THE EFFECTS OF MARKET REFORMS ON IRISH POTATO PRICE VOLATILITY IN NYANDARUA DISTRICT, KENYA

By

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.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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This thesis has been submitted for examination with our approval as University supervisors.

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DEDICATION

This work is dedicated to my wife Lucy and children Ann, Ken, Daniel and Ruth for their never ending support, prayers and encouragement.

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TABLE OF CONTENTS

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

ADC	Agricultural Development Corporation
AIC	Akaike Information Criterion
ADF	Augmented Dickey-Fuller
AIRC	Agricultural Information Resource Centre
AR	Autoregressive Process
ARCH-M	Autoregressive Conditional Heteroscedasticity in Mean
BIC	Bayesian Information Criterion
CMAAE	Collaborative Masters in Agricultural and Applied Economics
CPI	Consumer Price Index
DAO	District Agricultural Officer
DFID	Department of International Development of the United Kingdom
FAO	United Nations Food and Agricultural Organization
FAOSTAT	United Nations Food and Agriculture Organization Statistical Database
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
GARCH-M	Generalized Autoregressive Conditional Heteroscedasticity in Mean
GDP	Gross Domestic Product
GED	Generalized Error Distribution
GoK	Government of Kenya
GTZ	German Development Cooperation
Ha	Hectare
HCDA	Horticultural Crops Development Authority
IFPRI	International Food Policy Research Institute

IMF	International Monetary Fund
KARI	Kenya Agricultural Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
KFA	Kenya Farmers Association
Kg	Kilogram
Km	Kilometres
KNBS	Kenya National Bureau of Statistics
Ksh	Kenya Shilling
Mm	Millimeters
MoA	Ministry of Agriculture
Msc	Master of Science
PhD	Doctor of Philosophy
PP	Phillips-Perron
PSDA	Promotion of Private Sector Development in Agriculture
SAP	Structural Adjustment Programs
T/ha	Tons per Hectare
US	United States of America

ABSTRACT

In the early 1990's, the Kenyan government implemented reforms in the agricultural sector that affected the volatility of agricultural product prices. However, there is lack of empirical evidence on the effects of these reforms on the level and volatility of Irish potato prices. This study evaluates the effects of market reform policies involving the decontrol of input and output prices on the evolution and volatility of Irish potato prices in Nyandarua district. The purpose of this study is to examine the effect of market reforms on Irish potato price variability. By using an Autoregressive Conditional Heteroscedasticity in Mean model, a monthly time series data set for the period 1986-2005 was utilized to identify the effects of the market reforms on the volatility of Irish potato prices.

Results indicate that the implementation of market reform policies led to higher prices and reduction of price volatility. An increase in price level coupled with a decrease in price volatility after the implementation of market reform policies implies that with the reforms the Irish potato producers were better off than without the reforms. The high prices and low price volatility served as an incentive for the Irish potato farmers to boost production during the post reforms period. The study recommends development of storage and communication infrastructure, use of commodity exchange markets, improvement in productivity, and provision of an efficient market information system as necessary measures to enable the farmers to realize maximum benefits from the effects of the implementation of market reform policies.

CHAPTER 1

INTRODUCTION

1.1. Background Information

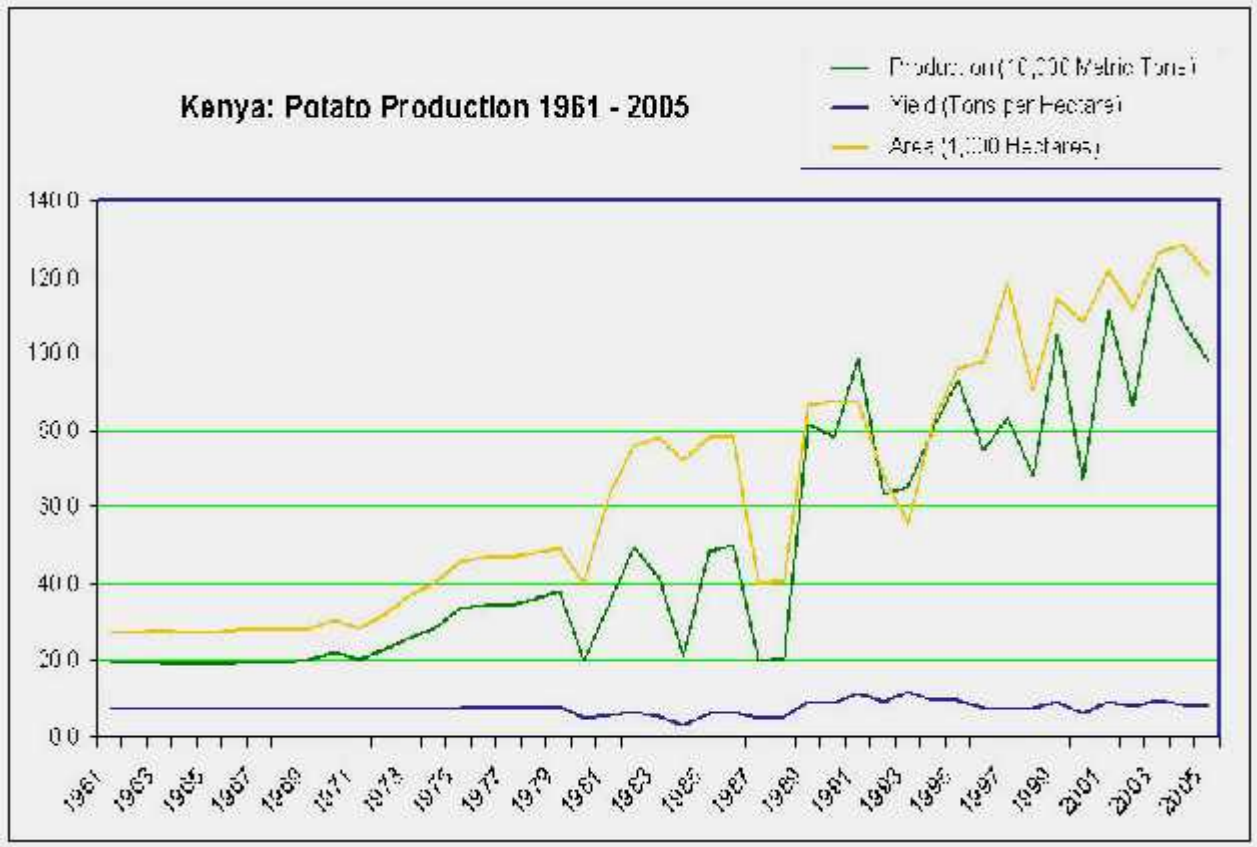
Irish potatoes are an important source of food, income and employment in Kenya. They contribute approximately 1.9 percent of Kenya's agricultural Gross Domestic Product (GDP), which is about 0.5 percent of the nation's GDP (Gitu, 2004). The crop directly employs about 500,000 farmers and indirectly supports over 2.5 million citizens (GoK, 2009). National annual output is approximately one million metric tons worth about Ksh. 5 billion at producer prices, which represents 11 percent of the national fruit and vegetable value (GoK, 2005).

The area under Irish potatoes in Kenya is estimated at about 130,000 hectares producing approximately 1 million metric tons per year (GoK, 2009). Kenya's Irish potato production accounts for about 6.5 percent of the 18.5 million metric tons produced in Africa (FAO, 2008a). This amounts to approximately 0.3 percent of the global output of 320 million metric tons (FAO, 2008a).

In Kenya, national Irish potato average yields are low at 7.5 tons per hectare, compared with a potential yield of 30 tons per hectare (FAO, 2006). On the other hand, the national demand is 1.2 million metric tons with the average annual per capita consumption being 28.5 kilograms (FAO, 2006). Therefore, the production gap is estimated at 200,000 metric tons. Furthermore, urban demand is increasing due to rapid urbanization leading to a rise in demand for fast cooking foods (Lawrence, 2004). The crop is mainly grown in high altitude areas of the country in Central, Rift Valley and Eastern provinces of Kenya. Central province leads in terms of area and production and

accounts for about 40-60 percent of the national potato production (GoK, 2009). Some of the key producing districts in the country include Nyandarua, Meru, Molo, Bomet, Uashin Gishu and Narok (Appendix 2). Despite the important role that Irish potato production plays in Kenya's agricultural sector, the crop is faced with several economic constraints including cost of production, credit availability, price volatility and market access (Lawrence, 2004). Consequently, the national production, yield and area under the crop have been fluctuating over the years (Figure 1.1).

Figure 1.1: National Irish Potato Production, Yields and Area Trends (1961-2005)



Source: International Potato Center: World Potato Atlas, 2008

Market reforms were a major aspect of the structural economic policy reforms implemented by most developing countries. The market reform policy allows the forces of demand and supply to determine what to produce, how to produce, and for whom to produce it. (Barrett, 1997). The market policy reforms were implemented in Kenya in 1996 as a major component of Structural Adjustment Program (SAP) prescribed by the International Monetary Fund and the World Bank (Karanja *et al*, 2003). These reforms were meant to enhance efficiency in price formation and to stabilize prices fluctuation. The prices of inputs were decontrolled making the sector very competitive.

However, despite the market policy reforms, fluctuations in Irish potato prices have been observed (Ng'ang'a, 2002). The observed price fluctuations affect production and incomes to the Irish potato producers which may result in the farmers not being able to produce enough potatoes for their domestic needs, generate adequate income to purchase enough food and meet other basic needs (Höffler and Maingi, 2006).

In the year 2005 farm gate prices in Nyandarua district which is a major producing zone ranged from Ksh.150 to Ksh.1500 per 110 kilogram bag while consumer prices in Kenyan urban markets ranged from Ksh. 600 to Ksh. 3,000 per 110 kilogram bag (GoK, 2009). These wide price variations in producer and consumer prices over the cropping period are an indicator of price volatility. Price volatility is defined as variation from the average value over a measurement period. If a price varies a great deal from month to month, the price volatility will be high, and conversely, if the month to month variation is low, the value of volatility will be low as well (Wolf, 2004). The price volatility measures price fluctuations over time and indicates the degree of spread of the prices. On the other

hand, price stability, is a situation where prices do not change much over time. This depicts an absence of volatility and is usually desirable.

The volatility may be measured through the standard deviation or variance of a sample and can either be measured as an absolute number (Ksh. 5) or a fraction of the mean. As such volatility reflects the degree of risk faced by someone with exposure to that variable. In most cases, price volatility for market players is often viewed as negative in that it represents uncertainty and risk. However, price volatility can be good if one sells on the peaks and buys on lows and one can make money, with greater money coming with greater volatility.

Price volatility is as a result of the effects on supply and demand of a commodity price. Some of the factors identified to cause price volatility include policy reforms, changes in production as a result of weather changes and crop diseases, changes in consumption patterns, exchange rate fluctuation and crude oil prices (Wolf, 2004). An increase or reduction in trading volumes like it can occur due to speculative activities can lead to price volatility. Similarly, an increase in the crude oil prices push the cost of producing agricultural commodities upwards through increases in the prices of inputs such as fertilizer and diesel but with a significant lag. The prices of oil and the consequent change in production and transportation costs affect the prices of agricultural products and can lead to price volatility (Wolf, 2004).

The negative effects of price volatility are an increase in price and market risks. These increase in risks lead to fluctuation in production and consequently incomes especially to the households with low asset base (Harwood *et al.,* 1999). The income shocks lead to liquidity constraints which force

farmers to sell cheaply immediately after harvest and buy expensively later in the season. Further, price volatility results to uncertainty which makes planning difficult leading to negative impacts on supply response (Harwood *et al.,* 1999). However, the positive aspect of price volatility is that farmers realize high incomes when prices are high.

The basic premise of the agricultural market reforms implemented in most developing countries in the last two and a half decades was that of improving the incentive structure for the farmers to generate a positive supply response and increase both agricultural output plus income levels (Barrett *et al.,* 2003). This was in the form of higher prices and well functioning markets. In Kenya, these reforms lead to liberalization of input and output markets by eliminating subsidies on agricultural inputs such as fertilizer and credit. These inputs were supplied to the farmers by the government at subsidized prices and sometimes on credit before the market reforms were undertaken (Karingi *et al.*, 2005). Since, farm inputs like fertilizer, fungicides, insecticides, farm implements and credit are important to the production of Irish potatoes, the market reforms involving the removal of government's monopoly in the importation and distribution of these inputs affected the sector.

The major objective of the implementation of market policy reforms was to provide incentives for increased production through higher and stable prices to the farmers through open market operations. However, despite the implementation of these reforms, agricultural production, and food production in particular has been on the decline (Nyangito *et al*., 2005). Fluctuations in volumes of the major food commodities marketed through formal outlets have also been observed while price volatility is a common feature in the markets (Nyangito *et al*., 2005). The observed price volatility has serious implications for poverty, risk and vulnerability in the rural areas. They may result in the

poor not being able to produce enough to meet their domestic needs, generate income to purchase food and meet other basic needs, or have means of dealing with natural calamities such as drought (Nyangito *et al*., 2005). The implementation of market policy reforms therefore do not seem to have worked to the benefit of the producers.

The price volatility of agricultural products is a major determinant of farmers' income variability and is important for individual investment decisions in farming and agricultural produce marketing. In addition, negative price shocks have a greater negative impact on the economic growth of developing countries like Kenya (Jordaan *et al*., 2007). A right assessment of price volatility contributes to a decision maker being able to make more informed production and marketing decisions. It also helps in the assessment of the effect of implementation of policies aimed at boosting the economic growth through stable and favorable commodity prices.

The effect of market reforms on the level and volatility of Irish potato prices is important due to the pivotal role that the crop plays in terms of food security, income generation and creation of employment to a large proportion of the Kenyan population (GoK, 2009). The level and volatility of some agricultural product prices thus affected the level of economic growth and poverty reduction (Karanja *et al.,* 2003).

From the foregoing, it is pertinent to understand how successful were agricultural market reforms in Kenya in terms of improving agricultural production and market performance through their effect on the level and volatility of food prices. However, available empirical evidence shows mixed results on how market reforms have affected the level and volatility of food prices in Kenya

(Karanja *et al.*, 2003). In fact there is lack of empirical evidence on the effects of agricultural market reforms on Irish potato price volatility in Kenya. Given the contribution of Irish potato sector to Kenya's economic development, understanding how market reforms affected Irish potato price volatility is important. Thus this study assesses the effects of market reforms on Irish potato price volatility in Nyandarua district, which is one of the major producing regions in Kenya. Understanding the effects of market reforms on Irish potato price volatility is of critical importance to researchers, farmers, consumers, processers and policy makers.

1.2. Problem Statement

The main rationale of the agricultural market reforms implemented in the majority of the developing countries in the last two and a half decades was that of improving prices for the farmers in order to increase output and income levels (Barrett *et al.*, 2003). This was in the form of higher prices and well functioning markets. In Kenya, these reforms lead to liberalization of input and output markets by decontrolling prices of inputs and outputs. This lead to elimination of subsidies on agricultural inputs such as fertilizer and credit. These inputs were supplied to the farmers by the government at subsidized prices and at times on credit prior to the undertaking of the market reforms (Karingi *et al.*, 2005). Since farm inputs like fertilizer, fungicides, insecticides, farm implements and credit are important to the production of Irish potatoes, the market reforms involving the removal of government's control in the import and distribution of these inputs affected the sub-sector.

These market reforms lead to direct and indirect effects on the level and volatility of agricultural produce prices. From current literature, the effect of market reforms on the level and volatility of

food prices in the Kenya is ambiguous. While some authors argue that the reforms lead to an increase in real prices (De Groote *et al.*, 2006; Karugia *et al.*, 2003), others report that the market reforms lead to a decline in food prices (Karingi and Nyangito, 2005; Nzuma, 2007). Moreover, many of the studies on the effect of market reforms on the level and volatility of agricultural food prices in Kenya have concentrated on maize (De Groote *et al.*, 2006; Karugia *et al.*, 2003; Karingi and Nyangito, 2005).

In the Kenyan potato sector there is lack of empirical evidence on the effects of market reforms on price volatility. It will be of use to potato farmers, policy makers and international development agencies working in the potato sector.

1.3. Purpose and Objectives

The purpose of this study is to examine the effect of market reforms on Irish potato price variability in Nyandarua district, Kenya. This study therefore attempts to analyze the effects of market reforms on Irish potato price volatility in Nyandarua district through a comparative analysis of the pre liberalization and post liberalization periods.

The specific objectives of this study are:

1. To evaluate the trends in Irish potato prices in Nyandarua district; both before and after the implementation of market reforms policies that took place in the year 1996 in Kenya.
2. To assess the effects of market reforms on Irish potato price volatility in Nyandarua district.

1.4. Hypothesis to be tested

The following hypotheses are tested:

1. That there is no relationship between Irish potato price volatility and seasons.

2. That market reforms have no effect on Irish potato price volatility.

1.5. Justification of the Study

The choice of Irish potatoes in this study can be justified based on its economic importance in Kenya. It contributes approximately 1.9 percent of the agricultural GDP which is about 0.5 percent of total GDP (Gitu, 2004). The crop ranks second after maize as a source of food security. Nyandarua district is selected for this study because it is the main Irish potato producing district in Central province, leading in area and production nationally. Of the approximately 130,000 hectares of land under Irish potato cultivation in Kenya, 22,750 hectares which is 17.5 percent of the national area is in Nyandarua district (MoA, 2009). Further, the district contributes 17.2 percent of the national Irish potato annual output of 1 million metric tons by producing 172,260 metric tons (MoA, 2009).

Understanding the effects of market reforms on Irish potato price volatility is of interest to researchers, farmers, policy makers and all stakeholders in the Irish potato sector. However, the extent to which the market policy reforms affected the level and volatility of Irish potato prices is not known. Overall, this study will contribute to the existing body of knowledge on effects of market reforms and Irish potato marketing.

1.6. Organization of the Thesis

This thesis is presented in five chapters. Chapter one contains the background information on the Irish potato sector in Kenya. The chapter also highlights the research problem, purpose, objectives, and hypotheses to be tested and further underscores the justification of this study. Chapter two provides a literature review on the approaches used to analyze price volatility and of empirical studies on Irish potatoes and price volatility. It provides a guide in the identification of the knowledge gap and the choice of model used in the analysis of the effects of market reforms on Irish potato price volatility.

Chapter three provides the methodology used in this study. The chapter derives the theoretical basis on the autoregressive conditional heteroscedasticity in mean (ARCH-M) model. This chapter describes the data sources, data analysis, area of study, and specifies the empirical model that was estimated. Chapter four provides the results of this study and the discussion. In this chapter the descriptive statistics and the ARCH-M model estimation results are discussed. Finally, chapter five gives the conclusions and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

This chapter explores the literature on price volatility. It assists in the identification of the empirical gap that this study is meant to bridge and guides on the choice of the right analytical method to use in the analysis of the effects of market reforms on Irish potato price volatility. The chapter begins by exploring the main empirical econometric modeling approaches applied in price volatility studies. The review of the models for assessing price volatility is important in the identification of the suitable model to adopt in this study. Next, a review of past economic evaluations on Irish potatoes and price volatility is provided. Lastly, the chapter provides a review of market reforms literature in the agricultural sector.

2.2. Approaches used to Analyze Price Volatility

The main approaches employed in the analysis of price volatility are mainly econometric approaches that use the autoregressive conditional heteroscedasticity (ARCH) models, the variants of ARCH models and integration of the ARCH models with other models. The variants of the ARCH models include the generalized autoregressive conditional heteroscedasticity (GARCH) and autoregressive conditional heteroscedasticity in mean (ARCH-M); while structural heteroscedasticity in mean (SHM) is one of the integrated models.

The traditional econometric models assume a constant one period forecast variance which is not conceivable in a stochastic process. Therefore, the ARCH model was introduced to describe how the conditional mean and variance of a time series evolves over time. The univariate ARCH model was originally applied by Engle (1982) in the estimation of inflation in the United Kingdom to assess the validity of Friedman's hypothesis that the unpredictability of inflation was the primary cause of business cycles (Engle, 1982). Friedman hypothesized that the level of inflation was not a problem; but it was the uncertainty about future costs and prices that would prevent the entrepreneurs from investing and lead to a recession (Engle, 2003). This is possible if the uncertainty was changing over time and this is econometrically termed as heteroscedasticity.

An ARCH process produces dynamic, mean reverting patterns in volatility that can be forecast (Engle, 2003). The ARCH random variables have non-zero mean, which can be expressed as a linear combination of exogenous and lagged dependent variables (Engle, 1982). The ARCH method allows a conventional regression specification for the mean function, with a variance which is permitted to change over the sample period (Engle, 1982) and is therefore an improvement of the performance of a least squares model in order to obtain more realistic forecast variances.

The specifications of the ARCH model provides for the conditional mean equation, conditional variance and conditional error distribution (Engel, 1982). The completion of the basic ARCH model requires assumptions about the conditional distribution of the error term ε_t. The assumptions are normal distribution, student's t-distribution and Generalized Error Distribution (GED). Given the distributional assumptions, the ARCH model is estimated using the method of maximum likelihood.

The ARCH models and their extensions are based on the theory of dynamic volatility (Engle, 1982). The ARCH is a dynamic model of time varying volatility and can be used to measure the volatility at any time and to forecast it into the near and distant future. Inserting the relevant variables into the model can test economic models that seek to determine the causes of volatility. Also, by incorporating additional endogenous variables and equations can similarly test economic models about the consequences of volatility (Engle, 2003). One of the principal assumptions underlying ARCH models is that there is an intrinsic non-linear trend in the price process that could lead to price volatility (Engle, 1982). This assumption is mainly fulfilled in instances where hedging and stockholding play a key role in price determination in any two successive times.

The advantages of the ARCH model lie in the fact that it accounts for both the predictable and unpredictable components of the price process. The focus is on the assumption of homoscedasticity and instead of considering heteroscedasticity as a problem to be solved; the model treats it as a variance to be modeled. This results in the correction of the deficiencies of least squares and computation of a prediction for variance of the error term (Engle, 2001). The model is used to evaluate volatility which is constant over an entire period and can be presented by a single value. The limitation of the ARCH model is in the fact that a relatively long lag in the conditional variance is often required and to avoid problems with negative variance parameter estimates, a fixed lag structure is typically imposed (Bollerslev, 1986).

The ARCH models have many empirical applications in economics with time series data but are largely used in financial time series such as stock prices, interest rates and exchange rates (Engle, 2003). They have a wide applicability in finance due to the importance in the trade-off between risk

and return in financial markets, a parameter which these models are able to forecast (Engle, 1982). In agricultural produce markets, the model is to a large extent used for assessing price volatility in tradable commodities such as cereals in situations where stockholding is important (Karanja *et al*., 2003).

This model is designed to capture unpredictability, fat tails and volatility clustering, the three pervasive characteristics of financial returns (Engle, 1982). The characteristics imply that the returns are almost unpredictable, have surprisingly large numbers of extreme values and both the extreme and quiet periods are clustered in time. When volatility is high, it is likely to remain high, and when it is low it is likely to remain low. In financial markets the volatility has been found to be higher when the asset prices are falling. However, these periods are time limited so that the forecast is sure to revert to less extreme volatility (Engle, 2003).

Engle models time-varying risk premia in the term structure of bond yields using the ARCH-in-mean model, which allows the conditional variance of a yield also to affect its conditional mean (Engle *et al*., 1987). When the conditional variance or standard deviation is included in the mean equation of a basic ARCH econometric model, we get the ARCH-in-Mean (ARCH-M) model (Engle *et al*., 1987). The advantages of the ARCH-M model is due to the fact that it can be applied to non-tradable and tradable commodities and is applicable to tradable commodities, such as cereals in an environment where stockholding is important. This model is commonly applicable to storable agricultural commodities where stockholding play an important role in price determination in any two successive periods. Theoretically, the storable commodities have an ARCH process because current price volatility transmits itself into future period by creating volatility in the inventory

carryover (Kilima *et al*., 2004). The model is also applicable to most agricultural commodity prices especially traded ones which tend to show persistence of price shocks and high first order auto-correlation (Engle *et al*., 1987). The shortcoming of the model is that since there is no real consensus on the economic reasons why uncertainty tends to cluster, the model tends to perform better in some periods and worse in other periods.

The ARCH-M is used in financial applications where the expected return on an asset is related to the expected asset risk (Engle *et al*., 1987). The estimated coefficient on the expected risk is a measure of the risk-return trade-off. A high coefficient implies the more favorable the compensation for risk taking (Engle *et al*., 1987). Thus a salient feature of the ARCH-M model is that it allows for an explicit modeling of the risk-return trade-off (Beach *et al.*, 2006).

The ARCH models were later generalized into generalized autoregressive conditional heteroscedasticity (GARCH) technique by Bollerslev, (1986), one of the most widely used extensions of the ARCH model. This essentially generalizes the purely autoregressive ARCH model to an autoregressive moving average model, in which the weights on past squared residuals are assumed to decline geometrically at the rate estimated from the data (Engle, 2001). The GARCH model is applied in exchange rates, bond returns and commodity returns (Engle, 2001).

The GARCH model is used in estimating time-varying volatility, or heteroscedasticity (Engle, 2001). The model is also suitable for estimating conditional volatility where the current observations depend on the observations of the immediate past, a simple description of adaptive expectation.

According to Bollerslev, (1986), the GARCH model can be specified by providing for conditional mean equation, conditional variance and conditional error distribution.

The advantages of the GARCH model are that the conditional standard deviation is the measure of volatility and distinguishes between the predictable and unpredictable elements of the price process. This leaves only the unpredictable component and is hence a more accurate measure of the actual risk associated with the price of a crop and in addition, the model allows for a more flexible lag structure (Bollerslev, 1986). The disadvantage of the GARCH model is the requirement for a long memory.

The GARCH models allow for a precise modeling of the relationship between future variances and past variances, as well as past variance forecast (Engle, 2001). It gives parsimonious models that are easy to estimate and is particularly successful in predicting conditional variances. A GARCH model also takes into account of time series variables that exhibit excess kurtosis, where their probability distributions have fat tails (Engle, 2001). Finally, GARCH Models takes into consideration of volatility clustering or persistence which occurs when large changes in returns are followed by large changes, and small changes are followed by small changes (Engle, 2001).

The innovative structural heteroscedasticity in mean (SHM) estimator model is used to find the determinants of price as reflected by the mean conditional on various regressors (Barett *et al.*, 2003). At the same time the model is used to assess factors like policy reforms, changes in consumption patterns, exchange rate fluctuations, changes in production patterns, crude oil price fluctuations that determine price volatility. The volatility is reflected in the time series conditional

variance and the interaction between the mean and variance of the time series (Barett *et al.*, 2003). This econometric model is an integration of the structural heteroscedasticity model, where the conditional variance of the dependant variable is modeled as a function of the regressors and the GARCH model (Barett *et al.,* 2003).

In the structural heteroscedasticity in mean model (SHM) the conditional variance of the dependent variable is modeled as a function of the regressors. The SHM model simultaneously estimates the mean and standard deviation of the observed transaction price conditional on a set of exogenous regresssors, inclusive of the estimated conditional standard deviation of price among the regressors in the conditional mean equation (Barett *et al.,* 2003). This model is suitable for data that is cross-sectional in nature, where it involves sales of individual commodities at different points in time and is estimated using the full information maximum likelihood criterion (Barett *et al.,* 2003). Thus, the SHM model is inappropriate for this study because it is suited for use in price volatility analysis in cross-sectional data while this study utilizes time series data.

The ARCH models are simple, generate volatility clustering and have heavy tails (Engle, 2003). Heavy tails mean that the models can be applied to time series probability distributions that assign relatively high probabilities to regions far from the mean or median as a result of clustered volatility. Heavy tails and clustered volatility are commonly observed in price fluctuations which do not display the independent and normally distributed properties (Engle, 2003).

The strengths of ARCH models is that they are applicable to both non-tradable and tradable commodities, can be applied to both perishable and non-perishable commodities and are applicable

to most agricultural commodity prices (Engle et al., 1987). Further, the model allows conditional volatility to directly influence the conditional mean. Thus the conditional mean and variance are simultaneously estimated (Kilima et al., 2004).

On the other hand, the weaknesses are that they are not sufficiently adaptive in prediction, are asymmetric between positive and negative, restrictive and provide no explanation of volatility (Engle, 2003). The shortcoming of the SHM model is the fact that it can only estimate volatility in cross-sectional data. When the strengths and weaknesses of the ARCH, variants of the ARCH and integrated models for assessing volatility are evaluated, the ARCH-M model turns out to be appropriate for this study. This is so because the model is suited for volatility modeling for a commodity like Irish potato which can be stored in anticipation to benefit from price movements. Theoretically storable commodities like Irish potatoes have an ARCH process because current volatility transmits itself into future volatility in the inventory carryover (Kilima et al., 2004). In addition the suitability of the model can be justified by the fact that Irish potato is a tradable commodity and the data utilized is a time series with varying mean and variance best estimated using the ARCH-M model.

2.3. Market Reforms, Price Volatility and Irish Potato Economic Studies

This section presents past studies in modeling of the effects of implementation of market reform policies on price volatility. Further, the section provides a review of previous economic studies on Irish potatoes in Kenya. It summarizes the major findings of these studies, indicates what

approaches have been used in the past and is useful in identifying the empirical gap that the current study intends to bridge and gives a guide on the right analytical approach to adopt.

A number of economic evaluations have been undertaken in the past on production, marketing and post harvest handling and storage technologies of Irish potatoes in Kenya. However, these studies (Mbogo, 1976; Mugambi, 1977; Nyangito, 1986) did not evaluate the effect of market reforms on Irish potato price volatility. The studies identified price volatility as a major problem in Irish potato marketing and recommended that this issue be further investigated.

Mbogo (1976) undertook a study on the economics of production and marketing of Irish potatoes in Meru district, Kenya using the conventional structure, conduct and performance method. The author used the regression and correlation models. He found that Irish potato prices in Meru district differ by transfer costs and was correlated to the prices in Nairobi. The local markets in Meru district were found to be weakly integrated and linked to the interregional markets like Nairobi through trade. The local traders were found to receive Irish potato price information from main consumer points like Nairobi via telephone from their agents in such centers. The Irish potato price differential between Nairobi and Meru was found to be at the maximum during the period when Meru farmers were harvesting their crop.

The author observed that Meru Irish potato growers do not store their produce after harvesting, for sale later into the Nairobi markets. The author recommends implementation of a strategy for planned marketing of Irish potatoes in Kenya. The strategy is to involve purchasing of buffer stocks from the key producing regions during the period of glut and release of these stocks during the

scarce periods when the supply declines leading to price increase. The approach recommended by the author is meant to stabilize the high fluctuations in supply and prices.

Another recommendation by the author is the formation of a national potato marketing organization to take the responsibility of holding potatoes in storage in order to control supply to the market so as to reduce price fluctuations. This organization could buy potatoes from producers at fixed floor prices based on production costs. To ensure continuity in the supply of Irish potatoes to the market he recommends coordination of growers in various regions. He argues that growers need to be encouraged to grow potatoes when production is cheapest in comparison to other farm enterprises.

Lastly, he recommends the need to have proper storage facilities by the farmers and the national potato marketing organization to enable storage of potatoes during the peak harvesting periods and release to the market during the time of scarcity. This would ensure that Irish potato farmers get adequate returns to enable them cover the cost of production and make profit. Nevertheless, the author was not able to empirically demonstrate the relationship between Irish potato price variability and season nor did he evaluate the trends in Irish potato prices. The author recommended further investigations on the pattern of potato yields and price variability. The similarity between this study and Mbogo (1976) study is that both studies examined the issue of price variability, though in different districts. However, the current study goes further and fills the empirical gap, on what effects did the market policy reforms have on the level of price volatility in Nyandarua district? This is realized by analyzing the Irish potato price volatility during the pre and post market liberalization periods. The current study contributes to the existing body of knowledge by presenting the effects

the market policy reforms have on Irish potato price level and volatility which is missing in the current literature.

Mugambi (1977) undertook a study on the economics of Irish potato storage in Kenya. The author used data from a survey and an Irish potato storage trial he carried out in Kibirichia location of Meru district and from similar trials set up in Ngecha and Molo in Kiambu and Nakuru districts respectively. The survey involved interviewing a random sample of 71 farmers while the Irish potato storage trials were set by the German Agricultural Team, International Potato Centre (CIP) and the author using house-stores, pits and improved granaries as storage structures.

The author concluded that price fluctuation in the potato market is a commonly observed phenomenon. Further, the author observed that some farmers store their potatoes to reap the benefits of shortage in later periods. However, he concluded that the number of those who practice storage is either too few or they store small quantities so that they are not able to stabilize prices.

Mugambi (1977) recommended an improvement in storage methods and techniques. To reduce dehydration of potatoes experienced during storage he recommended that traders, companies and other institutions need to be encouraged to construct cold stores for potatoes in production areas. As an effort to improve the Irish potato marketing system in Kenya, he recommends cooperative marketing be the main channel for distribution of Irish potatoes to the consumers. He argues that this would curtail the high profit margins received by traders to the detriment of both the producer and the consumer. He further observes that it will be more cost effective for a cooperative society to build the Irish potato cold stores.

Another recommendation by this author is the supply of Irish potatoes to the non-producing regions of the country like Coast province, Machakos and Kitui to cater for the local demand before exporting. To achieve this he recommended that the Irish potato cooperative society to organize for the transportation of potatoes to the deficit regions of the country. The similarity between the current study and Mugambi (1977) is the fact that both studies evaluate how to stabilize the variability in the Irish potato prices. However, the difference is that Mugambi's (1977) study concentrated on how storage can play a part in price stabilization while this study looks into the effect of market policy reforms on price variability. This study consequently contributes to literature on what role policy reforms had on Irish potato price stabilization.

Nyangito (1986) undertook a socio-economic analysis of the factors affecting Irish potato post-harvest practices and storage technologies in Kinangop, Nyandarua district using a Planning Stage of Farming Systems Approach. The study reported that price uncertainty, storage losses and limited market outlets as the main problems limiting farmers from storing potatoes for sale. He reports that farmers can benefit by storing the Irish potatoes and selling when the prices rise. According to the study, the producers were unable to withhold supplies from the market to wait for better prices which results to wide price variability in the potato market. The potato marketing system in Kinangop was found to be characterized by limited market outlets and price uncertainty which retards increased potato production. However, the study did not evaluate the trends in Irish potato supply and price patterns in Nyandarua district which is assessed in the current study.

The study by Nyangito (1986) reports the presence of price fluctuations in the potato markets in Nyandarua district. Further, the author reports that the prices that the farmers receive in Kinangop

vary according to the time of selling in relation to the harvesting periods. The prices were lowest during the harvest periods in July to August and highest during off-peak harvest periods in March to May. The author concluded that farmers find it difficult to predict future prices because potato prices fluctuate according to change in supply in the local and national markets. The author however did not empirically demonstrate the trends and magnitude of these price fluctuations.

The current study is different from Nyangito (1986) study in several aspects. First, the study by Nyangito (1986) was restricted to only one of the six divisions in Nyandarua district while the current study focuses on the whole of Nyandarua district. Second, the current study evaluates the trends in Irish potato prices and supply patterns which Nyangito (1986) failed to address. Further, the model he used did not take into consideration price volatility while a model for assessing price volatility is used in the current study. In addition, Nyangito's 1986 study was done before the implementation of market policy reforms while the current study encompasses both the period before and after these reforms. The current study will thus add to the literature on the effects of policy reforms on Irish potato supply, price level and volatility.

Barrett *et al.*, (2003) undertook a study to determine the volatility of livestock producer prices in Northern Kenya rangelands. The authors used detailed transaction level data from a project by the German technical assistance program GTZ in Marsabit and Moyale for the period 1994 – 1997. The data was analyzed using the structural heteroscedasticity in mean (SHM) econometric model.

This model is an integration of the structural heteroscedasticity model and the generalized autoregressive conditional heteroscedasticity in mean models. In this model, the conditional

variance of the dependent variable is modeled as a function of the regressors. The SHM model estimates the mean and standard deviation of the observed transaction price conditional on a set of exogenous variables including the estimated conditional standard deviation of price among the regressors in the conditional mean equation.

The authors used the sinusoidal terms to control for rainfall and seasonality in prices. They also included a dummy variable to account for the end of Ramadan to cater for the importance of religious festivals on small ruminant prices, a dummy variable for April and December, the customary months for circumcisions and weddings in the region, as well as the Christian holidays of Easter and Christmas and for the months of January, May and September when school fees are paid in Northern Kenya. The other variables included in the study by Barrett *et al.,* (2003), are characteristics of the animals sold that affect the price livestock fetch in the market which include attributes such as body condition, breed, age, size and castration. Since animals trekked rather than ferried using a truck from the market by buyers are expected to fetch lower prices, a variable representing trekking of animals to the market is included in the model.

The livestock prices were found to exhibit large variability across space, time and animal characteristics. Further, the prices were found to strongly respond to rainfall, reflecting the direct reliance of animal health and productivity on climate. The demand and supply shifts associated with ceremonial events and periodic demand for cash to pay school fees and demand shocks due to quarantines also affect prices significantly. The authors found out that market prices depend on age, gender and physical condition of the animal sold. Further, policy related shocks such as the imposition of quarantines and poor market infrastructure limit integration with the major terminal

market in Nairobi thus leading to price volatility and a negative impact on the livestock producer prices. The price risk premia was found to be negative.

The authors used data over a short period of time and were not able to establish the trends in livestock prices. This limits the conclusions drawn on risk premia, and the evolution and volatility of prices. Conversely, the current study uses data over a longer period of twenty years and assesses the Irish potato price trends. Further, the study utilized the SHM model that is only suitable for cross-sectional data unlike the current study which uses the ARCH-M model suitable for time series data. Another difference between the current study and the study by Barrett *et al.*, (2003) is the fact that the current study evaluates price volatility on Irish potato prices in central Kenyan highlands while Barrett *et al.,* (2003) assessed price volatility on livestock prices in northern Kenyan rangelands, regions of different agro ecological zones.

Höffler and Maingi (2006) carried out a value chain analysis of the Irish potato sub sector in Kenya. The authors reported an increasing demand for Irish potatoes in the last decade which they linked to changes in consumption habits mainly in the urban centers where chips have become an increasingly popular part of the diet. Production of chips has become the major form of value addition for potatoes. In urban centers, the Irish potato industry employs thousands as marketing agents, transporters, chips and crisp processors plus vendors like Nandos, Galitos and the Creamy Inn.

The analysis by Höffler and Maingi (2006) reveals that demand is not always met, quality of produce is sometimes poor and prices seem higher than production costs. According to the authors'

analysis, Irish potatoes are marketed through a fragmented chain characterized by many handlers, hardly any cooperation, no integration, and market failure, which result in high supply risks, high transaction costs, price inefficiencies and quality losses.

The results from the analysis of the value chain show several factors contributing to weak rural-urban linkages. Firstly, the predominant smallholder production is faced with failing input markets and production is adversely affected by poor quality and unreliable availability of seed potatoes. Secondly, scattered farms, limited storage facilities, poor road network, and insufficient transport facilities damage the potatoes and affect the post-harvest quality. Thirdly, there are challenges in the logistics of marketing, the physical infrastructure of markets and on market information.

The potato marketing was found to be struggling between the basic functions of a market and market failure and the study indicates the need for high public investment in rural marketing infrastructure by reallocation of resources from urban to rural areas. The analysis of the value chain is useful in identification of the factors leading to price volatility. The study identifies market integration, demand and supply disequilibrium, price inefficiencies, fragmented chain and market failure as the factors which lead to price volatility. Overall, the study by Höffler and Maingi (2006) underscored the importance of Irish potatoes as a food crop in Kenya and elicits the constraints experienced in the marketing of the produce which the current study attempts to appraise.

The authors use the value chain analysis as an analytical framework to describe the productive processes from input provision to production, transportation, processing, marketing, to final consumption. The approach concentrates on the descriptive analysis of the institutional

arrangements that link the various economic players and also highlights the importance of private sector development. Thus, Höffler and Maingi (2006) used a descriptive approach to draw their conclusions as compared with the current study which uses both descriptive and econometric approaches.

Ng'ang'a (2002) undertook a study on the marketing channels for Irish potato from Njabini location, South Kinangop division, Nyandarua district to Nairobi and its environs. The author used survey data collected using structured questionnaires administered to farmers and traders from December 2000 to April 2002. The weekly and monthly wholesale price data for other wholesale markets in Kenya from the Ministry of Agriculture for the period January-December 2000 and January-December 2001 was also utilized. The study by Ng'ang'a (2002) employed descriptive statistics to analyze the data.

The authors concluded that there is need for government interventions to reduce market risks through control of prices, bag size and potato supply into the fresh produce market. The desired interventions according to the study were: setting up of a minimum price (29 percent of the farmers), setting a minimum bag size of 110 kilograms (20 percent), setting up of a nearby processing plant (8 percent), setting up of a central market and store to control produce into the market (8 percent), provision of loans and inputs (8 percent) and improvement of roads (8 percent).

The study by Ng'ang'a (2002) is similar to the current study in that both were done in Nyandarua district in the Central province of Kenya and wholesale monthly Irish potato prices were analyzed. However, the contrast is that Ng'ang'a (2002) study concentrated in one location of Nyandarua

district while the current study utilizes data from the entire Nyandarua district. Also weekly and monthly wholesale Irish potato prices were analyzed from several markets in Kenya in Ng'ang'a (2002) study while the current study considers data from the Nyahururu wholesale market. The study by Ng'ang'a (2002) considered spatial Irish potato price variability using a two years survey data unlike the current study which analyses the temporal price variations using a twenty years time series data which is better in illustrating the actual seasonality in price trends.

Barrett (1997) analyzed the effects of liberalization measures on prices of rice, beans, manioc, maize and potatoes in Madagascar. The author estimated the effects of liberalization measures on the level and volatility of prices of these food commodities, using retail level nominal commodity prices from seventeen agricultural markets. The Consumer Price Index (CPI) was used to deflate the nominal prices to come up with real price series for rice from January 1983 to December 1991 and for beans, manioc, maize and potatoes from January 1984 to December 1991.

The author employed the ARCH-M model which permits the conditional variance to influence the level of the conditional mean, risk, and price level. A key assumption underlying ARCH-M model is that there is an inherent non-linear phenomenon in the price process that could lead to price volatility. The model is appropriate for time series data and allows for price modeling with time varying risk premia. In the ARCH-M econometric model the author used, the dummy variables included as independent variables were for the June-December 1991 period of nationwide pro democracy strikes, the second for the fourth quarters of the year and also for each of the regions. The 1-month lagged price level was included in the conditional variance equation to take care of the positive relationship between prices and inventory depletion in one period and price volatility in the

next. The study therefore guides on the dependent and independent variables included in the current study.

The ARCH-M potato price model indicated that short term mean prices fell and volatility increased sharply with liberalization while the long term mean prices increased. The exchange rate effect was positive and had a statistically significant correlation with mean price and insignificant relationship to price volatility, thus indicating linkage with world markets. Further, the short term mean seasonal and spatial price distribution generally decreased with liberalization. Conversely, the long term regional mean price differences increased reflecting increased intermediation costs arising out of increase in real cost of fuel, spare parts and vehicles over the previous ten years. Also, liberalization led to higher long term regional differences in potato price volatility in Madagascar.

The author concluded that reforms can ignite private trading and arbitrage and recommended that, for the food price distributions to stimulate production and growth there is need for improvement of market institutions, infrastructure, production and processing technologies. The similarities between Barrett, (1997) study and the current study is that both studies empirically analyze the effects of liberalization on potato price volatility using time series data using the ARCH-M econometric model. Further, potatoes were neither subject to parastatal marketing nor price control in both studies. In contrast the current study done in Kenya concentrates on Irish potatoes in one market while the previous study was carried out in Madagascar on five crops in 17 markets. All the potatoes were aggregated in the previous study, and some of the independent variables used were different in the two studies.

Barrett(1997) used real exchange rate, border parity price, rice buffer stock release volumes and a dummy variable for June-December 1991 period of nationwide pro democracy strikes and regional dummies as independent variables which are not used in the current study. On the other hand, the current study uses value of production, sales and reforms which were not used by Barrett (1997). The two studies have different sets of independent variables since they were focusing on different commodities, diverse regions and varying economic environments.

In addition, potatoes were exportable in Madagascar during the period of the study while in Kenya the potatoes were not generally exported. Aggregation of Irish potatoes and sweet potatoes makes it difficult to determine the specific effects of liberalization on price volatility on the particular potato type in Barrett (1997) study, an ambiguity which the current study attempts to clear. In addition, the current study uses data for a period of 20 years to evaluate the effects of market policy reforms on price volatility, which provides better results as compared to the study by Barrett, (1997) which uses a shorter period of 6 years.

The effects of market reforms on the evolution and volatility of producer prices of coffee, maize, tea and milk in Kenya was analyzed using an ARCH-M model in a study by Karanja *et al.*, (2003). The authors used milk and maize to represent food items while coffee and tea represented traded non-food commodities. A database of a 15 year period on monthly producer prices obtained from the marketing bodies concerned with the marketing and the regulation of the commodities was used. The periods 1985 to 1991 and 1992 to 1999 represented the pre reform and reform periods respectively.

The results from the study indicate that real producer prices for coffee, tea and maize significantly declined during the reform period while milk prices increased in the same period. Further, the results show that the market reforms were generally associated with higher volatility of commodity prices, although there were inter-commodity differences. The authors attributed these results to sequencing problems and the inconsistent nature of the implementation of market reforms and also due to limited private sector participation in agricultural markets. In addition, for traded products the authors associated the results to the international trends in agricultural commodity prices.

The authors conclude that market reforms do not always create the necessary conditions for increasing the level of real commodity prices. Another conclusion from this study is that there is need to employ caution in generalizing the effects of market reforms on prices, since the evolution of commodity prices tend to be commodity specific. The study recommends specific price policies aimed at addressing declining prices for food and for export crops. In view of the fact that the majority of rural households are net food buyers, the authors recommend a review of price support policies. According to the authors, these policies are assumed to contribute to growth in incomes in the rural areas but mainly benefit commercial food crop producers, who are mainly the medium and large scale farmers.

The similarity of Karanja *et al.,* (2003) and this study is that both empirically analyze the effects of market policy reforms on price volatility using time series data by use of an ARCH-M econometric model approach. The authors used a 15 years time series dataset in the study while the current study uses a 20 year period database which gives a better assessment of price volatility. Additionally, the study by Karanja *et al.,* (2003) was essential in identifying the dependent and independent variables

to consider in the current study. However, the study dealt with maize, milk, coffee and tea products which were subject to control by parastatal marketing and price control during the pre market reforms period while the current study focuses on Irish potatoes, a commodity that did not have price controls and was not under parastatal marketing arrangements.

2.4. Chapter Summary

In this chapter the literature review presented summarizes the approaches used in the analysis of price volatility, studies on price volatility and Irish potato economic evaluations in Kenya and the effects of market reforms on price volatility. This review is useful in the identification of the literature and empirical gap addressed in this study and the appropriate analytical approach to adopt in price volatility analysis.

In the past ARCH, ARCH-M, GARCH and the SHM econometric models have been used to study price volatility. When the conditional variance or standard deviation is included in the mean equation of a basic ARCH econometric model, we get the ARCH-M which allows for the existence of a direct correlation between price levels and also permits simultaneous estimation of time varying risk premia.

The chapter shows the lack of consensus on effects of market reforms on price volatility and an existence of an empirical gap on Irish potato price volatility in Kenya. The next chapter gives the theoretical framework and the analytical model used to assess the effects of market reforms on Irish potato price volatility in Nyandarua district. It also presents the specification of the empirical model used in this study.

CHAPTER 3

METHODOLOGY

3.1. Introduction

The main purpose of this chapter is to evaluate the alternative empirical models for analyzing price volatility and present the appropriate model to adopt in this study. The chapter is divided into four main sections. Firstly, the analytical framework for analyzing price volatility is presented. Secondly, the empirical model used to estimate the effect of market reforms on Irish potato price volatility in Nyandarua district is specified. Thirdly, the data types and sources are described. Lastly, the method used in data analysis is illustrated.

3.2. Analytical Framework

The autoregressive conditional heteroscedasticity (ARCH) model was originally developed by Engle (1982) to describe the inflationary uncertainty in the United Kingdom. However, the ARCH class of models has subsequently found wide use in characterizing time-varying financial market volatility (Bollerslev, 1986). The model allows for simultaneous estimation of conditional means and variances of a dependent variable over time (Engle 1982; Bollerslev, 1986). An autoregressive conditional heteroscedasticity (ARCH) econometric model is used in this study to calculate Irish potato price volatility which cannot be directly observed.

The selection of this model was motivated by three reasons. The first reason is a theoretical belief that storable commodities have an ARCH process because current price volatility transmits itself

into future period by creating volatility in the inventory carryover (Kilima *et al*, 2004). Secondly, the model allows conditional volatility to directly influence the conditional mean. (Kilima *et al*, 2004). The model is not just interested in the determinants of prices as reflected in the conditional mean and various regressors but also in the factors that explain price risk as revealed in the series conditional variance and the interaction between the mean and variance of the prices, that is, the price risk premium prevailing in the market (Gujarati, 2006). Third, data limitations and modeling difficulties disqualify the adoption of alternative models.

The conditional variance means that variance at any given period is dependent on time and previous variance (Green, 2003). This indicates that the variance is conditional on time and previous variance. It is used in studying prices which go through periods of high volatility and periods of low volatility, to model them econometrically as having the variance at time t as coming from an autoregressive (AR) process. This is the basis of the ARCH model. In this model, the unconditional variance is the variance of the whole process, whereas the conditional variance can be better estimated since it is assumed that we can estimate the previous values of the variance (Green, 2003). In this study price volatility is modeled as the conditional variance of Irish potato mean prices.

The ARCH model assumes an error structure in which the sign of the disturbance is not predictable, but in which the size of the forecast error is. Thus the conditional variance is homoscedastic but the variance at any time t conditional on preceding period information, is heteroscedastic. An important assumption underlying ARCH model is that there is an inherent non-linear phenomenon that could lead to price volatility (Deaton and Laroque, 1992; Bera and Higgins, 1995; Shiverly 1996, 2001). This assumption is mainly satisfied in situations where stockholding play an important role in price

determination in any two successive periods. In agriculture the model is used to measure price volatility mainly for tradable commodities like cereals (Karanja *et al.*, 2003).

The specifications of the ARCH model provides for the conditional mean equation, conditional variance and conditional error distribution. Following Engel (1982) the basic ARCH model can be defined as:

The conditional mean equation,

$$Y_t = X_t^{\prime} + \pounds_t \qquad (3.1)$$

Equation (3.1) can be expressed in general form as:

$$Y_t = f(X_t^{\prime}) \qquad (3.2)$$

The conditional variance equation,

$$\pm_t^2 = \mu + \sim\pounds_{t-1}^2 \qquad (3.3)$$

Equation (3.3) can expressed in general form as:

$$\pm_t^2 = f(\mu, \alpha) \qquad (3.4)$$

Where,

Y_t is the dependent variable over time t.

$X_t^{\prime}$ is a vector of independent variables.

$^{-}$ and α are constants.

$\pounds_t$ represents the error term which is independently and identically distributed (i.i.d).

The mean equation (3.1) is expressed as a function of exogenous variables with an error term. X_t' refers to exogenous or predetermined variables that are included in the mean equation while σ_t^2 is the one period ahead forecast variance based on past information and is therefore the conditional variance over time t. This allows for the existence of a direct correlation between price levels and volatility. Equation (3.3) of the conditional variance is a function of a constant term μ and news about the previous period volatility measured as the lag of the squared residual from the mean equation ε_{t-1}^2. The ε_{t-1}^2 refers to the presence of a first-order moving average and is called the ARCH term. Equations 3.1 and 3.3 are based on the macroeconomic theory of the trade-off between risk and volatility (Engle, 2003).

The ARCH fits regression models in which the volatility of a series varies through time. Usually, periods of high and low volatility are grouped together. ARCH models estimate future volatility as a function of prior volatility. To accomplish this, ARCH fits models of autoregressive conditional heteroscedasticity using conditional maximum likelihood method. The variance of the dependent variable is modeled as a function of past values of the dependent variable and independent or exogenous variables.

The completion of the basic ARCH model requires assumptions about the conditional distribution of the error term ε_t. The assumptions are: normal distribution, student's t-distribution and Generalized Error Distribution (GED). Given the distributional assumptions, the ARCH model is estimated using the method of maximum likelihood (MLE) which assumes that data is normally distributed.

The equations (3.1) and (3.2) are estimated simultaneously by method of maximum likelihood yielding consistent, and efficient estimates of¯ , μ and α parameters of interest.

The autoregressive conditional heteroscedasticity in mean (ARCH-M) model suggested by Engle, Lilien, and Robins (1986) is an extension of the ARCH model. The ARCH-M model was first used for modeling risk-return tradeoffs in the term structure of United States interest rates. The model extends the ARCH regression model in Engle (1982) by allowing the conditional mean to depend directly on the conditional variance and thus risk thereby influencing equilibrium price levels. The conditional mean implies that the mean price is conditional on time and previous price (Gujarati, 2005). In the ARCH-M regression model the conditional variance is interpreted to represent volatility. The bounds of the conditional variance is from zero to one, with zero indicating no volatility at time t while the value one represents maximum volatility at time t.

The ARCH-M allows price modeling with time varying risk premium, that is, the increase in the expected rate of return (mean price) is associated with the increased risk in rate of return (variance). In the model, the risk term ¤ included as one of the vectors of independent variables, estimates the relative risk premia. The ¤ estimate reflects a risk premium with respect to the conditional standard deviation (Engle, Liliens and Robins, 1986). This risk premia is that portion of observed price attributable to a risk premium. The short-term risk premia is the necessary mark-up by an existing firm to cover its price risk exposure (Barrett, 1997). The long- term risk premia captures general equilibrium effects on industry structure as risks impacts on entry, exit and investment levels. Long-term risk premia thus add to the short-term effects of risk.

The literature on risk and agricultural marketing in high-income countries indicates the risk premium to be positive (Barrett, 1997). This implies that equilibrium prices compensate suppliers for bearing price risk. In low income countries however, it is quite possible that consumers will require compensation for bearing food security risk induced by price variability thereby leading to a negative risk premia (Barrett, 1997). There are several advantages of using the ARCH-M model. First, the ARCH-M model addresses the potential problems with heteroscedasticity that would lead to inefficient estimators and possibly incorrect inferences (Brewer *et al.*, 2005). This model is appropriate to use when the variance of the residuals fluctuates significantly during the sample period. Further, the model allows for simultaneous estimation of the conditional mean and price volatility of a dependent variable over time. The model is more applicable to tradable agricultural commodities in an environment where stockholding is important (Karanja *et al.*, 2003). The ARCH-M model was applied in this study due to its suitability in modeling price volatility in commodities such as Irish potatoes where stockholding by farmers and traders is important in regulating supply in the hope of benefitting from price movements.

3.3. Empirical Model

An autoregressive conditional heteroscedasticity in mean (ARCH-M) model was used to model the effects of market reforms on Irish potato price volatility. The choice of the independent variables is based on Karanja *et al* (2003) and Barret (1997). Following Karanja *et al.*, 2003 the ARCH-M model is specified as;

The general model of the mean equation can be expressed as:

$$P_t = f(T, P_{t-1}, R, PR, SD, S, h_i) \qquad (3.5)$$

Equation (3.5) can be expressed as a specific model as:

$$P_t = \ _0 + \ _1T + \ _2P_{t-1} + \ _3R + \ _4PR + \ _5SD + \ _6S + ¤h_t^{1/2} + e_t \quad (3.6)$$

The general model of the variance equation can be expressed as:

$$h_t = (\ e^2_{t-1}, T, P_{t-1}, R, PR, SD, S) \quad (3.7)$$

Equation (3.7) can be expressed as a specific model as:

$$h_t = \sim_0 + \ ª_1 e^2_{t-1} + ª_2 T + ª_3 P_{t-1} + ª_4 R + ª_5 PR + ª_6 SD + ª_7 S \quad (3.8)$$

Where P stands for the real monthly Irish potato price in constant terms at Nyahururu market, T is the time trend in months while PR is the monthly Irish potato value of production in Nyandarua district. The SD represents a seasonal dummy, S is the monthly Irish potato sales in Nyahururu market and R is the market reforms dummy. The P_{t-1} is the lagged real mean monthly Irish potato prices and h_t stands for conditional variance over time (t), which is the variance of the residuals of the regression. $\sim_0$ and β_0 are constants, while β_t and λ_i are estimation coefficients. The e_t is the random error term which is independently and identically distributed, while λ_1 is the ARCH term. The risk premia in this study was estimated as a coefficient, ¤ with respect to the conditional standard deviation in the ARCH-M model. To address the problem of multicollinearity the functional relationship of the explanatory variables was computed and the results show that it is not a problem as indicated by the low values of the correlation coefficients in Appendix 1.

The ARCH-M model allows for simultaneous estimation of the conditional means and variances of the dependent variable over time (Engle, 1982). A two equation ARCH-M model comprising of a mean and variance equation, is estimated for the Irish potato twenty year price series, inclusive of the pre reforms and the post reforms periods. Therefore, equation (3.6) gives the ARCH-M

estimates for the mean equation which determine the level of the wholesale Irish potato prices. In this case, the dependent variable is the mean monthly Irish potato price.

In equation (3.6) the estimation coefficients explain how the respective independent variables affect the Irish potato wholesale prices in the post reforms period. A positive estimation coefficient in this equation indicates that the respective independent variable leads to an increase in Irish potato prices. The equation also estimates the risk term. A risk term coefficient indicates the risk premia which is the mark up to cater for Irish potato price risk. If the coefficient is positive, the implication is that the mark up to cater for price risk increased during the post reforms era. Conversely, a negative risk term coefficient implies that the mark up decreased in the post reform era.

The equation (3.8) estimates the Irish potato price variance which depicts the price volatility. The dependent variable is thus the conditional variance and the estimation coefficients show how the independent variables affect the price volatility. A positive estimation coefficient in equation (3.8) indicates that the respective independent variable lead to an increase in price volatility during the post reforms period. On the other hand, a negative estimation coefficient shows that the independent variable resulted in a decline in price volatility in the post reforms period.

In this study the Irish potato conditional mean price is dependent on time and the previous price. The conditional variance or volatility of the Irish potato price is dependent on a monthly time trend t and the immediate value of the variance at time t-1. Both the conditional mean and variance were estimated by the univariate ARCH-M regression model using STATA computer software using the maximum likelihood estimation (MLE) approach.

The description, units of measurement and based on the economic theory of price, the hypothesized directions of the regression variables P, T, PR, SD, S, R, P_{t-1} and h_t are as indicated in Table 3.1.

Table 3.1. Description of Variables and their Measurement

Variable	Symbol	Description	Unit	Coefficient	Expected Sign
Dependent Variable					
Price	P	Irish potato real prices in Nyahururu market	Ksh/Metric tone		
Independent Variable					
Time	T	Time trend in months	-	ß$_1$	+
Value of production	PR	Irish potato monthly value of production in Nyandarua district	Ksh	ß$_4$	-
Season	SD	Seasonal dummy	Dummy	ß$_5$	-
Sales	S	Monthly Irish potato sales in Nyahururu market	Metric tones	ß$_6$	-
Reforms	R	Market reforms dummy	Dummy	ß$_3$	+
Lagged Price	P_{t-1}	Lagged Irish potato prices in Nyahururu market	Ksh/Metric tone	ß$_2$	+
Conditional Variance	h_t	Risk premia	-	¤	-

Notes: SD = 1 in January, May, June, August, September, November and December which are the Irish potato harvesting months and SD = 0 elsewhere. R = 0 for period January 1986 to December1995 and R = 1 for period January 1996 to December 2005.

The endogenous variable used in this model is the real monthly wholesale Irish potato price (P) in Nyahururu market (Table 3.1). On the other hand, the exogenous variables are the time trend in months (T), monthly values of Irish potato production in Nyandarua district (PR), sales (S), lagged mean monthly Irish potato real prices in Nyahururu market (P_{t-1}) plus the seasonal (SD) and reforms (R) dummies. The hypothesized directions of the coefficients of SD and R are positive. The estimation coefficient representing risk premia ¤ is expected to be negative as is the case in most developing countries (Barrett, 1997).

The real monthly wholesale Irish potato prices (P) were obtained by deflating the nominal prices obtained from Nyahururu market using the monthly Consumer Price Index (CPI) from the Kenya National Bureau of Statistics (KNBS). The base year of analysis was 1997, such that October 1997 = 100.

The time trend in months (T) is included as an exogenous variable to serve as proxy for the slow moving process of technological change because it affects the Irish potato prices but is not directly observable though it is highly correlated with time (Table 3.1). The inclusion of the time trend in the ARCH-M econometric model helps to avoid spurious regression. In this study, value of production (PR) comprises of monthly Irish potato value of production in Nyandarua district given in Ksh. (Table 3.1). The value of production is expected to be one of the main factors that determine the

mean price and volatility of Irish potato prices. The value of production is hypothesized to have a negative effect on price volatility due to the fact that with increased value of production, the supply increases and with a stable demand for Irish potatoes the mean price is expected to decrease.

A seasonal dummy (SD) is included in this model (Table 3.1). The seasonal dummy accounts for the potential seasonality in the mean monthly Irish potato wholesale price data. This seasonal dummy is specified such that SD = 1 during the Irish potato harvesting months while SD = 0, otherwise. The seasonal dummy is expected to have a negative impact on the mean price since during the Irish potato harvesting months the quantity of Irish potatoes supplied in the market increase leading to the depression of the mean price since the demand for this food commodity in the Kenyan markets is inelastic.

Sales (S) represent the monthly values of Irish potato sales in Nyahururu market expressed in Kenya shillings per metric tone (Table 3.1). Since the Nyahururu market handles only a small proportion of the Irish potatoes produced in Nyandarua district, the sales volume are expected to have a minimal effect on the mean Irish potato prices. The hypothesized direction for the sales is negative since high sales volumes imply that the supply is high with the consequent lowering of the monthly mean price.

The lagged mean monthly Irish potato real (P_{t-1}) prices in Nyahururu market is measured by lagging the monthly price by one month and is an indicator of whether the prevailing price at any one time depends on the price in the previous period (Table 3.1). In the model, the prevailing time is represented by t while the previous time is denoted as t-1. This variable is included as an exogenous variable in this model, since most agricultural commodity prices show a high degree of dependency,

such that the price in the current time (P_t) highly depends on the price prevailing in the previous period (P_{t-1}). The variable is hypothesized to have a positive sign due to the fact that the prevailing Irish potato mean price at any one month is highly dependent on the price in the preceding period.

To account for the period before and after market reforms, a market reforms variable (R) is specified (Table 3.1). In this model, R is a dummy variable, where R = 0 represents the period from January 1986 to December 1995. This period is referred to as the pre reform period. On the other hand, R=1 represents the period from January1996 to December 2005, otherwise referred to as the post reforms period. The coefficient of market reforms dummy shows the effect of market reforms on Irish potato price volatility that is the thesis of this study.

A positive coefficient for the market reforms dummy variable (R) in both the mean and variance of the ARCH-M regression is taken to indicate a higher mean price and higher price volatility during the market reforms period. On the other hand, a negative coefficient of this variable indicates lower mean price and volatility during the reforms period. The market reforms variable is expected to have a positive effect on the mean price since the reforms were anticipated to improve the producer prices in the agricultural sector as a means of stimulating production and growth. On the other hand, the market reforms dummy is expected to be negative in the conditional variance model, since the market reforms were targeted to offer stable prices to farmers for increased production.

3.4. Data Sources

This study used monthly time series secondary data on Irish potato prices, value of production and sales from the Ministry of Agriculture in Nyandarua for the period 1986-2005. This dataset

comprises 240 observations. The data was collected from Nyandarua District Agricultural Office (DAO). The monthly time series Irish potato price data (Appendix 7) was collected by the Ministry of Agriculture market enumerators using standard questionnaires (Appendix 5 and 6) on a weekly basis and the monthly average prices aggregated from the weekly prices. The enumerators were trained through a project supported by German Technical Support (GTZ) and were supervised by the Nyandarua District Farm Management Officer. The data was screened to identify outliers, miscoded, missing or any other anomalies to improve performance of the analytical method. A spot check was done to evaluate whether the enumerators were collecting the data correctly was done.

Other sources of data included institutions involved in production, marketing, research and data collection of Irish potatoes in Kenya. These were the Kenya Agricultural Research Institute (KARI), Horticultural Crops Development Authority (HCDA) and German Technical Support (GTZ). The national Consumer Price Index (CPI) statistics were obtained from the Kenya National Bureau of Statistics (KNBS). However, rural CPI would have been preferred for this study but was not available for the period under consideration.

3.4.1 Data Analysis

To evaluate the trends in Irish potato prices in Nyandarua district; both before and after the implementation of market reforms policies in Kenya is achieved by computing descriptive statistics. The mean and coefficient of variation (CV) for real Irish potato prices in Nyahururu market are compared for the pre market reform and the post market reform periods. To assess the effects of market reforms on Irish potato price volatility in Nyandarua district is achieved by estimating an autoregressive conditional heteroscedasticity in mean (ARCH-M) regression for the monthly real

Irish potato prices from Nyahururu market over a 20 year period. The monthly data series were not adjusted since the long term effects are assessed in this study in contrast to the short term effects which would require adjustment. The data was analyzed using Stata computer package.

3.4.2. Area of study

This study was undertaken in Nyandarua district in the Central Province of Kenya (Figure 3.1). The district covers an area of 3,528 square kilometers with an arable land of 2,011 square kilometers. The district lies between $0^0$08'N and $0^0$50'S latitude and between 36^0 13'E and 36^0 24' E longitude (Jaetzold, 2006). The district is composed of six administrative divisions comprising of North Kinangop, Kipipiri, Oljolorok, Olkalou, Ndaragua and South Kinangop divisions. It has an oblong shape form that is quite long (Figure 3.1). To the North the district borders Laikipia, Nyeri and Murang'a districts, while to the East it borders Maragua, Kiambu to the South and Nakuru to the West (MoA, 2007).

Figure 3.1.Map of Nyandarua District, Kenya

Source: Kenya National Bureau of Statistics, 1999

Based on rainfall patterns, soils, temperatures and altitudes, the district is categorized into three major land use areas. These comprise of high potential, low potential and medium potential areas. The main food crops grown in the district include Irish potatoes, cabbages, carrots, peas and maize. On the other hand, cash crops are cut-flowers, wheat and pyrethrum while the main livestock enterprises are dairy, sheep, beef and poultry. However, Irish potato doubles up as the main staple food and cash crop in Nyandarua district which is also leading in supply to the Nairobi markets (MoA, 2007).

3.5. Unit Root Test

A common feature in time series variables is that their mean and variances may change over time. This is in view of the fact that estimation of a standard regression model is based on the assumption that the means and variances of the variables being tested are constant over time (Gujarati, 2005). All variables whose means and variances change over time are known as nonstationary or unit root variables (Dickey and Fuller, 1979). This implies that the current shocks have permanent effects on the time series variables and thus the fluctuations are not transitory. The unit root test is used to determine whether time series variables are affected by transitory or permanent shocks (Engle, 2003).

The test for stationarity is carried out because the stationarity or nonstationarity of a time series can strongly influence its behaviour and properties. For example, persistence of shocks will be infinite for nonstationary series. In addition, stationarity is useful to avoid spurious regression in variables whose R^2 in their regression is high despite the fact that the two variables are totally unrelated. If

variables in the regression model are nonstationary, then it can be proved that the standard assumptions for asymptotic analysis will not be valid. Hence the ‘‘*t*-ratios’’ will not follow the *t*-distribution, thus hypothesis tests about the regression parameters cannot be validly undertaken. Unit root tests enable us to determine which model to be use in evaluating volatility because visual methods are not adequate to ascertain this. When the time series is found to be non-stationary, an ARCH model is suitable to assess volatility in the time series data base since it can model varying mean and variance (Gujarati, 2005).

Stationarity implies that the mean, variance and covariance of a series are time invariant (Green, 2004). Alternatively, a variable is said to be nonstationary if it has no clear tendency to return to a constant value or linear trend (Gujarati, 2005). A nonstationary data has a mean and variance that are not constant (Green, 2004). Use of nonstationary or unit root variables in estimating regression equations yields misleading inferences (Green, 2004). In effect, statistical inference associated with stationary processes is no longer valid if the time series are indeed realizations of nonstationary processes. When a unit root is identified, the data is differenced to determine the order of integration. This is the number of times a nonstationary series has to be differenced to transform it into a stationary series. A nonstationary series ‘‘Y_t’’ is integrated of order ‘‘d’’ denoted ‘‘I (d)’’ if it becomes stationary after being differenced ‘‘d’’ times (Gujarati, 2005). Where ‘‘Y_t’’ is a nonstationary time series dataset, ‘‘**I**’’ is the order of integration and ‘‘d’’ is the number of times ‘‘Y_t’’ is differenced to make it stationary.

Several tests for unit roots have been proposed in the literature. The commonly used ones are the Dickey-Fuller (DF) (1979) and Philips-Perron (PP) (1988) unit root tests. The Philips-Perron (1988) is a more powerful test for unit roots than the Dickey-Fuller (1979) test in small samples and follows a first order autoregression. In large samples the results of the PP and DF test statistic are similar in most empirical evaluations. In this study both tests are used for comparison purposes in testing for unit roots in the regression variables. The null hypothesis in the unit root test is that the time series under consideration has a unit root, that is it is nonstationary while the alternative hypothesis is that the time series is stationary (Green, 2004).

Following Dickey and Fuller (1979) the Augmented Dickey-Fuller (ADF) test is specified as:

$$\Delta y_t = u + {}_t + \sim y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-1} + e_t \qquad (3.7)$$

Where y_t is a random variable with non zero mean, *u* is a constant, t is time trend variable, e_t is the error term with mean zero and a constant variance and the coefficient *a* is the test statistic. The ADF test involves the estimation of α, which is referred to as the Dickey-Fuller or the tau test statistic. In equation (3.7), we test the null hypothesis of $\alpha = 0$ against the alternative hypothesis of $\alpha < 0$. Where Δ denotes the first difference, y_t is the time series being tested, u, ß and c are constants while k is the number of lags which are included in the model to ensure that the residuals e_t have zero mean and constant variance (Dickey and Fuller, 1979). Schwartz Bayesian Criterion (SBC) and Akaike Information Criterion (AIC) are used to determine the optimal lag length, k. If the null hypothesis cannot be rejected, it implies that the time series is nonstationary at the level series and therefore it requires taking first or higher order differencing of the level data to establish stationarity.

The ADF test rejects the null hypothesis in favor of the alternative hypothesis when the estimated tau test statistic is less than the critical value from the ADF table (Gujarati, 2005), implying that the series are stationary. Alternatively, if the estimated tau test statistic is greater than the critical value we do not reject the null hypothesis of a unit root thus showing that the series are nonstationary.

Phillips-Perron (PP) test is used to test for a unit root hypothesis on a data series. The PP test rejects the null hypothesis in favor of the alternative hypothesis when the estimated PP statistic is less than the critical value (Gujarati, 2005). Conversely, if the estimated PP statistic is greater than the critical value we do not reject the null hypothesis of a unit root. A rejection of the null hypothesis in the PP test implies that there is no unit root in the data series and hence the data is stationary and does not need to be differenced.

3.6. Structural Break Test

When we use a regression model involving a time series data set, it may happen that there is a structural change in the relationship between the regressand and the regressors. By structural change, we mean that the coefficients in a regression model do not remain the same in separate subsamples of data (Gujarati, 2005). A test for structural change is an econometric test to determine whether the coefficients in a model are the same in separate subsamples. Often the subsamples come from different time periods (Hansen, 2001). The structural change may be due to political and economic factors like policy changes or to a variety of other causes. These factors can cause relationships among economic variables to change over time.

A significant structural change that impacts on a commodities supply and demand invalidates the use of a single set of time series data for planning purposes; such as mean price. Furthermore, the results of standard test of stationarity such as Augmented Dickey-Fuller (ADF) test can be influenced by structural breaks. When structural breaks are not properly accounted for in testing for unit roots, incorrect conclusions regarding the stationarity of the data will likely be drawn (Green, 2004). The Chow test procedure splits the data into two sub periods and then estimates the parameters for each sub period. The equality of the two sets of parameters is tested using the F statistic (Hansen, 2001). In this study the Chow test is used to test for a structural break that is assumed *apriori* to have occurred with the onset of the implementation of market reforms.

3.7. Chapter Summary

The chapter provides the analytical framework for analyzing price volatility used in this study. This is followed by the specification of the ARCH-M empirical model used to estimate the effect of market policy reforms on Irish potato price volatility in Nyandarua district. Then data types and their sources and the study area which is Nyandarua district are described. Next the model diagnostic unit root tests of the Augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) are described as a guide in determining the appropriateness of the autoregressive model for assessing the Irish potato price volatility. Lastly, the structural change test is illustrated to determine whether there was a structural change occurring at the onset of the implementation of the market reform policies.

When the strengths and weaknesses of the various approaches for analyzing price volatility are considered the ARCH-M model turns out to be the appropriate choice. This is further demonstrated by the performance of this model in past studies in yielding robust estimates of the regression coefficients for assessing volatility and its ability in the estimation of time varying risk premia. The next chapter presents the empirical results realized from the statistical plus econometric estimation of the variables under this study and discusses their economic implications for the Irish potato sub-sector in Nyandarua district.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Introduction

This chapter presents the empirical results of the effect of market reforms on Irish potato price volatility in Nyandarua district. First, the descriptive statistics for the variables used in the volatility model are given. The discussion of the descriptive statistics is followed by the presentation of the econometric results. The two equation ARCH-M estimates of real Irish potato prices and variance are reported. The mean equation estimates the effect of value of production, sales and lagged prices on the Irish potato prices during the post-reforms period. This equation also estimates the risk premia over the same period. The variance equation estimates the effect of value of production, sales and lagged prices on Irish potato price volatility during the post reforms period.

4.2. Descriptive Statistics

The pre-reform period represent the time from January 1986 to December 1995 which is the era before the reforms. On the other hand the post-reform period correspond to the period from January 1996 to December 2005, the period after the reforms. The entire period stand for the time from January 1986 to December 2005, the period spanning from the time before the reforms to the period after the reforms. The two periods were selected because they mark the era before and after the implementation of Structural Adjustment Programs (SAPs) which were initiated in Kenya in the mid 1980's.

The descriptive statistics of the variables used in the model to estimate Irish potato price volatility are presented in Table 4.1.

Table 4.1. Descriptive Statistics of Variables used to Estimate Price Volatility

		Pre-reform period		Post-reform period		Entire period	
Variable	**Units**	**Mean**	**CV[a] (%)**	**Mean**	**CV[a] (%)**	**Mean**	**CV[a] (%)**
Dependent variable							
Price	Ksh/t.	1010.13	64.04	5996.16	50.21	3503.15	94.51
Independent variable							
Value of prodn.	Milln. Ksh.	12.76	70.78	89.38	62.66	13.20	66.78
Sales	Mt.	31.13	60.71	48.96	53.37	40.05	61.05
Lagged price	Ksh/t.	999.00	62.98	5949.14	50.36	3474.07	94.67

Note: [a] The Coefficient of Variation (CV) is a ratio of the standard deviation to the mean.

Source: Author's Computations

The ten year mean monthly wholesale real Irish potato price paid to farmers increased from an average of 1010 Ksh/tone in the pre reform period (January 1986 to December 1995) to 5996 Ksh/tone in the post reform period (January 1996 to December 2005). This represents a 494 percent increase in the wholesale price (Table 4.1). In order to determine whether the mean prices were significantly different between the two periods, a two way t- test is done and the results are as reported in Table 4.2.

Table 4.2.Two Way t Test on the Mean Prices

Period	No. of observs.	Mean	Standard error	Standard deviation
Pre reforms	120	1010.13	59.33	3010.54
Post reforms	120	5996.16	274.82	649.91
Entire period	240	3048.65	236.71	3667.04
Difference	-5895.03	281.15	-6451.23	-5338.81
t value	-20.97			
α	0.05			
Rejection region	t < -1.96 or t > 1.96			

Notes: α represents the level of significance and t is the test statistic.

Source: Author's Computations

The test statistic falls in the rejection region and the null hypothesis is rejected at the 95 percent level of significance. The implication is that Irish potatoes mean price before the implementation of the market reform policies was significantly different from the mean price after the implementation of the market reforms.

The increase in mean real Irish potato prices during the post-reforms period was as a result of low supply growth as compared with the increase in demand. A rise in demand is attributed to an increase in population, rapid urbanization and change in tastes and preferences in favor of an increase in the consumption of Irish potatoes. The increased wholesale prices benefited the farmers in Nyandarua district whose net returns increase with increasing prices. However, the rise in Irish potato prices would hurt the consumers.

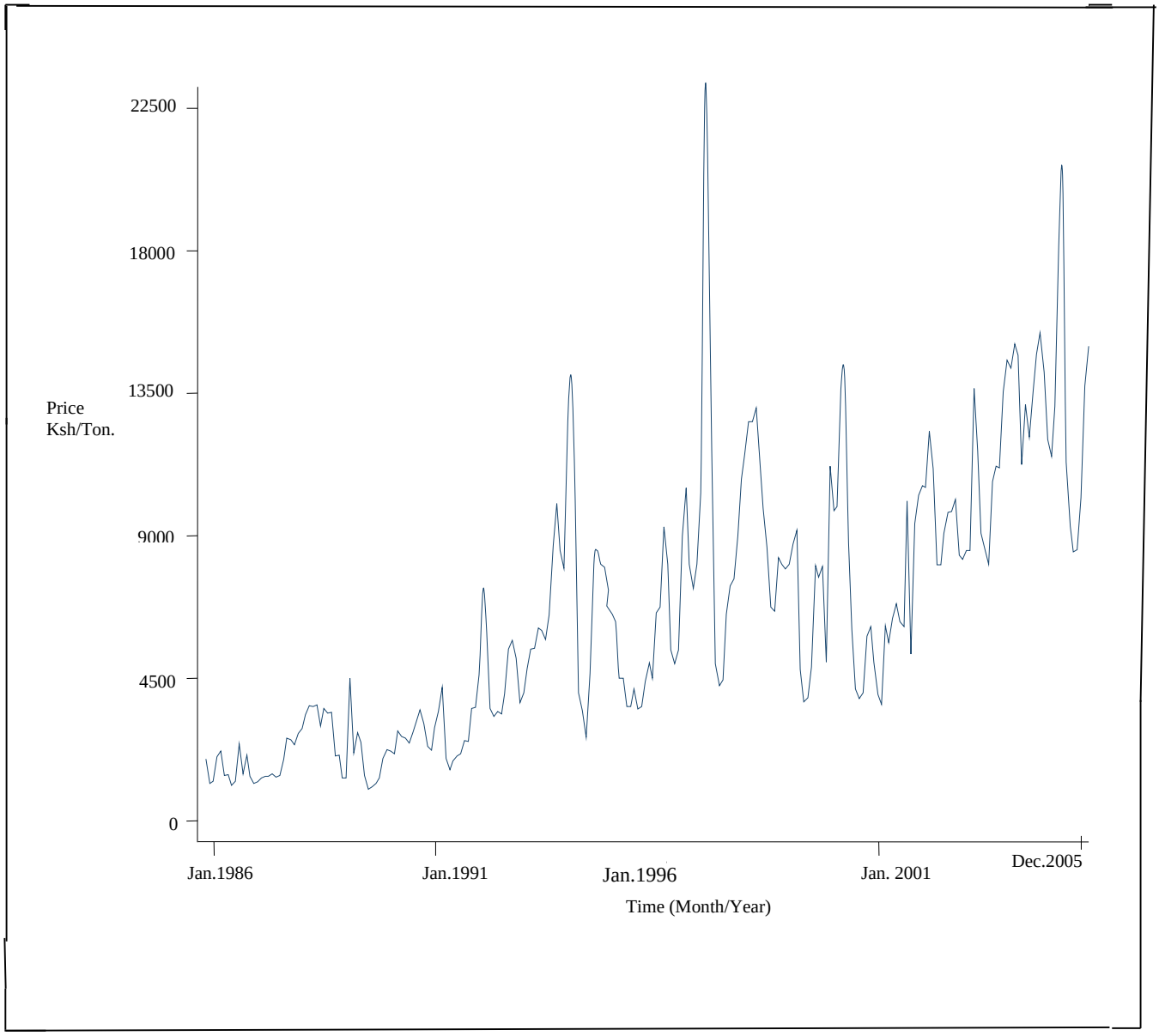
The variability of Irish potato prices as represented by the coefficient of variation (CV) declined during the post reforms period from 64 percent to 50 percent (Table 4.1). The reduction of the variability of the mean Irish potato wholesale price implies that Nyandarua farmers received more

stable prices and returns from their Irish potato sales during the post reform period in comparison with the pre reform period. However, this does not rule out volatility during the post-reforms period as indicated by the marked difference in the mean price during the two periods. The variability of the mean wholesale price was higher during the pre reforms period than in the post reforms period as shown by the coefficient of variation.

The increase in Irish potato prices and decline in the price variability show that Nyandarua farmers received higher and stable revenues from Irish potatoes during the post-reforms period as compared with the pre- reforms period. Hence, the Irish potato farmers were better off during the post market reforms period in comparison with the pre market reform period. The implication is that the high and relatively stable Irish potato prices during the reforms period served as an incentive for Nyandarua district farmers to increase production. However, the high and stable prices were not favorable to the consumers in the post reforms period as compared to the pre market reforms period. Thus the Irish potato consumers were better of during the pre market reforms period as compared to the post market reforms era as indicated by the increase in the mean price by 494 percent and reduction in the coefficient of variation from 64 percent to 50 percent (Tables 4.1).

The decline in the variability of the mean monthly Irish potato price from 64 percent to 50 percent (Table 4.1) during the post reforms period can be explained by the reduced variability in the value of production from 70 percent to 62 percent (Table 4.1). Thus since the fluctuations in demand for Irish potatoes in the Kenyan markets is low, the source of price variability lies in fluctuation in value of production. In essence, value of production fluctuations arose out of variation in weather, pest and diseases and farm management practices.

Figure 4.1.Monthly Real Irish Potato Prices (Ksh/Tone) Trend (1986-2005)



Source: Author's Computations

Figure 4.1 shows the mean real monthly wholesale Irish potato prices from January 1986 to December 2005. The Irish potato prices are highly variable in Nyandarua district and they fluctuate in up and down fashion with an increasing trend (Figure 4.1). The up and down fluctuations are due

to fluctuations of supply occasioned by changes in weather conditions, pest and disease incidences; and husbandry practices against a relatively stable demand for Irish potatoes in the district. Irish potato has a stable demand since it is a food item which according to economic theory has an inelastic demand. There are differences in the price fluctuations between the months and the years with less variability observed in the period after the reforms. This can be depicted the value of standard deviation of the mean Irish potato prices of 3010.54 during the pre reforms period and 646.91 in the post reforms period (Table 4.2). The movements in real Irish potato prices show an increase in the mean price during the post liberalization period. A likely cause of these price fluctuations is due to the fact that demand for Irish potatoes in Nyandarua district is relatively stable, whereas supply fluctuates due to weather conditions, pests, diseases and farm management practices.

The strong seasonality of supply is aggravated by the fact that there are only a few storage facilities available to the farmers and traders. This leaves the supply dependent on the natural growth pattern. A notable feature is the remarkable price increase during 1999, when potato prices more than tripled (Figure 4.1). This was because of a poor harvest due to heavy *El Niño* rains which resulted to a increase in Irish potato Blight and also resulted to rotting of the potatoes leading to a shortage and hence a sharp increase in prices.

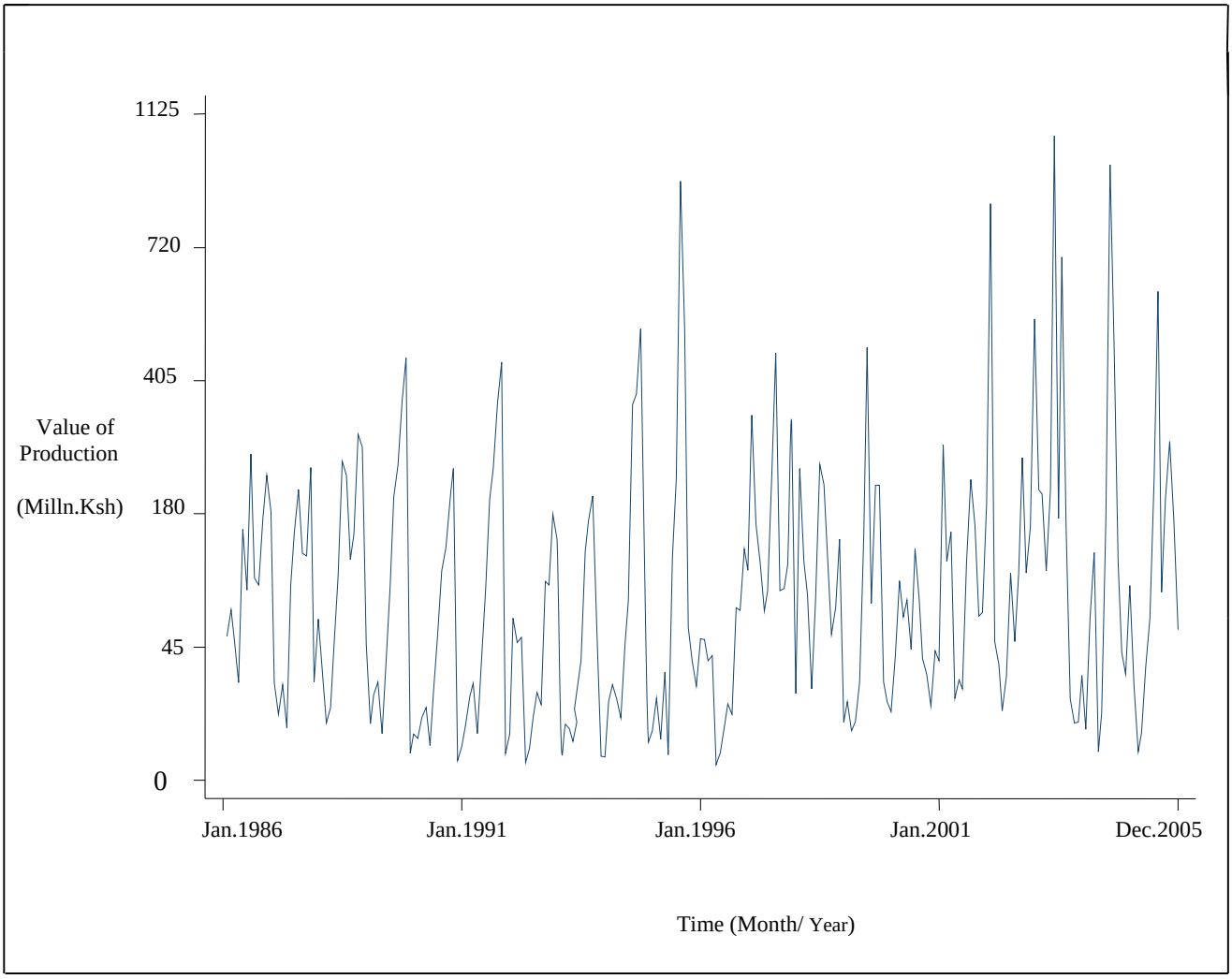
There was also a price increase in the years 1994 and 2004 when Nyandarua district received low rainfall levels leading to a decline in Irish potato value of production due to water stress and high incidence of pests especially the tuber moth as illustrated later in Figures 4.3 and 4.2 respectively. The marked fluctuations around an upward trend as shown in Figure 4.1 are an indicator of

nonstationarity of the mean real monthly wholesale Irish potato prices. However, to confirm the existence of nonstationarity trends, a unit root test is performed.

The results show that the mean monthly Irish potato value of production increased by 600 percent from 12.76 Million Ksh. per month during the pre reforms period to 89.38 Million Ksh.per month in the post reforms period (Table 4.1). However, the variability of Irish potato value of production reduced from 71 percent to 63 percent over the same period (Table 4.1).

As stated above the decline in value of production variability during the post- reform period lead to a reduction of price variability during the same period. The monthly mean Irish potato value of production for the pre- reforms period was lower than for the post reforms period. As depicted by the CV (Table 4.1), variability of value of production for the pre reforms was higher than during the post reforms. The high mean Irish potato value of production and low variability during the reforms period imply that the reforms lead to an increase in the overall potato value of production in Nyandarua district.

Figure 4.2. Irish Potato Value of production (Milln. Ksh.) Trend for Nyandarua District (1986-2005

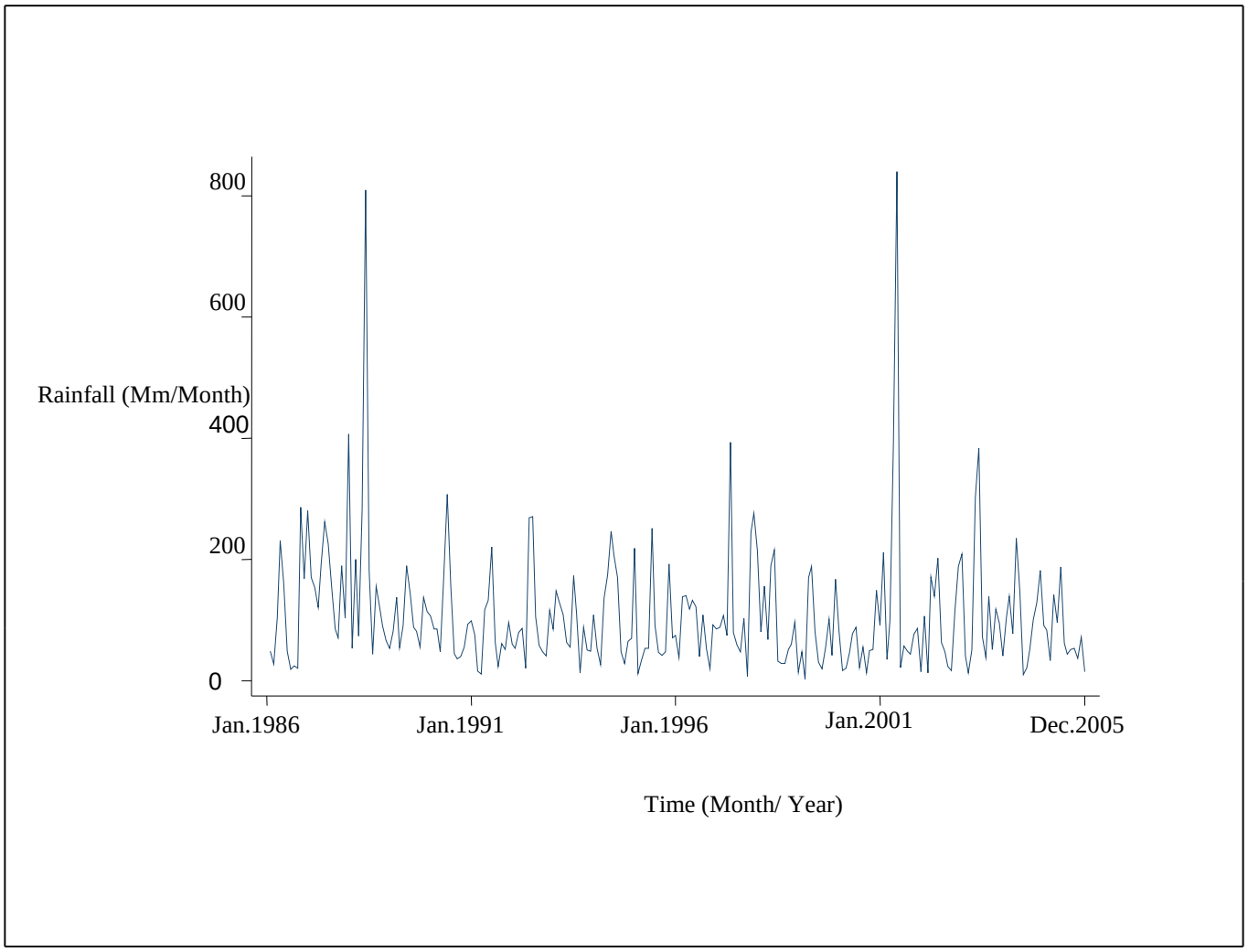


Source: Author's Computations

The mean monthly Irish potato value of production increased during the post reforms period due to high and less variable prices (Figure 4.2). The farmers thus realized high and stable incomes from their Irish potato enterprises in this period. Consequently, this served as an incentive for farmers to increase production of Irish potato during the post reforms era (Appendix 4). Comparing figure 4.2

and 4.3 shows that the Irish potato value of production follows the rainfall pattern, with the value being high during the years when the rainfall levels are high. On the other hand, the value of production declines during the years when the district receives low rainfall levels. The increase in Irish potato value of production after the market reforms can also be attributed to favorable weather conditions as a result of good rains received during this period as illustrated in Appendix 3 and Fig. 4.3.

Figure 4.3. Monthly Rainfall Trend (Mm) for Nyandarua District (1986-2005)



Source: Author's Computations

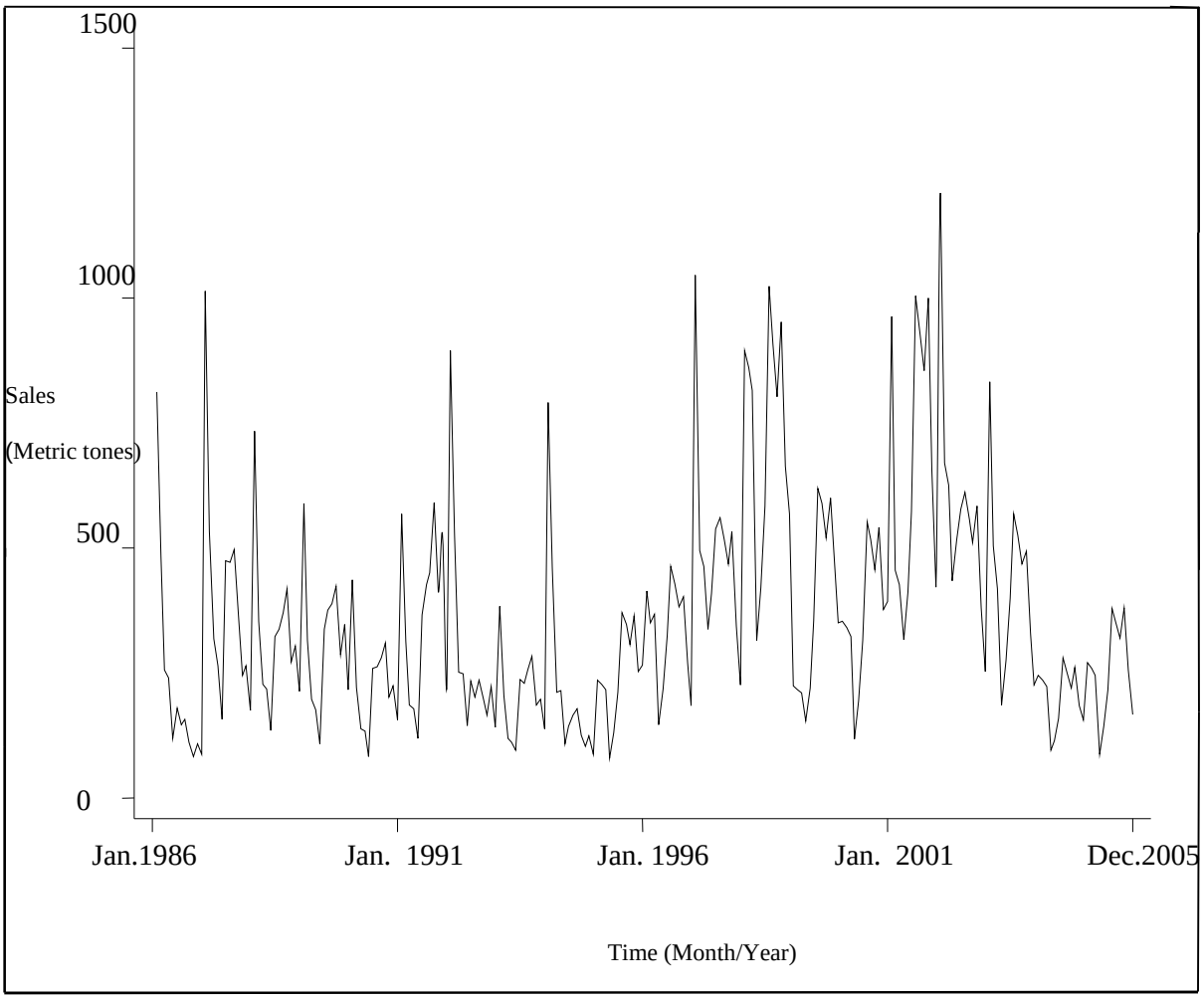
The Nyandarua district's monthly Irish potato value of production pattern for the last twenty years is as depicted by Figure 4.2. The potato value of production shows high variability between months and years. The value of production figures exhibit up and down trends with no visually distinct pattern. The variability arise out of availability of rainfall (Figure 4.3) and the season, since most of the farmers grow the crop using rain fed conditions since they have not invested in irrigation infrastructure and they also sell their produce immediately after harvest due to lack of proper storage structures and immediate cash needs. The rainfall is highly variable in Nyandarua district as evident in Figure 4.3. When the amount of rainfall is favorable (Figure 4.3) and also during the harvesting season, the value of production is recorded to be high (Figure 4.2).

Another key factor explaining the fluctuation of the potato value of production is the price, with the farmers responding to low prices by reducing production and high prices by increasing production. The value of production trends lead to a high degree of variability in supply which leads to price volatility. In addition, high variability in Irish potato value of production is associated with problems of adverse weather conditions, incidence of pests and diseases, low soil fertility and lack of funds to acquire farm inputs especially fertilizers and certified seed potato.

The mean monthly Irish potato sales volumes in Nyahururu market were higher during the post reforms period than in the pre reforms period (Table 4.1). The mean sales volumes increased from 31 metric tones during the pre reforms period to 49 metric tones during the post reforms period, an increase of 57 percent. This increase in the sales volume can be explained by an increase in the supply and demand of Irish potatoes to the market. However, variability of the sales volume as

represented by the CV, was lower during the post reforms period compared to the pre reforms period (Table 4.1).

Figure 4.4.Monthly Irish Potato Sales (Metric tones) Trend in Nyahururu Market (1986-2005)



Source: Author's Computations

The trend of monthly Irish potato sales in Nyahururu market for the twenty year period is as depicted in Figure 4.4. The sales volumes show high variability between months and can be explained by a variability in value of production. In Nyandarua district, the Irish potato value of

production follows the rainfall pattern which leads to the seasonality of supply. However, Irish potatoes are sold throughout the year in Nyahururu market (Figure 4.4). In view of the fact that the crop has a fairly stable demand in the Kenyan markets, seasonality of supply may lead to price volatility due to demand and supply disequilibrium. This variability in sales volume was as a result of variability in the quantities of Irish potato supplied and demanded in the market. The decreased variability of the sales volumes during the post reforms period implies a reduction in the supply and demand variability over this period as compared to the pre reforms period.

In summary, the mean prices, value of production and sales volume increased but their variability declined. These findings imply that the implementation of market reform policies by the Kenyan government lead to the realization of high and stable incomes by the Irish potato farmers. This leads to the conclusion that the potato farmers in Nyandarua district are better off with the implementation of market reform policies than without them.

4.3. Unit Root Test Results

The Augmented Dickey-Duller (ADF) and Phillips-Perron (PP) methods were used to test for the existence or non-existence of unit roots in the variables used in estimating the Irish potato price volatility model and the results of the tests are as presented in Table 4.3.

Table 4.3. Unit Root Tests for Irish Potato Mean Prices (Ksh/Tone), Value of production (Milln. Ksh) and Sales (Metric tones)

Series	Level series		First differences			I (d)
	ADF	PP	Lags	ADF	PP	
Dependent variable						
Real price (Ksh/tone)	-2 .416	-2 .416	1	-6.236 [c]	-7.574[c]	I (1)
Independent variables						
Value of prodn. (Milln.Ksh)	-2.538	-2. 538	1	-4.521 [c]	-5.613 [c]	I (1)
Sales (Metric tones)	-2.574	-2.574	1	-5.487 [c]	-4.569 [c]	I (1)
5% Critical values	-2.60	-2.60		-3.50	-3.50	

Note: [c] Denotes rejection of the null hypothesis of a unit root at 5 percent level of significance (MacKinnon, 1991).

Source: Author's Computations

The null hypothesis of nonstationaity or unit root is accepted if the absolute values of the computed ADF and PP statistics exceed the absolute critical values at 5 percent level of significance. The ADF and PP test critical values at 5 percent level of significance are given as -2.6 and -3.5 (Gujarati, 2005) at the level and first difference series (Table 4.3). As can be seen from Table 4.3 the absolute value of the computed test statistic for the real Irish potato price was -2.416 for the level series. In the first difference of the price series the ADF and PP statistics were calculated as -6.236 and -7.574 respectively (Table 4.3). The absolute value of the computed test statistic for the real price level series |-2.416| is less than the critical absolute value |-2.6 | at 5 percent level of significance in both the ADF and PP test. However, the absolute values of the computed test statistics for the real price first difference series (| -6.236| and |-7.574|) are greater than the critical absolute value |-3.50| at 5 percent level of significance in both the ADF and PP test.

These results reveal that the price series are nonstationary and are integrated of order one, that is, they are **I** (1). When similar comparisons of the computed and the given ADF and PP test statistics

are done for value of production and sales data series, the results show that these series are also nonstationary (Table 4.2). From the results of the unit root tests, the conclusion is that the data series used in the volatility model in this study are **I** (1) in the level series and the first differences series are **I** (0).

The nonstationarity of the level series of the real Irish potato prices, value of production and sales imply that the means and variances of these variables change over time. These nonstationary variables can separate from each other over time and lose their relationship. Regressions carried out on nonstationary variables often yield false results implying that the estimates are invalid and have no economic value meaning; hence the need to test for unit roots to determine the right choice of model to apply (Gujarati, 2005). Hence given that the level series are **I** (1) and the first difference are **I** (0), justifies the use the ARCH-M econometric model which is used to model varying mean and variance, in the evaluation of Irish potato price volatility in this study.

4.4. Structural Break Test Results

A regression using the entire period assumes there is no difference between the two time periods and therefore estimates the relationship between Irish potato real prices and time, value of production, sales, season, and lagged real price for the entire time period consisting of 240 observations. This implies that, this regression assumes that the intercept as well as the slope coefficient remains the same over the entire period; that is there is no structural break.

Regressions using the pre-reform and post-reform periods assume that the two periods are different; that is the intercept and the slope coefficients are different. This assumes the presence of a structural break occurring at the onset of the reforms. We apply the Chow test to ascertain whether there is a structural break and hence the same regression model would not apply to both pre-reform and post-reform periods. The null hypothesis is that there is no structural change and the alternative hypothesis is that there is a structural change occurring at the onset of market policies.

Thus using the Chow test, the calculated F is 0.380 while the critical F is 2.21 at 5 percent level of significance (Gujarati, 2005).The computed F value does not exceed the critical F value at 5 percent level of significance. Therefore we fail to reject the null hypothesis of no structural change. The conclusion is that there is no structural change in the relationship between the mean Irish potato monthly wholesale prices and the time trend, sales, value of production and season. The values of the parameter of the model remain the same throughout the entire twenty year period. Therefore using the data for entire period to estimate volatility of the Irish potato mean monthly wholesale prices is justified.

4.5. Factors Influencing Irish Potato Prices

In Table 4.4 the autoregressive conditional heteroscedasticity in mean regression estimates for the mean equation are presented.

Table 4.4. Autoregressive Conditional Heteroscedasticity in Mean Estimates of Mean Irish Potato Prices

Dependent Variable: Monthly Mean Irish Potato Prices (Ksh/Tone) from January 1986-December 2005(P_t)

Independent variable	Estimation coefficient	Standard error	ρ
Constant ($_0$)	-122.71	93.11	0.19
Lagged Price (P_{t-1})	0.96[a]	0.01	0.00
Value of production (PR)	-0.01[a]	0.00	0.00
Time (T)	4.15 [a]	0.67	0.00
Reforms(R)	164.31[b]	65.93	0.01
Season (SD)	-186.21[a]	33.68	0.00
Sales (S)	-3.91	1.75	0.32
Risk term (¤)	-0.00005[a]	7.60e-06	0.00
n	240		
AIC	3933.04		
BIC	3964.36		
Durbin Watson d statistic	1.71		

Notes: [a] Significance at 1percent level, [b] significance at 5 percent level while n, AIC, BIC denotes the number of observations, Akaike Information Criterion and Bayesian Criterion.

Source: Author's Computations

The lagged price of Irish potatoes (P_{t-1}) coefficient is positive and significant at 1 percent level of significance (Table 4.4). This implies that the lagged price of Irish potatoes (P_{t-1}) has a positive and significant influence on price at the 1 percent level of significance. The positive and significant Irish potato lagged price coefficient indicates that the lagged price is a significant factor that influences the mean price. Thus, the current mean price at any one given time period highly depends on the price in the preceding period. This finding shows that the preceding period price contributes 96 per cent in the prediction of the prevailing price at any given time.

The value of production (PR) of Irish potatoes coefficient is negative and significant at 1 percent level of significance (Table 4.4). This result reveals that the value of production of Irish potatoes has a negative and significant effect on prices at 1 percent level of significance. This finding indicates that a 1 percent increase in value of production leads to a 0.01 percent reduction in Irish potato price. Thus low equilibrium prices clear the market when production is high and high prices clear the market when production is low. Economically, the implication is that Nyandarua Irish potato farmers receive low prices during peak production periods. In order to stabilize the prices received between the glut and scarcity periods there is need to have strategies to manage Irish potato supplies to the market to reduce the demand and supply disequilibrium. This will enable the farmers realize more stable incomes from their Irish potato enterprises.

The reforms (R) coefficient is positive and significant at 5 percent level of significance (Table 4.4). This result reveals that the reforms had a positive and significant effect on prices at 5 percent level of significance. A positive and significant coefficient for the market reforms dummy variable (R), imply a higher mean price during the reforms period. This finding indicates that the implementation of market reform policies leads to a 164 percent increase in the mean Irish potato price. This result confirms the preliminary indication from descriptive statistics that during the reforms period there was a rise in the mean real Irish potato prices.

The season coefficient (SD) was negative and significant at the 1 percent level (Table 4.4). This indicates that mean Irish potato prices are depressed during the harvesting season. The mean Irish potato prices are low during the harvesting months of January, May, June, August, September, November and December. The large season coefficient of -186 indicates that the mean Irish potato

prices are highly dependent on the season. The major factor influencing Irish potato prices in Nyandarua district is the season. This occurs because Irish potato supply follows the seasons while the demand is inelastic. Thus during the harvesting months the supply is high leading to lowering of prices while in the other periods the supply is low leading to price increase because few farmers store their Irish potatoes.

The sales volume (S) has the expected negative sign but is insignificant in determining the mean monthly Irish potato price in Nyahururu market (Table 4.4). A negative sign of the sales volume is an implication that an increase in supply results in a decrease in price. From Table 4.4, it can be observed that I percent increase in the Irish potato sales volume lead to a 4 percent reduction in the mean price. The sales volume is insignificant in determining the mean price because of the fact that most of the Irish potatoes produced in Nyandarua district are collected from the farm gate by traders and marketed through major towns such as Nairobi, Murang'a, Machakos, Nakuru, Nyeri and Mombasa. The reason for this is because Nyahururu market is not easily accessible from most parts of the district due to poor infrastructure and is also not centrally located but is situated at the Northern end of the district neighboring Laikipia district as shown in the map of the district (Figure 3.1). The market is also limited in space and lacks in modern infrastructure facilities like storage.

The risk term denoted as ¤ estimates the relative risk premia (Table 4.4). The ¤ estimate reflects a risk premium with respect to the conditional standard deviation. As expected *apriori*, the estimation coefficient of the risk term (¤) is negative and significant at 1 percent level of significance (Table 4.4). A negative and significant risk term (¤)coefficient means that the mark up for an existing Irish potato firm to cover price risks decreased as a result of reforms. The reforms lead to a decline of

investments and market involvement costs for the traders. A negative risk premia found in this study implies that the cost of carrying out Irish potato business declined during the post reforms period in comparison with the pre reforms period.

4.6. Conditional Variance of Irish Potato Prices

The Table 4.5 presents the results of the econometric model estimates for the Irish potato price variance, which represents price volatility.

Table 4.5. Autoregressive Conditional Heteroscedasticity in Mean Estimates of the Irish Potato Price Volatility

Dependent Variable: Conditional Variance (h_t)

Independent variable	Estimation coefficient	Standard error	ρ
Constant ($\sim_0$)	374.14[a]	80.07	0.00
Lagged Price (P_{t-1})	0.91[a]	0.01	0.00
Value of production (PR)	-0.01[a]	0.001	0.00
Time (T)	3.62[a]	0.581	0.00
Reforms(R)	-241.55[a]	63.18	0.00
Season (SD)	-165.09[a]	36.59	0.00
Sales (S)	-2.88	2.05	0. 61
ARCH term (a_1)	3.31[a]	0.40	0.00
n	240		
AIC	3910.21		
BIC	3945.01		
Durbin Watson statistic	1.81		

Notes: [a] significance at 1percent level while n, AIC, BIC denotes the number of observations, Akaike Information Criterion and Bayesian Criterion.

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Source: Author's Computation

The coefficient of the lagged Irish potato price (P_{t-1}) is positive and significant at 1 percent level (Table 4.5). This result reveals that the lagged Irish potato price (P_{t-1}) positively and significantly influenced the conditional variance (h_t) of Irish potato prices at 1 percent level. A 1 percent increase in lagged price results to a 0.91 percent rise in Irish potato price volatility. This implies that the volatility of Irish potato prices in one given month is related to the prices prevailing in the preceding period.

The positive and significant lagged Irish potato price coefficient implies that the price volatility show a high level of autoregression. This means that the mean Irish potato price in the current month depends, among other things, on the mean Irish potato price of the previous month. This occurs due to market conditions which are slow in creating supply and demand equilibrium. It is therefore necessary to improve the Irish potato markets to make them more responsive in correcting supply and demand equilibrium with the view of reducing the level of price volatility.

The coefficient of market reforms (R) is negative and significant at 1 percent level of significance (Table 4.5). According to this result, the market reforms negatively and significantly influenced the conditional variance (h_t) of Irish potato prices at 1 percent level. This means that the mean Irish potato wholesale prices indicated lower volatility during the reforms period. Therefore, the implementation of the market reform policies by the government resulted to a 241 percent reduction in Irish potato price volatility.

The implementation of market reform policies by the Kenya government thus lead to a stabilization of Irish potato prices in Nyandarua district. Subsequently, the second hypothesis set out in chapter 1

of this study is therefore rejected; that is reforms have no effect on Irish potato price volatility. The conclusion is that, reforms lead to a decrease in Irish potato price volatility in Nyandarua district. Indeed, the results portray the volatility of Irish potato prices tend to continue over an extended period as shown by the positive and significant lagged variance ARCH term (a_1) at 1 percent level of significance.

The lower Irish potato price volatility during the reforms period implies that the reforms lead to an improvement of household welfare for the Irish potato farmers through stable incomes. The implication is that with the implementation of market policy reforms, producers required less compensation for bearing Irish potato production risk induced by price volatility. Subsequently, reduced price volatility during the market reforms period served as an incentive for the farmers to increase Irish potato production.

The coefficient of the seasonal dummy (SD) is negative and significant at 1 percent level of significance (Table 4.5). This result reveals that seasonality of Irish potato production negatively and significantly influenced the conditional variance (h_t) of Irish potato prices at 1 percent level. The economic implication is that the Irish potato price volatility declined by 165 percent during the harvesting season when the rainfall levels are low. This indicates that seasonality of Irish potato production is a key factor influencing price volatility.

The volatility of Irish potato prices is thus weather related with the volatility of prices declining during the main harvesting period when prices are low. This is an indication that Nyandarua district Irish potato farmers rarely store their produce after harvest for the purposes of selling during the

short supply season. With these results the first hypothesis set out in this study is rejected, that is there is no relationship between Irish potato price volatility and the season. This leads to the conclusion that seasonality affects the Irish potato price volatility, with the level of volatility becoming low during the harvesting season. Further, it implies that there is poor market information dissemination between Nyahururu market and other Irish potato urban and rural markets.

If there was good market information flow between Nyahururu market and other markets, the observed price volatility could not have occurred due to efficient price transmission mechanism. This would be so in view of the fact that Irish potato production patterns vary between various producing regions within the country. Therefore an Irish potato regulation system needs to be put in place in order to reduce the Irish potato price volatility in Nyandarua district. This would be to the benefit of producers, traders and ultimately the consumers as it would enable them manage the risk associated with price volatility.

The sales volume (S) coefficient was negative and insignificant in the conditional variance equation model (Table 4.5). This implies that the Irish potato sales volume in Nyahururu market did not significantly affect the price volatility in Nyandarua district. The explanation for this insignificant effect of sales volume on price volatility is the fact that Nyahururu market handles only a limited quantity of the Irish potatoes produced in Nyandarua district since most of the potatoes are sold at the farm level to wholesale traders who deliver the produce to markets for sale in rural and urban market outlets outside the district.

The coefficient of value of production (PR) is negative and significant at 1 percent level (Table 4.5). This result reveals that value of production negatively and significantly influenced the conditional variance (h_t) of Irish potato prices at 1 percent level. This implies that Irish potato value of production significantly influences price volatility with a 1 percent increase in value of production leading to a 0.01 reduction in Irish potato price volatility. This occurs because an increase in production leads to an improvement of supply and demand equilibrium thereby stabilizing the prices. The implication here is that Irish potato producers receive relatively stable prices and consequently incomes during the period when production is high. Conversely, the farmers receive relatively unstable prices and hence incomes during the period when production is low.

4.7. Chapter Summary

This chapter reports on the descriptive statistics of estimates of the mean and the variability of the Irish potato prices, value of production, sales and lagged prices in Nyandarua district during the pre and post reforms periods. For each of the variables, a twenty year time series trend is constructed and discussed. Then, the diagnostic test to confirm model adequacy is performed. This is followed by a report on the two-equation ARCH-M model estimation of the conditional means and variances of the monthly real Irish potato prices over a twenty year period.

The first equation ARCH-M estimation coefficients show how Irish potato lagged price, value of production, time, reforms, season and sales influence the mean wholesale real prices over the post reforms era. This equation also estimates the risk premia which represents a mark up to cater for Irish potato price risk during the post reforms period. Lastly, the second ARCH-M estimation

coefficients which represent the Irish potato price variance or volatility are reported. From the findings in this chapter, the conclusion is that the implementations of market reform policies lead to a realization of high and less volatile Irish potato prices in Nyandarua district. The next chapter presents the main conclusions and policy recommendations drawn from the results reported in the current chapter.

CHAPTER 5

CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1. Introduction

The purpose of this study was to examine the effects of the implementation of market reform policies by the Kenyan government from the early 1990's on Irish potato price volatility in Nyandarua district. The reform policies were designed to reduce or eliminate the bias against agriculture and open the sector to market forces. The study had two specific objectives. The first one was to evaluate the trends in Irish potato prices in Nyandarua district while the second was to assess the effects of market policy reforms on Irish potato price volatility in the district.

In order to evaluate the trends in Irish potato prices, descriptive statistics comprising of the mean and the coefficient of variation were computed. The results of the descriptive statistics were compared for the pre reform and post reform periods. The period 1986-1995 and 1996-2005 represented the pre reform and post reform periods respectively. The effects of reforms on Irish potato price volatility in Nyandarua district were assessed by estimating an autoregressive conditional heteroscedasticity in mean model for the monthly real Irish potato prices from Nyahururu market over a twenty year period. The results were then compared for the periods before and after the market policy reforms.

5.2. Summary of Major Conclusions

The results from the descriptive statistics show that the mean monthly wholesale Irish potato price in Nyandarua district increased after the implementation of market policy reforms. In the same

period, the variability of the mean wholesale Irish potato price declined. The increase in the mean monthly wholesale Irish potato price coupled with a decrease in the price variability imply that Nyandarua district farmers received higher and stable incomes from their Irish potato sales during the post reforms period as compared with the pre reforms period.

The mean monthly Irish potato value of production increased while the variability of value of production declined during the post reforms period. This was as a result of high and less variable prices which served as an incentive for the farmers to increase production. The economic implication is that the increase in Irish potato value of production during the post market reforms period had a positive effect on producer prices leading to the farmers' realization of high and stable incomes from their Irish potato enterprises. A reduction in variability of value of production occurred as a result of stable Irish potato prices as indicated by a reduction of the coefficient of variation (CV) of the prices during the reforms period. The implementations of the reforms lead to an increase in Irish potato value of production of 76.62 Million Ksh. from the pre market policy reforms period to the post market reforms period and an 8 percent reduction in price variability.

The mean monthly Irish potato sales volumes were higher by 57 percent during the post reforms period as compared to the pre reforms period. The increase in the sales volume during the post liberalization period was due to an increase in supply as a result of increased production to meet the shortfall in demand. On the other hand, variability in the sales volume reduced during the post reforms period in comparison with the pre reforms period. The lowering of variability in sales volumes was due to more stable supply and demand conditions during the post reforms era as a result of boost in production thus reducing the supply and demand disequilibrium.

The trend of the Irish potato sales volumes show that a relatively high supply is realized during the main harvesting months. In addition, this trend indicates that the produce is sold throughout the year with monthly variability in sales volumes depending on supply. Since this food crop has a relatively stable demand in the domestic market, the monthly variability in supply lead to price volatility due to supply and demand disequilibrium.

To surmise, the results from the descriptive statistics show that Irish potato prices, value of production and sales increased by 494 percent, 18 percent and 57 percent respectively in the post reforms period. On the other hand, the variability of the prices, value of production and sales decreased by 14 percent, 8 percent and 7 percent respectively during the post market reforms period. This implies that the Irish potato farmers realized higher and stable incomes from their Irish potato enterprises during the post reforms era. Therefore the implementations of market reform policies made the Irish potato farmers in Nyandarua district better off than they were before these reforms.

The results of the econometric model estimates of the mean equation indicate that the lagged price and the market reforms dummy were positive and significant at 1 percent level while value of production, seasonal dummy and the risk premia were negative and significant at 1 percent level. However, the sales volume was negative and not significant. This implies that the lagged price, implementation of market reforms, value of production and seasonality were significant in determining the Irish potato mean price while the sales volumes did not significantly influence the mean price.

The lagged price variable had the expected positive sign in the mean equation model implying that the Irish potato price in the current period is highly dependent on the price in the previous period. Thus the price this season determines the quantity to be produced in the next season since farmers respond to previous price in making their production decisions. In effect, at any point in time the farmers' expectation of the future price is a function of past realizations. Also, the market reforms dummy had a positive sign as expected indicating that market reforms lead to higher mean Irish potato prices as a result of increased demand arising out of increase in population, urbanization and change of tastes and preferences in favor of Irish potato consumption. The empirical evidence suggests that the Irish potato mean price increased by 164 percent due to the implementation of market policy reforms.

The Irish potato value of production had the expected negative sign indicating that increase in production led to a rise in supply leading to a price decline. The results show that a 1 percent increase in value of production is associated with a 0.01 percent reduction in the mean Irish potato price. This occurs because Irish potato demand is relatively stable and thus an increase in supply leads to price decline when the supply exceeds the demand. As expected, the risk premia had a negative sign implying that market reforms led to a decline in the cost of carrying out Irish potato business. The implementation market reform policies lead to a reduction of the cost of transacting Irish potato business by 10^{-5}. Thus, the Irish potato traders were better off with the implementation of the market reforms policies than before.

The sales volume in Nyahururu market had the expected negative sign but had no significant effect in the determination of the mean Irish potato price. This was the case because the market handles

only a small proportion of the Irish potatoes produced in Nyandarua district due to its limited space and non-strategic location**.** A big proportion of Irish potatoes produced in Nyandarua district is traded in markets outside the district after it is sold to the transporters by the farmers at the farm gate level.

On the other hand, the econometric model estimates of the conditional variance equation show that the lagged price was positive and significant at 1 percent level while value of production, the seasonal and market reforms dummies were negative and significant. Nevertheless, the sales volume was positive and not significant. The lagged price had the expected positive sign showing that the Irish potato price volatility in a given month is related to the prices in the previous period. A negative coefficient in the value of production variable as expected implies that an increase in value of production led to a reduction of Irish potato price volatility. Thus Irish potato producers realized more stable prices and therefore incomes when value of production increased during the post market reforms period as compared to the period before these reforms.

The seasonal dummy variable had the expected negative sign in the conditional variance equation model indicating that seasonality of Irish potato production influences the price volatility with the volatility declining during the harvesting period when prices are depressed. These Irish potato prices decline in the harvesting season due to distress sales by the producers to meet their cash liquidity needs, lack of appropriate storage facilities and poor market arbitrage between Nyahururu and other urban and rural markets.

The sales volume had the expected positive sign but was not significant in the conditional variance equation model implying that the Irish potato sales volume did not significantly affect the price volatility. This was the scenario because Nyahururu market handles only a limited quantity of the Irish potatoes produced in Nyandarua district since most of it is marketed through other rural and urban market outlets outside the district.

The market reforms dummy was significant and had the expected negative sign in the conditional variance econometric model. The economic implication of this is that the market policy reforms implemented by the Kenyan government led to a decline in Irish potato price volatility. The hypothesis tested in this study, that market reforms had no effect on Irish potato price volatility is therefore rejected. Thus the implementation of agricultural market policy reforms was favorable to the Irish potato producers.

There are five conclusions that can be drawn from this study. First, the mean Irish potato price at any one given month is dependent on the previous month price. Therefore the farmers, traders, processors and consumers can use the expected prices for decision making in their operations. Secondly, the mean prices are negatively correlated with value of production. This result implies that the Irish potato farmers receive low prices when the production is high. Thus, for the farmers to realize stable prices and hence incomes strategies to manage Irish potato supplies to the market are needed.

Thirdly, the Irish potato monthly real prices were high after the reforms. The increase in the mean price was as a result of the slow growth in supply as compared to the increase in demand. The

supply increased as a result of increased production while the demand rose due to increase in population, rapid urbanization and change in tastes and preferences. Fourth, the mean Irish potato prices are depressed during the harvesting months when supply is much higher than the demand. This occurs since there is low on-farm and off-farm storage because liquidity constraints force the farmers to sell most of their produce after harvest. Lastly, the risk premia is found to be negative thus implying that the cost of doing Irish potato business decreased after the reforms.

In addition, three conclusions can be drawn from the autoregressive econometric model estimates of the real Irish potato price variance. Firstly, the mean Irish potato prices indicated lower volatility during the reforms period. Indeed, reforms lead to a decrease in Irish potato price volatility as a result of increased production thus bridging the gap between production and demand. The lower price volatility served as an incentive for the Irish potato farmers to increase production during the reforms period.

Secondly, the seasonality of Irish potato production is found to be a key factor influencing the volatility of the mean price. The Irish potato price volatility is weather dependent, with the volatility decreasing during the harvesting months when the rainfall is low. An Irish potato regulation mechanism therefore needs to be put in place in order for the traders, producers and consumers to be able to manage the risk associated with high price volatility.

Lastly, the Irish potato value of production is found to significantly influence the price volatility. An increase in production results to a reduction of price volatility because of the improvement in supply and demand equilibrium. The implication is that an increase in value of production lead to a

reduction in uncertainty and risk associated with price volatility. The farmers therefore realized more stable incomes with an increase in value of production.

The Irish potato price volatility is found to decline during the period when value of production is high. In order to reduce high price volatility there is need to have a sustained increase in value of production to meet the increase in demand. The value of production can be increased through the farmers' adoption of appropriate technical innovations from research that lead to increased output per unit area. This can be realized through increased investment by the government and the private sector in research and extension activities. An increased adoption of relevant technological innovations would lead to a rise in the average yield from the current level of 7.5 tons per hectare. This increase in yields would ultimately translate into a rise in national output to meet the nation demand of 1.2 million metric tons per year and export needs. Another way of increasing Irish potato value of production is through expansion of the area under the crop by opening up of new land or by replacing other less profitable farm enterprises with Irish potatoes.

5.3. Policy Recommendations

This study found that price volatility in the Irish potato sector is as a result of factors having effects on supply and demand. Since the demand of Irish potatoes is relatively inelastic, the price volatility can mainly be stabilized by controlling the supply to the market through storage during periods of glut. At the farm level the farmers can achieve this by enhancing on-farm storage through use of improved storage structures to prevent post harvest losses. At the market level, the supply can be controlled through cold storage that needs to be built by the Local Government. This calls for

improvement in the market infrastructure through provision of adequate storage space and installation of cold stores in the Irish potato markets.

The variability in value of production was found to be a major contributor to Irish potato price volatility. This is because production follows the natural rainfall pattern. Further, the results indicate that Irish potato price volatility declined during the reforms period. This implies that during the reforms era the farmers realized stable incomes which can stimulate production. The variability in value of production which affects supply of Irish potatoes to the market can be controlled through improvement in production by utilization of irrigation techniques, since with high value of production the volatility was observed to decline. Further, if the production is increased it will be possible to meet the national demand and with storage the supply to the market can be controlled between the glut and scarcity periods thus leading to price stability.

Another result is that seasonality influences price volatility, with the volatility decreasing during the harvesting months. This affects the farmers' decision making since they are uncertain of the price to expect in the forthcoming period. To reduce this uncertainty Irish potato virtual commodity exchange markets need to be improved. By use of the exchange markets producers and traders will be brought together thereby ensuring efficient price information transmission to all the market participants thus reducing uncertainty in prices.

Overall, this study indicates that the implementation of market reform policies favored the Irish potato producers but made the consumers worse off. Thus market reform policies need to be considered together with complimentary measures to cushion consumers from price shocks. To

achieve this, the Kenyan government and other stakeholders in the Irish potato sub sector need to institute measures to improve production, storage and marketing.

5.4. Contribution of this Study

This study utilizes the autoregressive conditional heteroscedasticity in mean econometric model to analyze the effects of reforms on the mean and volatility of agricultural commodity prices, which can be applied for price volatility analysis in other crops and countries. The empirical contribution of the current study is that it provides robust estimates of the mean and volatility of Irish potato prices both before and after the implementation of the market reform policies in Kenya that are useful for policy analysts.

This is the first study in Kenya that assesses the effects of market policy reforms on Irish potato price volatility. Further, the study is the first of its kind to employ recent developments in time series econometrics analysis and specifically the autoregressive conditional heteroscedasticity in mean model to analyze price volatility in the Irish potato sector in Kenya. The most important finding from the descriptive statistics is that the implementation of the market reform policies provided the Irish potato producers with higher and stable prices and thus incomes. The regression results indicate that the implementation of market policy reforms lead to a decrease in the Irish potato price volatility. This suggests that the reforms lead to a reduced price risk for Nyandarua Irish potato farmers.

Overall, the empirical results from the descriptive statistics and regression analysis show that the implementation of market policy reforms was associated with a higher price level and lower price volatility for the Irish potato farmers in Nyandarua district. This suggests that the implementation of market policy reforms led to higher prices and a reduction in price volatility for Nyandarua Irish potato growers. Therefore, these reforms left the Irish potato producers better off and this served as an incentive for the farmers to increase production. In conclusion, the market policy reforms were successful in accomplishing their goals and benefited the Irish potato growers.

5.5. Direction for Future Research

The body of knowledge in the Irish potato sector can be improved by understanding the effects of market policy reforms on both producers and consumers. This study analyzed the effects of market policy reforms on producer price level and volatility. There still remains an empirical gap on what effects the implementation of these policy reforms had on retail price level and volatility. Given that developing countries like Kenya are faced with the dual challenge of providing stimulative prices to producers and affordable food prices to the consumers, future studies should evaluate the effects of agricultural policy reforms on the level and volatility of agricultural commodity prices to both producers and consumers. The results from such studies will better inform on the appropriate policy options for the Kenyan agricultural sector.

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APPENDIX

Appendix 1: Correlation Matrix for the Explanatory Variables

	Time	Value of production	Season	Reforms	Lagged Price	Sales
Time	1.00					
Value of production	0.13	1.00				
Season	0.02	0.07	1.00			
Reforms	-0.78	-0.12	-0.01	1.00		
Lagged Price	0.79	0.08	0.01	-0.75	1.00	
Sales	0.21	0.21	0.03	-0.37	0.24	1.00

Source: Author's computation.

Appendix 2: Irish Potato Area (Ha) and production (Tones) for the Main Producing Districts in Kenya (1986-2005)

Year	Nyandarua		Narok		Nyeri		Molo		Meru	
	Area	Prod	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.
1986	12,690	191,760	1,855	60,561	106,092	106,092	8,217	82,170	11,625	107,462
1987	12843	194072	3,000	190,034	106,092	106,092	10,372	107,320	408	4,600
1988	13,000	186,000	2,980	131,150	106,092	106,092	40,396	155,940	14,440	96,240
1989	12,000	156,000	4,300	53,480	106,092	106,092	4,430	35,440	10,260	129,276
1990	11,520	115,200	5,500	108,336	106,092	106,092	5,663	50,967	17,143	143,778
1991	11,800	154,440	4,000	783,900	106,092	106,092	4150	37350	16,075	144,975
1992	1,050	121,550	4,200	623,524	106,092	106,092	4,313	37,955	7840	6272
1993	12,077	99,770	2,500	79,847	106,092	106,092	5,940	48,320	9,921	80,290
1994	12,821	160,263	2815	89907	106,092	106,092	6120	49784	15,072	150,720
1995	15,128	184,850	2287	19,058	106,092	106,092	5487	69505	16,069	160,890
1996	15,093	156,510	2100	26,460	106,092	106,092	7,001	88,684	639	5692
1997	15,139	223,149	3,000	82,342	106,092	106,092	7,843	62,117	861	7,671
1998	13278	195718	2,700	22,710	106,092	106,092	7,864	60,195	760	3,570
1999	14,840	148,400	2,650	92,235	106,092	106,092	10,770	71,028	657	5853
2000	10,160	92,538	3,144	35,050	106,092	106,092	7,845	43,750	19,910	134,340
2001	12,400	925,382	3,620	44,093	106,092	106,092	11,453	93,922	15,730	143,840
2002	13,140	925,382	6,500	42,120	106,092	106,092	10,030	88,500	16,574	151557
2003	14,120	925,382	7,250	46,980	106,092	106,092	12,390	108,250	20,050	190,800
2004	18,000	925,382	9,000	78,840	106,092	106,092	12,310	105,264	19,850	148,550
2005	13,000	925,382	7,569	49,047	106,092	106,092	14,894	125,426	20,150	148,550

Source: Ministry of Agriculture Statistics, 2008

Appendix 3: Average Monthly Rainfall (Mm) for Nyandarua District (1986-2005)

Year	Month											
	January	February	March	April	May	June	July	August	Sept.	October	Nov.	December
1986	48.1	26.7	103.1	230.8	160.6	47.9	18.3	24.3	20.7	286.4	280	170
1987	154	120.7	192.8	261.6	226	153.5	85.4	70.8	189.7	103.8	407.3	52.7
1988	199.8	73.1	281.1	810.2	181.8	43	155.8	126.5	90	65.8	53.3	80.9
1989	137.6	54.5	89.4	189.5	144.6	87.9	80.8	54.7	137.1	114	105.8	84.7
1990	85.2	47.1	172.2	306.9	156.9	44.4	35.3	39.5	55.5	92.9	98.2	75.4
1991	15.3	10.8	116.5	131.9	220.7	63.1	23.4	60.6	51.1	95.4	59.7	53.2
1992	0	86.3	20.5	269	270.8	105	57.8	47.2	40.2	116	85.5	148.1
1993	127.4	109.1	63.2	55	173.2	110.2	12.1	87.9	50.6	48.5	108.2	52.8
1994	25.8	135.9	173.6	246.1	206	170.2	47.5	27.7	64.5	69.9	218.5	11.7
1995	0	52.9	168	53.6	251.5	91.2	46.5	41.4	47.2	192.7	70.3	74.7
1996	37.7	138.2	140	118.2	132	0	39.2	108.4	52.2	18.9	92	84.6
1997	88.2	0	74	393	79.6	58.6	47	102.8	6.6	244.6	276.6	214.8
1998	79.8	156	67.6	189.3	215.3	31.5	27.8	27.8	51.3	59.5	96.7	13.2
1999	47.2	2.1	170.2	188.1	80.4	30.3	19.7	54.4	101	41.5	167	81.3
2000	0	19.8	46.5	76.9	87.7	21.4	55.3	12.5	48.9	51.2	149.2	90.9
2001	212	34.7	98.8	393	840	21.2	57.3	48.1	43.7	76.6	85.6	14.2
2002	106.3	12.4	171	138.7	202.4	62.8	47.8	23.1	16.7	114.3	188.7	208.5
2003	41	12.8	50.5	302.2	383.3	72.5	38.1	139.2	51.1	118.3	94.4	40.7
2004	103	139.5	77	235.1	148	9.9	21	51.2	100.5	128.5	181.6	91.2
2005	82.9	32.4	141.7	95.5	187.8	61.7	43	50.9	53.2	36.6	71.1	14.2

Source: Ministry of Agriculture, Nyandarua District, 2008

Appendix 4: Monthly Irish Potato production (Tones) for Nyandarua District (1986-2005)

	January	February	March	April	May	June	July	August	Sept	October	Nov.	Dec.
1986	10766	12784	10496	7335	18840	14264	24492	15206	14668	19647	22877	20185
1987	7302	4960	7173	3944	14628	18587	21812	17022	16846	23465	7397	12126
1988	8035	4274	5472	9915	15215	23933	22908	16583	18463	25985	24960	10257
1989	4251	6402	7368	3513	9187	14615	21277	23648	28523	31703	2038	3475
1990	3139	4728	5441	2594	6784	10793	15712	17464	21064	23412	1503	2566
1991	4208	6338	7294	3478	9095	14469	21064	23412	28238	31386	2018	3440
1992	12177	10332	10727	1337	2368	4692	6570	5695	14895	14667	19964	18126
1993	2746	4178	3850	2925	4357	8983	17130	19488	21368	11162	1820	1763
1994	5908	7170	6108	4647	10224	13477	28215	29011	33858	15070	2855	3720
1995	6176	3069	8126	1884	16684	22644	44962	33803	11484	8993	7042	10618
1996	10584	8985	9328	1145	2055	4074	5710	4949	12945	12754	17360	15762
1997	27388	19205	16366	12692	14205	23046	32064	14205	14362	16199	26887	6530
1998	23429	16400	13902	6873	13589	23742	22180	17181	10934	12965	18119	4376
1999	5906	3692	4430	7383	18458	32486	13290	22149	22149	7383	5906	5168
2000	9261	14961	12253	13535	9831	17383	13538	9118	7978	5557	9689	8976
2001	25185	16425	18615	6163	7528	6844	16425	22585	19163	12319	12592	20806
2002	43259	10383	8651	5191	7786	15574	10382	15575	24225	15573	19034	34607
2003	21830	21528	15716	21829	48389	19646	39292	19209	6112	4306	4365	7858
2004	3810	12124	17112	2148	5057	19606	46209	32076	16281	9630	7967	14618
2005	7061	2118	3530	8476	12145	22595	36717	14122	21183	25419	19488	11297

Source: MoA, 2008

Appendix 5: Market Data Entry Form

MARKET PRICES

Agricultural produce Prices

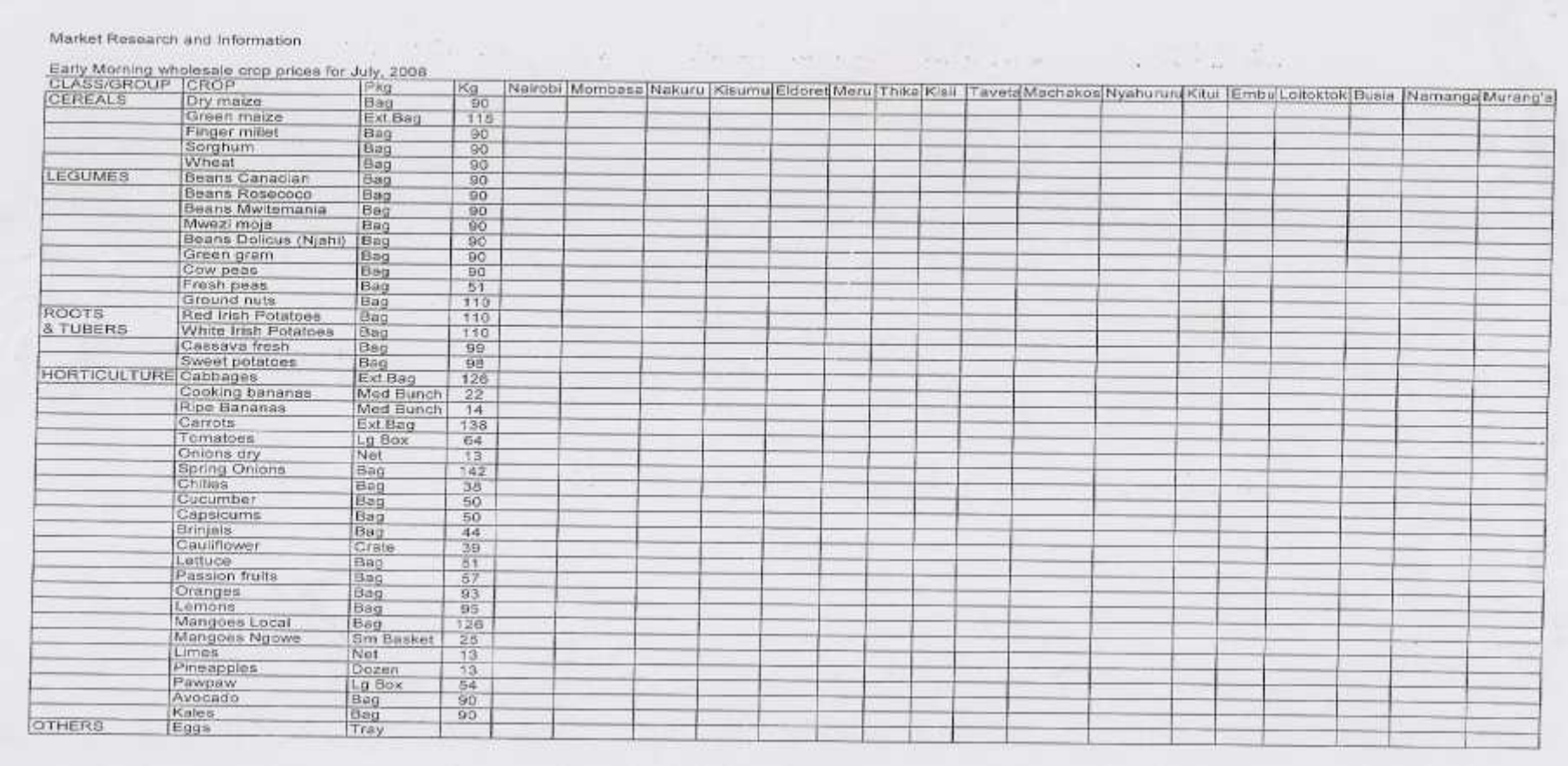
Date:

Market.....

CLASS GROUP	CROP	PACKAGE	KG	CODE	PRICE
CEREALS	Dry maize	Bag	90	20	
	Green maize	Ext.Bag	115	19	
	Finger millet	Bag	90	41	
	Sorghum	Bag	90	42	
	Wheat	Bag	90	48	
LEGUMES	Canadian Wonder	Bag	90	4	
	Rose Coco	Bag	90	5	
	Mwitemania	Bag	90	7	
	Mwezi moja	Bag	90	6	
	Dolicus (Njahi)	Bag	90	35	
	Green grams	Bag	90	46	
	Cow peas	Bag	90	45	
	Fresh peas	Bag	51	27	
	Ground nuts	Bag	110	44	
ROOTS & TUBERS	Red Irish Potatoes	Bag	110	29	
	White Irish Potatoes	Bag	110	30	
	Cassava fresh	Bag	99	43	
	Sweet potatoes	Bag	98	31	
HORTICULTURE	Cabbages	Ext.Bag	126	9	
	Cooking bananas	Med Bunch	22	2	
	Ripe Bananas	Med Bunch	14	3	
	Carrots	Ext.Bag	138	13	
	Tomatoes	Large Box	64	32	
	Onions dry	Net	13	22	
	Spring Onions	Bag	142	23	
	Chillies	Bag	38	11	
	Cucumber	Bag	50	14	
	Capsicums	Bag	50	12	
	Brinjals	Bag	44	8	
	Cauliflower	Crate	39	10	
	Lettuce	Bag	51	17	
	Passion fruits	Bag	57	25	
	Oranges	Bag	93	24	
	Lemons	Bag	95	16	
	Mangoes Local	Bag	126	21	
	Mangoes Ngowe	Small Basket	25	36	
	Limes	Net	13	18	
	Pineapples	Dozen	13	28	
	Pawpaw	Large Box	54	26	
	Avocado	Bag	90	1	
	Kales	Bag	90	15	
OTHERS	Eggs	Tray		47	

Source: MoA, 2008

Appendix 6: National Markets Data Entry Form



Market Research and Information

Early Morning wholesale crop prices for July, 2008

CLASS/GROUP	CROP	Pkg	Kg	Nairobi	Mombasa	Nakuru	Kisumu	Eldoret	Meru	Thika	Kisii	Taveta	Machakos	Nyahururu	Kitui	Embu	Loitoktok	Busia	Namanga	Murang'a
CEREALS	Dry maize	Bag	90																	
	Green maize	Ext Bag	115																	
	Finger millet	Bag	90																	
	Sorghum	Bag	90																	
	Wheat	Bag	90																	
LEGUMES	Beans Canadian	Bag	90																	
	Beans Rosecoco	Bag	90																	
	Beans Mwitemania	Bag	90																	
	Mwezi moja	Bag	90																	
	Beans Dolicus (Njahi)	Bag	90																	
	Green gram	Bag	90																	
	Cow peas	Bag	90																	
	Fresh peas	Bag	51																	
	Ground nuts	Bag	110																	
ROOTS & TUBERS	Red Irish Potatoes	Bag	110																	
	White Irish Potatoes	Bag	110																	
	Cassava fresh	Bag	99																	
	Sweet potatoes	Bag	98																	
HORTICULTURE	Cabbages	Ext Bag	126																	
	Cooking bananas	Med Bunch	22																	
	Ripe Bananas	Med Bunch	14																	
	Carrots	Ext Bag	138																	
	Tomatoes	Lg Box	64																	
	Onions dry	Net	13																	
	Spring Onions	Bag	142																	
	Chillies	Bag	38																	
	Cucumber	Bag	50																	
	Capsicums	Bag	50																	
	Brinjals	Bag	44																	
	Cauliflower	Crate	39																	
	Lettuce	Bag	61																	
	Passion fruits	Bag	57																	
	Oranges	Bag	93																	
	Lemons	Bag	95																	
	Mangoes Local	Bag	126																	
	Mangoes Ngowe	Sm Basket	25																	
	Limes	Net	13																	
	Pineapples	Dozen	13																	
	Pawpaw	Lg Box	54																	
	Avocado	Bag	90																	
	Kales	Bag	90																	
OTHERS	Eggs	Tray																		

Source: MoA, 2008

Appendix 7: Average Monthly Irish Potato Prices (Ksh/110Kg Bag) for Nyahururu Market 1985-2005

	Month											
Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1986	215	130	139	224	245	158	162	124	140	269	165	229
1987	155	130	137	150	155	155	165	153	160	217	291	284
1988	266	306	324	372	403	400	405	333	396	377	382	226
1989	230	150	150	500	240	310	276	158	110	120	130	150
1990	220	250	243	236	316	296	289	273	314	346	389	342
1991	260	246	326	384	470	220	180	210	228	237	281	278
1992	394	399	511	813	658	396	366	384	376	446	603	635
1993	571	415	448	534	603	605	676	668	636	722	965	1115
1994	950	888	1400	1600	1125	450	387	294	516	900	950	900
1995	891	809	725	700	500	500	400	400	462	393	400	490
1996	553	500	730	750	1033	900	600	550	600	1000	1167	900
1997	817	900	1150	2500	2333	1300	550	475	494	725	825	850
1998	1000	1200	1288	1400	1400	1450	1250	1097	960	750	735	925
1999	900	883	900	973	1021	532	418	432	539	894	856	892
2000	557	1246	1089	1104	1515	1556	974	672	463	430	450	648
2001	683	558	442	409	684	626	711	763	700	682	1124	585
2002	1042	1143	1178	1172	1367	1235	897	897	1008	1083	1086	1128
2003	933	919	950	950	1517	1300	1010	956	900	1192	1246	1238
2004	1505	1618	1590	1674	1633	1250	1460	1346	1510	1638	1713	1575
2005	1340	1279	1456	2018	2266	1259	1035	944	953	1135	1525	1665

Source: Ministry of Agriculture Nyandarua District, 2008