3.069659	0.0053
R-squared	0.281341	Mean dependent var		0.001492
Adjusted R-squared	0.251397	S.D. dependent var		0.044941
S.E. of regression	0.038884	Akaike info criterion		-3.582662
Sum squared resid	0.036287	Schwarz criterion		-3.485886
Log likelihood	48.57461	Hannan-Quinn criter.		-3.554794
F-statistic	9.395552	Durbin-Watson stat		2.138831
Prob(F-statistic)	0.005312			

Appendix 2.2.2: Augmented Dickey-Fuller Unit Root test for Rainfall

Null Hypothesis: RAIN has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=6)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-5.001054	0.0004
Test critical values:		
1% level	-3.711457	
5% level	-2.981038	
10% level	-2.629906	

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

Augmented Dickey-Fuller Test Equation
 Dependent Variable: D(RAIN)
 Method: Least Squares
 Date: 05/09/18 Time: 21:02
 Sample (adjusted): 1992 2017
 Included observations: 26 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RAIN(-1)	-1.045499	0.209056	-5.001054	0.0000
C	2.937171	0.586839	5.005074	0.0000
R-squared	0.510309	Mean dependent var		0.003486
Adjusted R-squared	0.489906	S.D. dependent var		0.116100
S.E. of regression	0.082920	Akaike info criterion		-2.068080
Sum squared resid	0.165017	Schwarz criterion		-1.971303
Log likelihood	28.88504	Hannan-Quinn criter.		-2.040212
F-statistic	25.01054	Durbin-Watson stat		1.929018
Prob(F-statistic)	0.000041			

Appendix 2.3: Correlation Test for Multicollinearity

		Correlation							
	TEMP	RAIN							
TEMP	1.000000	-0.205775							
RAIN	-0.205775	1.000000							

Appendix 2.4: Breusch-Godfrey Serial Correlation LM Test for Autocorrelation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.727524	Prob. F(1,23)	0.4025
Obs*R-squared	0.827863	Prob. Chi-Square(1)	0.3629

Test Equation:

Dependent Variable: RESID

Method: Least Squares

Date: 05/09/18 Time: 21:44

Sample: 1991 2017

Included observations: 27

Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.244652	0.593885	0.411951	0.6842
TEMP	-0.070805	0.250540	-0.282608	0.7800
RAIN	-0.052174	0.136679	-0.381731	0.7062
RESID(-1)	0.205969	0.241479	0.852950	0.4025

R-squared	0.030662	Mean dependent var	-1.41E-16
Adjusted R-squared	-0.095774	S.D. dependent var	0.046464
S.E. of regression	0.048638	Akaike info criterion	-3.072880
Sum squared resid	0.054409	Schwarz criterion	-2.880904
Log likelihood	45.48388	Hannan-Quinn criter.	-3.015796
F-statistic	0.242508	Durbin-Watson stat	1.936261
Prob(F-statistic)	0.865769		

Appendix 2.5: Heteroskedasticity Test- White

Heteroskedasticity Test: White

F-statistic	1.852418	Prob. F(5,21)	0.1461
Obs*R-squared	8.263686	Prob. Chi-Square(5)	0.1423
Scaled explained SS	13.75577	Prob. Chi-Square(5)	0.0172

Test Equation:

Dependent Variable: RESID^2

Method: Least Squares

Date: 05/09/18 Time: 21:48

Sample: 1991 2017

Included observations: 27

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.757148	2.119085	1.773005	0.0907
TEMP	-1.786514	1.342222	-1.331012	0.1975
TEMP^2	0.274498	0.330473	0.830622	0.4155
TEMP*RAIN	0.374773	0.295844	1.266794	0.2191
RAIN	-1.801110	1.038786	-1.733861	0.0976
RAIN^2	0.227176	0.129730	1.751137	0.0945
R-squared	0.306062	Mean dependent var		0.002079
Adjusted R-squared	0.140839	S.D. dependent var		0.004349
S.E. of regression	0.004031	Akaike info criterion		-7.996575
Sum squared resid	0.000341	Schwarz criterion		-7.708611
Log likelihood	113.9538	Hannan-Quinn criter.		-7.910948
F-statistic	1.852418	Durbin-Watson stat		2.432271
Prob(F-statistic)	0.146069			

Appendix 3: Regression results

Dependent Variable: PRICE1
Method: Least Squares
Date: 05/09/18 Time: 21:56
Sample: 1991 2017
Included observations: 27

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.405778	0.517067	-0.784769	0.4403
TEMP	0.219102	0.235043	0.932180	0.3605
RAIN	0.657437	0.121531	5.409636	0.0000
R-squared	0.549705	Mean dependent var		1.743481
Adjusted R-squared	0.512180	S.D. dependent var		0.069241
S.E. of regression	0.048361	Akaike info criterion		-3.115813
Sum squared resid	0.056131	Schwarz criterion		-2.971831
Log likelihood	45.06347	Hannan-Quinn criter.		-3.073000
F-statistic	14.64918	Durbin-Watson stat		1.647163
Prob(F-statistic)	0.000069			