An estimation of the aggregate wheat supply function for Zimbabwe

M.Sc. Thesis

Knowledge Gweru

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Agricultural Economics and Rural Policy Group

Wageningen University

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Abstract

Wheat is the second most strategic food crop in Zimbabwe after maize. The main wheat products include wheat flour and wheat bran. Wheat flour is the most used ingredient for making bread and other bakery confectionaries which are now taken mostly by Zimbabweans for everyday consumption. Wheat bran is also used for making stock feeds in the manufacturing sector. Thus, the wheat industry contributes substantially to food security and employment. However, wheat supply has declined over the years. The widening gap between wheat supply and increasing demand led Zimbabwe to rely on wheat imports to meet domestic demand for wheat products. Increased wheat imports have dampened domestic wheat prices, which disincentives local production. This study was conducted to estimate the aggregate wheat supply function for Zimbabwe from 1965 to 2018. The output response function derived from profit-maximising was applied to determine the effect of price and non-price factors on wheat production. All variables were in logarithmic form and were tested for stationarity. The function was estimated using the Nerlovian partial adjustment model. Model results reveal that lagged real prices of wheat, lagged wheat output, lagged rainfall and land reform policy were the major factors significantly affecting wheat output. The results indicate that lagged real price had a positive impact with an elasticity of 0.79 and 1.72 in the short-run and long-run respectively, suggesting that wheat farmers are relatively unresponsive to output prices in the short-run but more responsive in the long run. The results further confirm non-price factors such as lagged wheat output and land reform policy had a negative impact on wheat production, but rainfall from previous season had a positive effect on wheat produced in the next season. The study recommends further research on other important variables which were not captured in this study to draft policy conclusions.

Key words: Aggregate, Wheat supply, Elasticity, Short-run, Long-run.

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May God bless you all

Abbreviations

ADS	Agricultural Diversification Scheme
CPI	Consumer Price Index
FTLR	Fast Track Land Reform
GDP	Gross Domestic Product
GoZ	Government of Zimbabwe
GMB	Grain Marketing Board
IMF	International Monetary Fund
OLS	Ordinary Least Squares
RBZ	Reserve Bank of Zimbabwe
R& D	Research and Development
USDA	United States Department Agricultural
UDI	Unilateral Declaration Independence
ZAIP	Zimbabwe Agriculture Investment Plan
ZESA	Zimbabwe Electricity Supply Authority

Chapter 1: Introduction

Background and problem statement

In the expansion of the Zimbabwean economy agriculture plays a vital role through its impact on overall economic growth, household's income generation and food security (Mlambo and Zitsanza, 1997; Juana and Mabugu, 2005; Toringepi, 2016).

Wheat is progressively becoming a key staple food in Africa due to rapid urbanization and income growth. But the African countries produces only about 30% to 40% of what is required for domestic consumption, leading to heavy reliance on imports and making the African region to be exposed to global market and supply shocks (Negassa et al., 2013).

Although the demand for wheat has grown to about 450,000 metric tonnes per annum (Zvinavashe and Mutambara, 2012), wheat production in Zimbabwe has dramatically declined since 2000. The country's production level fell from 340,000 metric tonnes in 2000 to about 20,000 metric tonnes in 2018 (Index Mundi, 2018). In which case, for the country to meet its annual consumption level, it requires to import 430,000 metric tonnes of wheat. The country has however been unable to meet this target.

Wheat is the second most essential strategic food crop in Zimbabwe after maize (Kapuya et al., 2010, Mutambara et al., 2013). This shows its importance in ensuring that the country has adequate food supply. The increase in demand for wheat products, especially as an important food item in urban areas, makes it imperative to understand the reasons behind the fall in production and factors that determine the aggregate wheat supply in Zimbabwe.

Research Objective and questions

The objective of this study is to estimate the aggregate wheat supply function for Zimbabwe.

Research Questions

1. What are the trends in wheat consumption, acreage and supply levels?

2. Which factors affect wheat supply in Zimbabwe and how large is their effect?

3. How can wheat supply be increased and what is the impact of increased wheat supply?

Organization of thesis

The first chapter introduces and outlines the research objective of the study and provides the research questions. Chapter 2 presents an overview of agriculture in Zimbabwe and describes the wheat sector, wheat consumption, acreage and supply levels. Chapter 3 derives the factors that explain wheat supply and further expresses equations for exogenous variables as well as market price equations for quasi fixed inputs. Chapter 4 discusses the data. Chapter 5 provides the empirical model and discusses its estimation. The estimation results are presented in chapter 6. It also discusses the policy implications. Finally, in chapter 7 conclusions are drawn, caveats of the study identified and areas of further research provided

Chapter 2: Wheat

Introduction

The purpose of this chapter is to give an insight of Zimbabwean agriculture. The first section of the chapter presents an overview of agriculture in Zimbabwe and provides a summary of land use. The second section discusses the wheat sub-sector highlighting the production, and consumption patterns as well as the wheat value chain. Lastly, this chapter concludes by synthesizing police issues emerging from the review provided in the first two sections.

2.1 Overview of Agriculture

Economic growth, household income generation, and food security are mainly determined by the agricultural sector in Zimbabwe (Dzvimbo et al., 2017). This entails that Zimbabwean development is based on agriculture (Maiyaki 2010). More than 70% of the population highly depends on agriculture for a living. The country produces many agricultural products including cereals (maize, wheat, barley, and sorghum), oilseed crops, (groundnut, soya beans and sunflower), cash crops (tobacco, cotton, horticultural crops, and sugar cane) as well as livestock. The agricultural sector provides inputs to the industrial sector which in turn provides inputs and services to the agricultural sector through backward and forward linkages. In addition, the sector contributes approximately 30% to export earnings and finally accounts for about 12.5% of the country's Gross Domestic Product (GDP) (Index Mundi, 2018)

Zimbabwe has a total land area of 39.6 million hectares, and 83.3% of the total land area (33 million ha) is devoted to agriculture whilst the rest is set aside for forests, national parks and urban settlement (Lyons and Khadiagala, 2010; Mushunje and Belete, 2001). The total land area can be categorised into five natural regions based on the land use potential and rainfall patterns (Table 2.1 and Figure 2.1).

Table 1.1: Natural Regions of Zimbabwe and Farming Systems in each Region

Natural Region	Province Spread	Area(million ha) and % of land area	Rainfall (mm per year)	Farming System
I	Manicaland	0.792 (2%)	more than 1 000	Specialised and diversified farming
II	Mashonaland Central, Mashonaland-East, Mashonaland-West, Manicaland, Harare	5.94 (15%)	750-1000	Intensive farming
III	Manicaland, Midlands	7.524 (19%)	650 – 800	Semi-intensive farming
IV	Masvingo, Matebeleland-South, Matebeleland-North, Manicaland, Midlands, Bulawayo	15.048 (38%)	450-650	Semi-extensive farming
V	Masvingo, Matebeleland South, Manicaland, Bulawayo	10.692 (27%)	Less than 450	Extensive farming

Source : Mlambo, 2014

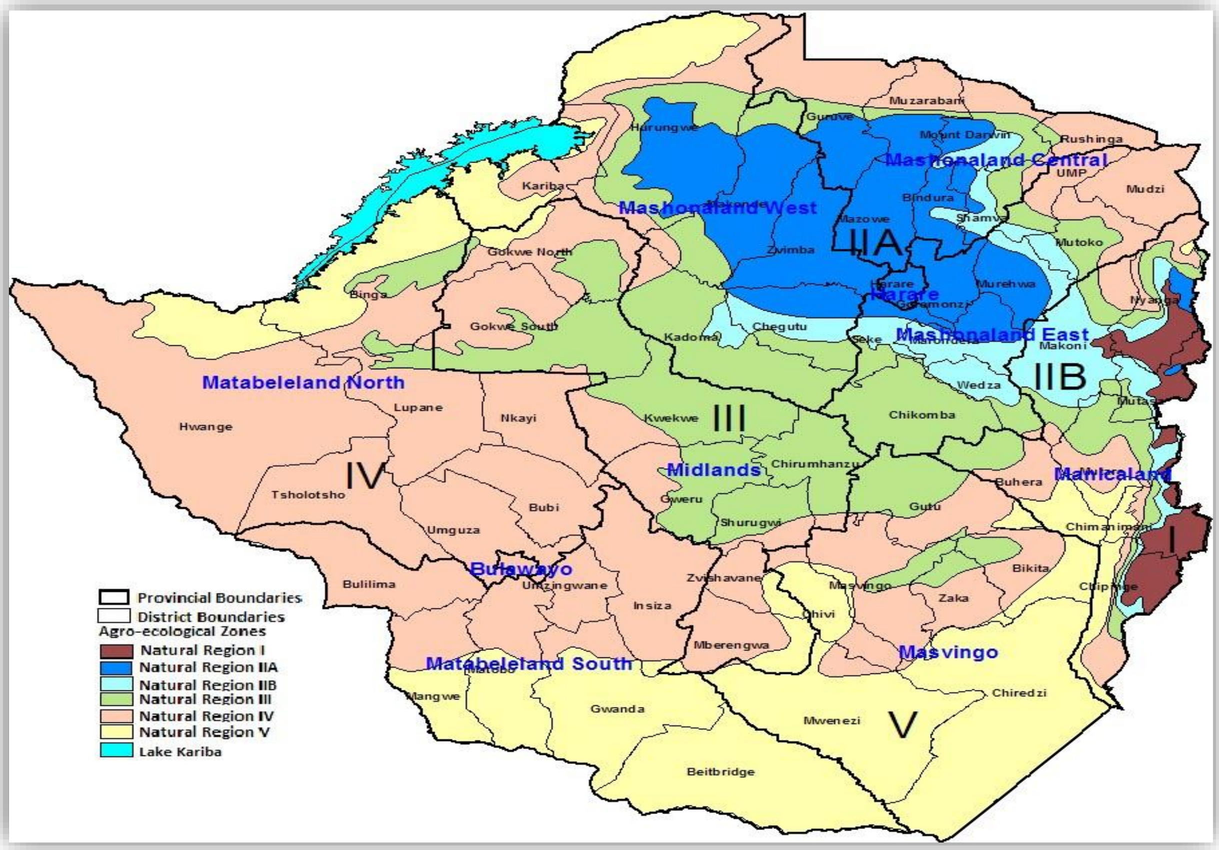


Figure 2.1: Zimbabwe Agro-Ecological Regions. Source: adapted from ZAIP,2017

Figure 2.1 shows five different Agro-Ecological Regions which have also been mentioned in Table 2.1. The figure gives an overview of how different farming systems are distributed around the country.

The country experiences two distinct seasons that is the winter season (May to October) and summer season (November to April). These seasons allow farmers to alternate between summer crop production and winter crop production, which enables them to generate income throughout the year. However, winter production is subject to the availability of irrigation. Except for winter crops (wheat, barley, and horticultural crops), other major crops are grown in summer when effective rains are received for plant development (Mutambara et al., 2013).

The land use is grouped into ten different categories (Table 2.2)

Table 2.2: Land distribution in Zimbabwe

Farmer Cluster	Land Category	Area (Million hectares)	%	Number-of Farmers
Smallholder Farmers	Communal	16.4	41.9	1,100,000
	Old resettlement	3.5	9.0	72,000
	New resettlement A1	4.1	10.5	141,656
Small - Medium Scale Commercial	New resettlement A2	3.5	9	8,000
	Small-scale commercial farms	1.4	3.6	14,072
Large-scale Commercial	Large-scale commercial farms	3.4	8.7	4,317
	State farms	0.7	1.8	
	Urban land	0.3	0.8	
	National parks and forest land	5.1	13.0	
	Unallocated land	0.7	1.8	

Source: (Mlambo 2014)

The land distribution process created new resettlement schemes A1and A2 which were set to promote small scale farms and medium to large farms respectively (Maguranyanga and Moyo, 2006; Moyo, 2011).

2.2 Wheat sub-sector

Wheat is an important cereal crop which was introduced in Zimbabwe in the 19th century by the European missionaries (Morris, 1988). Wheat is grown in winter between May and August as shown in Figure 2.2 below. Cropping in winter is usually done under full irrigation because the country receives almost no rainfall which hinders crop production (Kapuya et al., 2010). Crops grown in winter require cold weather for successful crop development and high productivity.

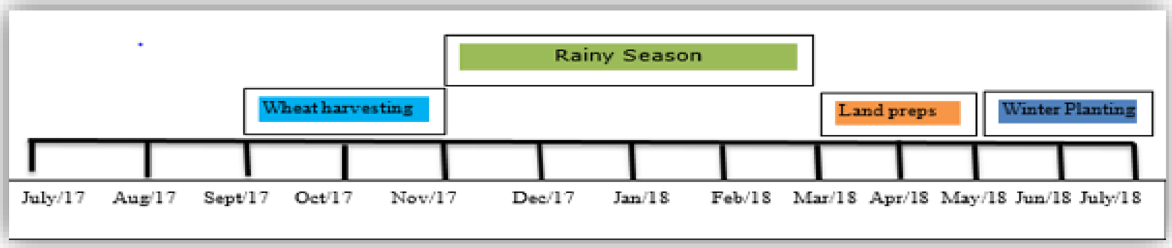


Figure 2.2: Wheat cropping calendar. Source: (Kapuya et al., 2010)

The crop is best grown in heavy loam soils and it is usually planted in rotation with soya beans (Negassa et al., 2013). Barley and tobacco are the major crops which compete for land with wheat production. Deliveries of wheat to the market are between September and February (Mutambara et al., 2013).

Since winter cropping requires irrigation, it implies that the crop requires significant initial capital investment for dams and water reservoirs construction, drilling boreholes, purchasing water main-lines, and power reticulation (Mutambara et al., 2013). Given this significant capital requirement wheat is mainly produced by medium and large-scale commercial farmers. However, smallholder farmers under smallholder irrigation schemes and on wetlands also produce wheat even though at subsistence levels (Anseeuw et al., 2011).

The agricultural sector and wheat sector more specifically is represented by the Commercial Farmers Union (CFU), Zimbabwe Commercial Farmers Union (ZCFU), Crop Producers Association (CPA) and Zimbabwe Farmers Union (ZFU). Wheat prices were controlled by the state-owned Grain Marketing Board (GMB) up until 1994 (Mutambara et al., 2013). Even though there was market deregulation after 1994, the GMB remains the major buyer of wheat and possesses most of the wheat storage facilities. GMB works as a grain trade and processing company. It sells wheat, maize, soya-beans etc. But also processed products such as wheat flour and maize flour. GMB has been responsible for announcing minimum guaranteed producer prices since 1980. Since, the introduction of dollarization in 2009, the producer price was higher than the import price (Kapuya et al., 2010), (Chinyoka, 2013). Consequently, the local processors opted to import cheaper wheat and this left local producers with no ready market to sell their produce on except for GMB which is known for inconsistent and unreliable payment arrangements to farmers.

Wheat value chain

The wheat value chain in Zimbabwe can be described by means of five different levels which consist of input suppliers, producers, traders, processors, and end market consumers (Mutambara et al., 2013). Figure 2.3 shows the different levels and summarises the structure of the wheat value chain in Zimbabwe.

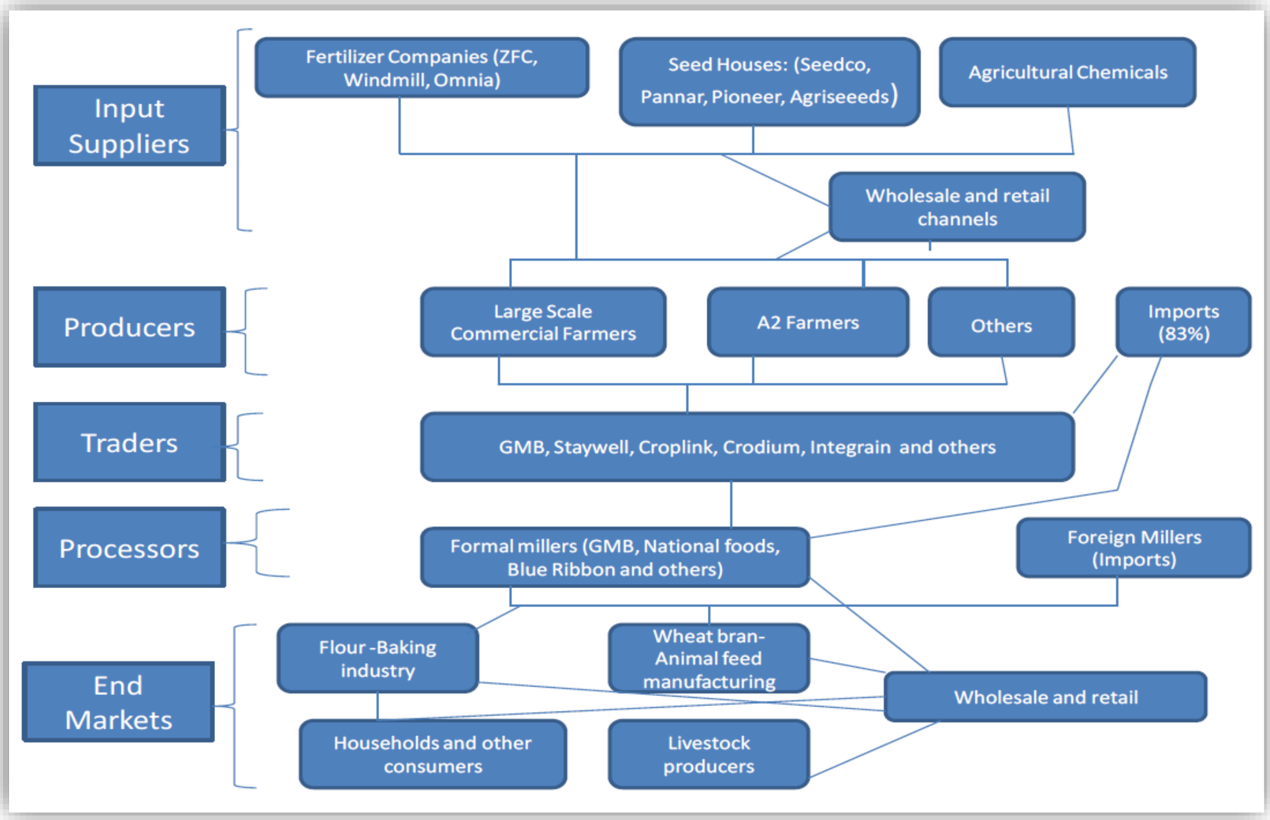


Figure 2.3: Wheat value chain in Zimbabwe. Source: Mutambara et al. 2013

From the producers, the crop is sold to the traders (GMB, Stay-well, and others), and processors (GMB, Blue ribbon and National foods). The processors produce flour and bran which is then used by the end markets in the baking industry, stock feeds industry and for household consumption.

Wheat Production: Provincial contribution

As a result of the requirements for wheat production, the main wheat producing provinces are Mashonaland West, Mashonaland Central, and Mashonaland East contributing on average 52%, 17%, and 10% respectively to the total output of wheat produced (Figure 2.4, numbers are for 2017). These provinces have favourable climatic conditions and potential irrigation facilities which contribute to wheat production. Matebeleland North province produces the least wheat in Zimbabwe, it contributes 1% of the total output (Ministry of Agriculture, 2017).

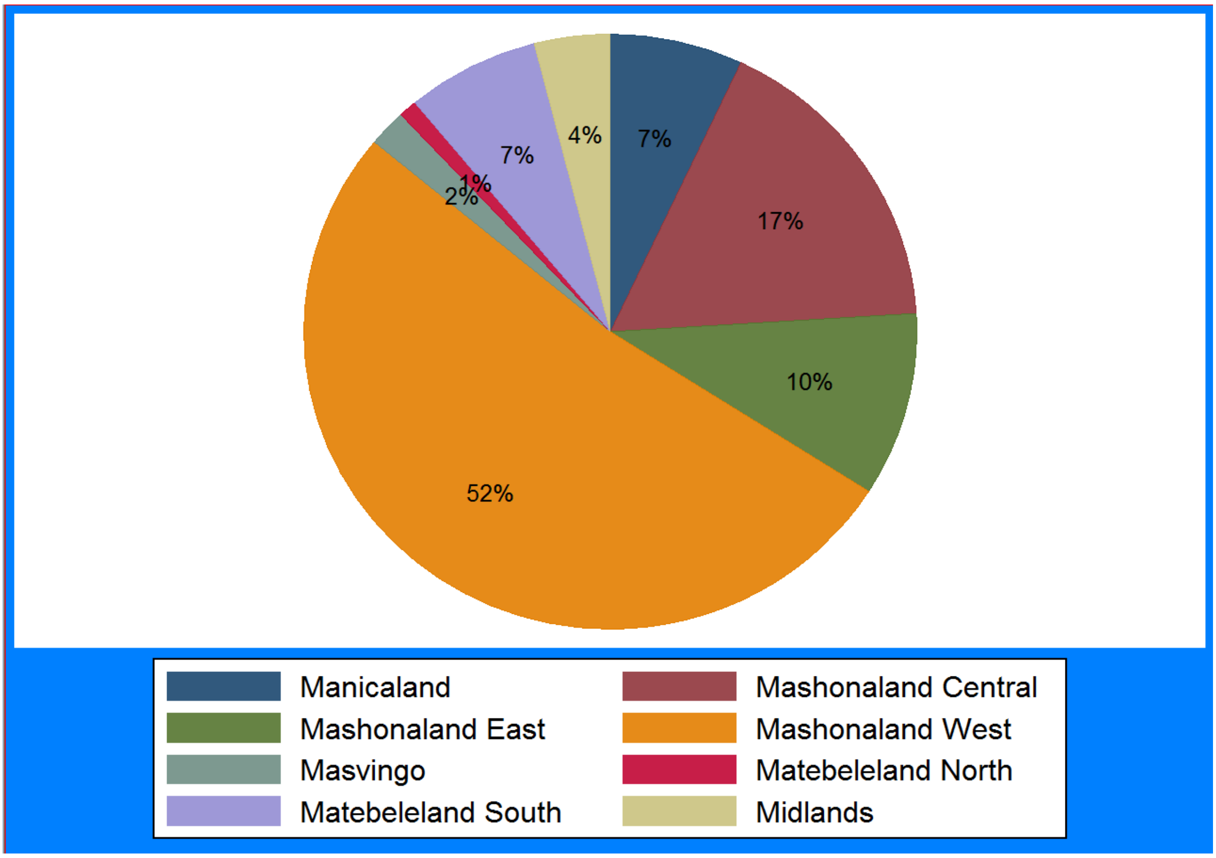


Figure 2.4: Wheat production (%) by province in 2017. Source: Ministry of Agriculture, 2017

Wheat grows and yields higher under cool conditions; hence wheat is grown in winter under irrigation as it is a temperate crop. However, other climatic factors like temperature, frost, moisture, early rain, and hail affect the yield of wheat. Temperature is the main climatic factor affecting development and yield of wheat in Zimbabwe (Chawarika et al., 2017).

Production and Consumption Analysis

Wheat is a staple crop mainly used as human food in the form of bread, pasta products, and cake. The crop consists of 20% bran and can then be sold to stock feed millers for the manufacturing of livestock feed. Figure 2.5 shows the widening gap between wheat production and wheat consumption in Zimbabwe from 1960 when the crop was commercially introduced to present.

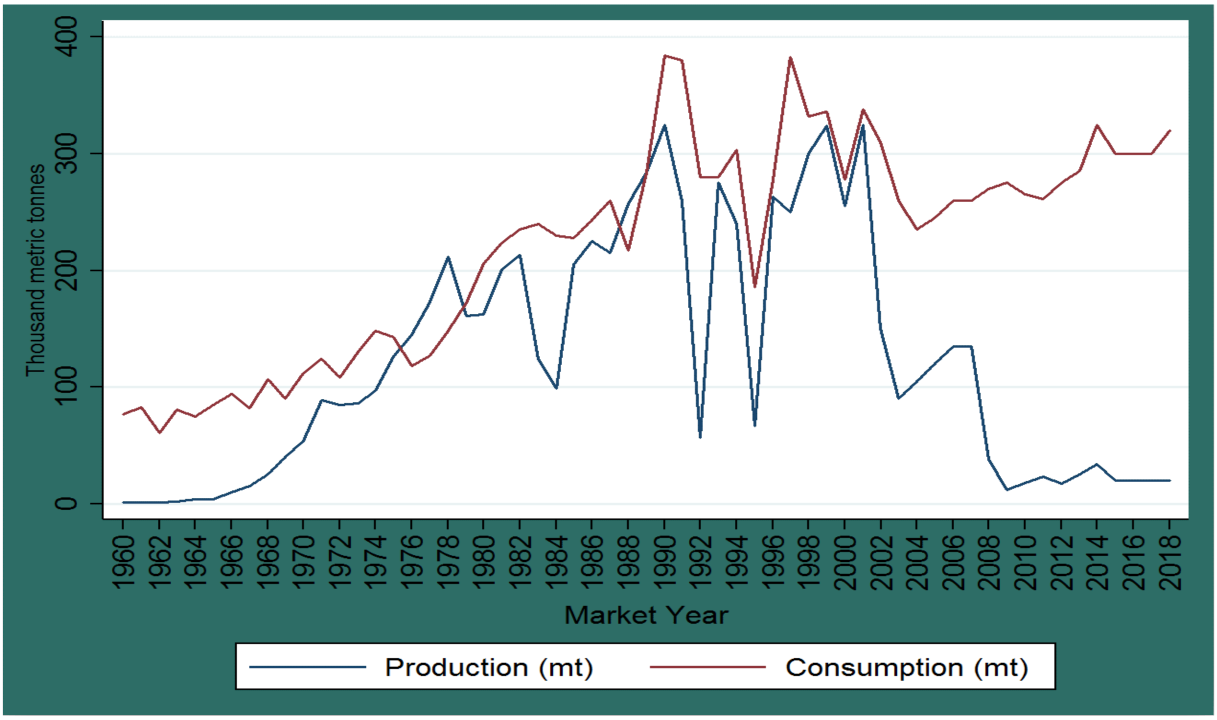


Figure 2.5: Wheat production and consumption trend from 1960 to 2018. Source: Index Mundi 2018. See also table in Appendix.

Figure 2.5, shows that before 1969, Zimbabwe was a net importer because consumption was greater than production. During that period limited research on the wheat cultivars that produce higher yield had not been developed and irrigation infrastructure was not established considering the fact that the crop requires relatively much water (Rukuni, 1994).

We observe an upward trend in wheat production from 1970 to 1990, with some deeps observed in 1979, 1980 and 1984. Figure 2.5, also reveals the decline of wheat production since 2002. The country encountered international sanctions just before its Independence in 1980, however, it embraced an inward-looking food self-sufficiency approach and succeeded to put up with the increase in wheat production during the period of 1960 to 1980 (Mutambara et al., 2013).

The country adopted the strategy of providing subsidized soft loans for headwork's and irrigation equipment for the commercial farming areas, this was accompanied with extensive research, development, and extension (Rukuni, 1994). The strategy resulted in increased wheat production leading to wheat exports from 1976 to 1978. Wheat self-sufficiency was a result of improved infrastructure, improved mechanization, improved know-how and a cool winter which favour irrigated wheat (Rukuni, 1994).

However, the dawn of Zimbabwe's independence in 1980 saw the earlier investments in the wheat sub-sector declining due to increasing government budgetary constraints. However, the wheat sub-sector enjoyed price subsidy support from 1980 to 2000 to encourage investment in irrigation and this led to a gradual increase in production (Rukuni et al., 2006).

From 2000 to present domestic consumption surpassed domestic supply (Figure 2.5). The country shifted from being a net exporter to a net importer of wheat. The country last recorded exports of 88 000 mt in year 1995, thereafter the production continuously decrease (Appendix A-I). Domestic demand for wheat has stabilized around 450 000 mt per year, however, production has dramatically declined from a peak of 325 000 mt in 2001 to 20 000 mt in 2018 (Index Mundi, 2018). Wheat consumption has increased due to an increase in urban population and changing in preferences thereby widening the gap between production and consumption. This ultimately enlarge the import demand of the commodity. Since 2000, following the fast-track land reform program, the drop in production became particularly severe (Mutambara et al. 2013). The loss of agricultural expertise as well as the decline in investment led to a further decrease in wheat production (Rukuni, 2006).

The international "economic sanctions" in the 1990s had a negative impact on wheat production. Economic sanctions are actions taken by foreign countries to limit or terminate their economic relations with a targeted country for the purpose to persuade that country to change its behaviour or policies (Chingono, 2010). The economic sanctions caused economic instability, they also contributed to the isolation of the country from the International Community. For example, the International Monetary Fund (IMF) withdrew its support to Zimbabwe in 1999. In addition, the World Bank stopped supporting the infrastructure development in 2001 (Ministry of Finance, 2003). This has seen an unexpected decline in wheat production due to lack of funding for expanding the irrigation infrastructure and repairing the deteriorated equipment. In addition, economic instability resulted in currency problems that subsequently led the dollarization in 2009. This was an approved replacement of the Zimbabwean dollar with the U.S. dollar as a result of high inflation (Mpofu, 2015). The acceptance of the U.S dollar prevented many farmers from planting crops as they did not have money to purchase seed because the previous year's crop was sold in Zimbabwean dollars (USDA, 2009). Hence, this led to the decrease in wheat production in the country.

2.3 Policy issues

From the previous sections plus literature some important policy issues can be identified. These policy issues will be discussed here.

Competition with imports

The position of Zimbabwe of depending on wheat imports means that trade policies have a key influence on the determination of domestic prices (Kapuya et al., 2010). The local wheat producer's performance has turned down due to stringent competition from imports. The country import wheat from Canada, America, Poland, Turkey and Russia. Being a landlocked country, imports are mainly delivered through Beira port in Mozambique and then conveyed to Zimbabwe by rail. Transaction costs of importing are very high and the country faces a rise in wheat import bills due to increased wheat imports (Mutambara et al., 2013). To lessen the total reliance on wheat imports, domestic wheat production must be enhanced.

No clear property rights

Farmers in Zimbabwe lease the land from year to year ("A 99-year lease"). This is a legally binding agreement between government and landholders. However, the lease is not transferable, making it hard for the farmers to invest more on their farms. Moreover, the government possesses the power to withdraw the lease from the farmers. This poses a high risk for the farmer to develop infrastructure on the farm. Farmers have limited decision making powers regarding the land property (Richardson, 2005).

Lack of credit

As aforementioned, the non- existence of land property rights hinders farmers to access loans from financial institutions. Lack of international finance opportunities have restricted recovery of the wheat sector. This led farmers failing to procure inputs in time and repairing irrigation equipment. Availability of medium to long-term financial credits to farmers positively affect wheat production (Ahmad et al., 2018). Therefore, a favourable environment is of greater importance for the farmers to access loans easily and to develop their infrastructure.

Delayed payment by GMB

The GMB is entirely state-owned parastatal. The provision of funds for grain purchases relies on the government treasury, however the government has fiscal problems and no funds are being released to GMB (USDA, 2016). Consequently, this led to the delayed payment of farmers. Because of the delayed payments by GMB, farmers are failing to prepare themselves well for the next seasons. They cannot access enough funds for inputs procurement. As a result, thousands of hectares remain unutilised (Richardson, 2005). This coupled with other challenges has negatively affected wheat production in Zimbabwe.

Government Support

Currently, the government is assisting the agricultural sector by pursuing contract farming. To restore self-sufficiency and to reduce wheat imports, the government intervenes through Zimbabwe's agro-import substitution programme (Command Agriculture). The country is driving and expanding the programme as one of its key policies to increase wheat production (Marufu, 2017). Through the programme, the government supply wheat inputs and repairing farm machinery hence encouraging more farmers to participate in wheat cropping.

Chapter 3: Theory

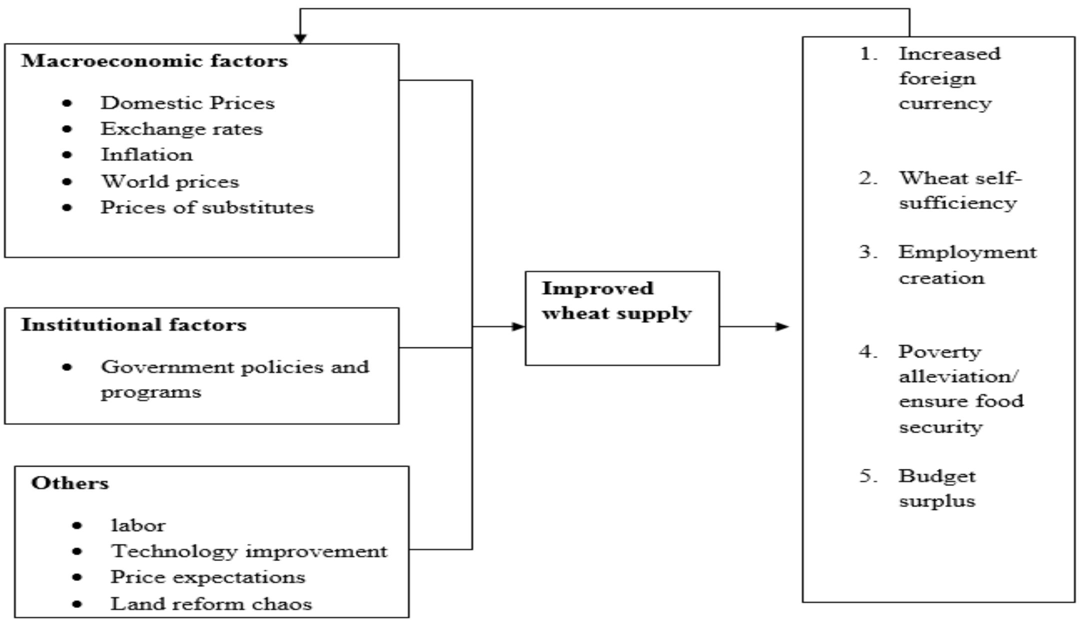
Introduction

The broad objective of this chapter is to presents the economic theory. The first section of the chapter illustrates the conceptual framework which provides the theoretical underpinnings of the research. The second section gives an insight into the analytical technique and production function. The third section explains short-run profit maximisation and the derivation of the shadow prices for quasi-fixed inputs. Finally, this chapter concludes by expressing the price and shadow price equations.

3.1 Conceptual Framework

Figure 3.1 puts forward a number of constraints that influence the supply of wheat. The framework highlights the cause and effect relationships between wheat supply and its constraints. Determinants of wheat supply are macroeconomic factors (e.g. exchange rate), institutional factors (e.g. policy), labour availability and quality, technology and price expectations. Figure 3.1 shows besides various factors that affect wheat supply that improvement in wheat supply can lead to wheat self-sufficiency, increase in foreign currency earnings through a reduction of imports and improved welfare expressed in poverty reduction, more employment and improved government budget.

Figure 3.1: Factors affecting wheat supply and impacts of improved wheat supply adopted from (Mahofa 2007).



3.2 Analytical technique

Micro-economic theory states that price of a product is the main factor affecting supply. Output prices play a vital role in the economic system, as it facilitates the allocation of farm resources, income distribution and encourages farm investment as well as capital development in agriculture (Chabane, 2002; Shoko et al., 2016). A general increase in the level of product's price, *ceteris paribus*, permits an intensive use of variable inputs, thereby improving crop production in the country. However, price alone is not the only explanatory variable. Therefore, price and non-price factors are of paramount importance in the supply function (David, 2013).

Therefore, following the conceptual framework (Figure 3.1), the supply function is made dependent on macroeconomic factors, institutional factors, the environment, technology, and weather. These encompasses both price and non-price factors related to production (Key et al., 2000).

<u>Production function</u>

Taking the prices of the productive factors as given, the producer's task is to determine the low-cost combination of factors of production that can produce the anticipated output. This is best understood in terms of a production function, that expresses the relationship between the quantities of factors used and the output produced. This can be expressed mathematically as $Y = f(x_1, x_2, L, C, G, T)$ where the quantity produced is a function of the combined input amounts of each factor. In the formula, Y denotes the quantity of output. The producer is presumed to use $x_1 and\ x_2$ as variable factors of production (for reasons of simplicity we assume here that there are only two variable inputs), that is, factors which can vary with the level of production. The producer is also presumed to use quasi-fixed factors, that is, factors which cannot be varied with the level production in the short run. These includes are L labour, C capital, G land, and T technology.

3.4 Profit maximisation

In the short run, costs for quasi-fixed inputs are not relevant for profit maximisation since the producer cannot change their quantities as they are fixed.

Therefore,

$$\max_{x_1,x_2}(p \times f(x_1, x_2, L, C, G, T) - (w_1 x_1 + w_2 x_2)) \quad \text{..(1)}$$

Where w_1 denotes the price of variable input x_1 and w_2 represents the price of variable input x_2.

To solve a maximisation problem with multiple choice variables:

1. Take the partial derivatives of the function with respect to each variable.
2. Set each partial derivative equal to zero and solve.

First Order Conditions for the variable factors:

$$p \times \frac{\partial f(x_1,x_2,L,C,G,T)}{\partial x_1} = w_1 \text{...(2)}$$

$$p \times \frac{\partial f(x_1,x_2,L,C,G,T)}{\partial x_2} = w_2 \text{...(3)}$$

At the optimal level of each input, the value of the marginal product will equal the price.

First Order Conditions for the fixed factors

$$p \times \frac{\partial f(x_1,x_2,L,C,G,T)}{\partial L} = P_L \text{...(4)}$$

P_L denotes the shadow price of labour. As the labour amount cannot be adjusted the shadow price show the value of labour in the production.

$$p \times \frac{\partial f(x_1,x_2,L,C,G,T)}{\partial C} = P_C \text{...(5)}$$

P_C represents the shadow price of capital

$$p \times \frac{\partial f x_1,x_2,L,C,G,T}{\partial G} = P_G \text{...(6)}$$

P_G signifies the shadow price of land

Technology indicates the way inputs are combined into output. we assume it is represented by the functional relationship between output and inputs. So, we cannot explicitly calculate a shadow price for it.

3.5 Price equations

$p = p_w \times ER + tr_p + ta_p + s$ ....(7)

Where p_w -world price of the product, ER- exchange rate, tr_p - transaction cost, ta_p-tariffs and s-subsidies

$w_1 = w_{1w1} \times ER + tr_{w1} + ta_{w1} + s_{w1}$...(8)

$w_2 = w_{2w2} \times ER + tr_{w2} + ta_{w2} + s_{w2}$...(9)

Where w_{1w1} and w_{2w2} are the world prices of the variable factors 1 and 2 respectively, ER-exchange rate tr_{w1} and tr_{w2} transaction costs, ta_{w1} and ta_{w2} tariffs and s_{w1} and s_{w2} subsidies on variable input 1 and 2 respectively.

Therefore, having the prices of the variable inputs and shadow prices of quasi-fixed inputs, an empirical model can be formulated and solved. Hence, the empirical model for this paper is built from the above equations. However, to analyse the adjustment of the quasi-fixed factors, in the long run, the difference between the market price and shadow price of the quasi-fixed inputs can be determined. The bigger the difference the larger the incentive to adjust the amount of quasi fixed inputs.

For example, the difference between the shadow price and market price of capital indicates the incentive to invest or disinvest. If the shadow price is less than the acquisition cost (market price in case of buying a capital good) this implies that the marginal revenue of a unit of quasi-fixed input is less than the marginal costs at the acquisition (Drabik and Peerlings, 2018). For that reason, it is not profitable to expand the use of quasi-fixed inputs.

Furthermore, it is not profitable to sell quasi-fixed inputs if the shadow price is higher than the salvage value. Salvage value is an estimated resale price of a quasi-fixed input at the end of its life, i.e. the market price in case of selling a capital good (Adnan and Iqbal, 2018). Conversely, if the shadow price is higher than the acquisition costs this implies that the marginal revenue of a unit of quasi-fixed input is higher than the marginal cost at the acquisition. Farmers are likely to invest when the shadow price of an additional unit of quasi-fixed input surpasses the costs of acquisition.

Therefore, in the long run, an adjustment in the amount of quasi-fixed inputs is profitable till to the point where the market price equals the shadow price. Below I give equations for the market price of labour, capital, and land.

Labour

The market price of labour at farm level is determined by the general wage corrected for the qualifications/skills of the labour and the transaction costs to find/hire labour.

$P_L{}^m = \varpi + q + tr_L$..(10)

Where ϖ represents the wage rate, q denotes the qualifications/skills of the labour and tr_L represents transaction costs.

Capital

The market price of capital $P_C{}^m$ is assumed is assumed exogenous but there are transaction costs involved that could be interpreted as the difference between the acquisition costs and salvage value. Transaction costs can be also interpreted as adjustment cost of investment (Lansink and Stefanou 1997).

$P_C{}^m = \overline{P_C{}^m} + tr_C$..(11)

Where: $P_C{}^m$– market price of capital and tr_C transaction costs of capital adjustment.

Land

The market price of land $P_G{}^m$ is probably endogenous in the sense that it is determined by the profitability of wheat production. For reasons of simplicity we ignore this and assume the price is exogenous but we take land characteristics into account (e.g. location and land quality).

$P_G{}^m = \overline{P_G{}^m} + Q_G S_C$..(12)

$P_G{}^m$- market price of land, Q_G – land location/quality

Chapter 4 - Data

Introduction

This chapter presents secondary data gathered from different sources. It describes the variables, data sources and summary statistics.

4.1 Data Sources

Secondary data were collected from multiple sources. First, the domestic producer prices of both wheat and barley were obtained from the Grain Marketing Board (GMB). Second, the world prices of wheat were obtained from the United Nations Conference on Trade and Development Statistics database (UNCTADSTAT). Third, exchange rates and inflation rate were obtained from the International Monetary Fund through the Federal Reserve Economic Database. Fourth, yearly data for wheat yield and acreage were obtained from the United States Department of Agriculture (2017) through the Index Mundi website. Fifth, rainfall data was obtained from the World Bank database.

4.2 Data

This study uses annual time series data for the period 1965 to 2018 to estimate the wheat supply response function for Zimbabwe. Table 4.1 reports statistical summaries of the data included in the study. Specifically, statistical calculations comprising the mean, standard deviation, minimum and maximum values are presented for each variable.

Table 4.2: Variables

Variable	Mean	Std. Dev	Min	Max
Wheat yield (thousand tonnes)	133.87	100.91	4	325
Price of wheat (us$/tonne)	4.00	2.24	1.49	11.01
Price of barley(us$/tonne)	4.24	3.30	1.67	23.73
Exchange rate(zw$/us$)	25.51	111.53	0.57	698.22
World wheat price (us$/tonne)	2.52	0.80	1.61	5.98
Inflation rate (cpi)	568.87	3518.84	0.36	24411.03
Average annual rainfall (mm)	652.71	137.09	411.52	974.87
Acreage (thousand ha)	28.85	16.62	2	57
Land Reform	0.35	0.48	0	1

Table 4.2 presents a correlation matrix which shows the correlation coefficients between the explanatory variables. All prices were converted to real prices using a GDP deflator obtained from Index Mundi 2018**.** It is noted that acreage and wheat yield are highly correlated as well as exchange rates and inflation (Table 4.2).

Table 4.2: Correlation matrix

	Exchange rate	*World-price*	*Rainfall*	*Acreage*	*Land reform*	*Inflation*	*Price of barley*	*Price of wheat*	*Wheat yield*
Exchange rate	1								
World price	0.2483	1							
Rainfall	-0.0266	0.0835	1						
Acreage	0.0107	0.2523	0.283	1					
Land reform	0.5764	0.3653	0.1078	0.1388	1				
Inflation	0.966	0.3486	-0.0837	0.0807	0.7031	1			
Price of barley	0.2121	0.4327	-0.1933	0.2698	0.6642	0.4273	1		
Price of wheat	0.3301	0.4176	-0.1361	0.3672	0.6928	0.495	0.8834	1	
Wheat yield	-0.0725	0.2294	0.2053	0.9549	0.136	0.0037	0.2655	0.4275	1

4.3 Description of variables

Annual domestic wheat yield measured in metric tonnes is used as the dependent (endogenous) variable. The annual yield is used although winter wheat is harvested only once a year. For the purpose of consistency and uniformity in the study an average annual wheat yield is used. The use of wheat yield is besides economic variables influenced by the biological nature of agricultural production as well as the influence of climate (Ozkan et al., 2011).

The annual domestic producer prices of wheat and barley are independent (exogenous) variables, they are measured in US dollar per metric tonne. We take yearly prices for wheat and barley despite that they are harvested only once a year. A positive relationship between wheat production and price of wheat yield is expected. An increase in the price of a substitute (i.e. barley) implies a reduction in wheat production (Becker, 2017). Therefore, a negative relationship is expected between domestic barley prices and total wheat yield.

The nominal exchange rate is the price of the Zimbabwean dollar expressed in the US dollar. US dollar is the main international trading currency in Africa, therefore, it was chosen. In addition, the annual average was used for consistency and uniformity in the analysis. An increase in the exchange rate implies a depreciation of the Zimbabwean dollar implying an increase of the world prices expressed in Zimbabwean dollars. This makes exporting more attractive and imports more expensive. The bulk of wheat inputs used in wheat production becomes more expensive and forces farmers to reduce production.

The world price of wheat is another independent variable used in the study to explain the domestic producer price of wheat in Zimbabwe. World price movements moderately affect domestic wheat prices (Dasgupta et al., 2011). In order to accurately estimate the price transmission between the world and domestic prices, the world prices were obtained in US dollar per metric tonne. Moreover, for consistency, the annual average world prices were used in the study. An increase in the world price of wheat is expected to put pressure on the country's foreign exchange requirements in case of imports, affecting the entire wheat value chain. An increase in world price increases the import bill which strains foreign exchange more. Wheat imports decrease consequently, and therefore increase demand for local wheat supply. Depreciation of the Zimbabwean dollar increases import prices of wheat incentivizing domestic production.

The annual inflation rate measured as the rate of change of prices (CPI) will be used as an independent variable. Cost-push inflation occurs when a factor of production's price increases. Cost of production as well increases. Consequently, farmers curb their production which in turn affects supply. Therefore, a negative relationship is expected between the annual inflation rate and wheat production.

Total annual rainfall expressed in millimetres (mm) per annum and lagged annual average rainfall recordings will be also used as independent variable. It is expected that annual rainfall received previous season has a positive effect on total wheat produced. Thus, if abundant rain is received in the previous year it means that there will be enough water to irrigate wheat in the next season. The reverse is true in case of drought, which in turn affect wheat production.

Acreage measured in hectares is another independent variable included. This refers to the total land area employed for wheat production annually. A positive relationship between wheat yield and area devoted to wheat production is expected.

The final independent variable of the study is the dummy which captures the effect of structural changes generated by the Fast Track Land Reform Programme (FTLRP). FTLRP started in 2000 hence the dummy variable separate two periods (before and after) (Waeterloos and Rutherford, 2004). The dummy variable takes the value of 0 or 1 to indicate the absence or presence of the land reform programme. The land invasion had images of theft and irrigation equipment destruction which dominated the coverage (Scoones et al., 2011). The programme interfered with normal farm operation in the commercial sector. Therefore, it is expected that the programme will have a negative and significant effect on wheat yield.

A time trend is another explanatory variable. This variable acts as a proxy for technological change. Occurrence of a technological change increases the productivity of labour, capital and other factors of production (Doraszelski and Jaumandreu, 2018). Subsequently, this increases crop production. Therefore, a positive relationship between wheat yield and technological change is expected. Since, a rapid adoption of modern technology increases cereal production (Montgomery and O'Sullivan, 2017).

Chapter 5: Empirical Model and Estimation

Introduction

The purpose of this chapter is to present the supply response equation. The first section explains the empirical model derived from the profit maximising framework. The section further shows the steps on how to formulate and estimate the reduced form equation. The second section discusses and presents the final supply response equation.

5.1 Empirical Model

Based on the profit-maximising framework discussed in chapter 3, the supply response function can be determined. In chapter 3, we showed that the supply response is affected by both price and non-price factors (Key et al., 2000). Instead of calibrating and/or estimating the model in chapter 3, I will formulate and estimate a reduced form equation. More specifically I will use the Nerlovian partial adjustment model. The model is easy to estimate and has been applied often for many crops in developing countries (Leaver, 2004; Ozkan et al., 2011; Mythili, 2012; Utuk, 2014; Ogundari, 2018). Using this model, one can determine the short run and the long run elasticities easily. Moreover, its ability to include non-price factors into the model makes it more realistic and better able to capture the trends in agricultural production (Yu et al., 2011).

The Nerlovian partial adjustment model can be formulated as follows:

$$Y_t^* = \alpha + \beta P_t^e + \gamma X_t + \theta_t, \quad \text{.........}(5.1)$$

Where $Y_t^* =$ desired level of output for time t, $\alpha =$ the intercept, $\beta =$ coefficient for the expected real output price, P_t^e= the expected real output price for time t, $\gamma =$ the coefficients associated with X_t, X_t = the vector of non-price factors and θ_t = error term, $\mathrm{E}(\theta_t) = 0$,

$$Y_t - Y_{t-1} = \delta(Y_t^* - Y_{t-1}) + \omega_t \quad \text{.........}(5.2)$$

Where $Y_t =$ the actual output produced, $Y_{t-1} =$ the output of previous year, δ = partial-adjustment coefficient, ω_t = error term, $\mathrm{E}(\omega_t) = 0$,

$$P_t^e = P_{t-1}^e + \mu(P_{t-1} - P_{t-1}^e) + \varphi_t \quad \text{.........}(5.3)$$

Where: $P_{t-1} =$ the price of the previous year, P_{t-1}^e = the expected real output price of previous year, φ_t = error term , $\mathrm{E}(\varphi_t) = 0$ and μ = expectation coefficient.

Equation 5.1, illustrates that the desired output of the crop in period t, is a function of expected real prices and of non-price factors. Equation 5.2, shows that the actual adjustment in output will be only a fraction of the desired adjustment. Since full adjustment of the output in the short run may not be feasible. Equation 5.3, specify an equation that explains formation of price expectations based on actual and past prices. Producers may adjust their expectations as a fraction (μ) of the difference between the actual price and the expected price in the last period (t-1).The equation to be estimated is obtained through the following steps:

<u>From equation 5.2</u>

$Y_t - Y_{t-1} = \delta(Y_t^* - Y_{t-1}) + \omega_t$

$Y_t = Y_{t-1} + \delta Y_t^* - \delta Y_{t-1} + \omega_t$

$Y_t = \delta Y_t^* + (1-\delta)Y_{t-1} + \omega_t$..(5.4)

<u>Then, substitute equation 5.1 into 5.4</u>;

$Y_t = \delta[\alpha + \beta P_t^e + \gamma X_t + \theta_t] + (1-\delta)Y_{t-1} + \omega_t$

$Y_t = \delta\alpha + \delta\beta P_t^e + \delta\gamma X_t + \delta\theta_t + (1-\delta)Y_{t-1} + \omega_t$..(5.5)

<u>From equation 5.3</u>

$P_t^e = P_{t-1}^e + \mu P_{t-1} - \mu P_{t-1}^e + \varphi_t$

$P_t^e = \mu P_{t-1} + (1-\mu)P_{t-1}^e + \varphi_t$...(5.6)

<u>Then, substitute equation 5.6 into 5.5</u>

$Y_t = \delta\alpha + \delta\beta[\mu P_{t-1} + (1-\mu)P_{t-1}^e + \varphi_t] + \delta\gamma X_t + \delta\theta_t + (1-\delta)Y_{t-1} + \omega_t$

$Y_t = \delta\alpha + \delta\beta\mu P_{t-1} + \delta\beta(1-\mu)P_{t-1}^e + \delta\beta\varphi_t + \delta\gamma X_t + \delta\theta_t + (1-\delta)Y_{t-1} + \omega_t$...........(5.7)

<u>We lag equation 5.5 by one period</u>

$Y_{t-1} = \delta\alpha + \delta\beta P_{t-1}^e + \delta\gamma X_{t-1} + \delta\theta_{t-1} + (1-\delta)Y_{t-2} + \omega_{t-1}$..(5.8)

<u>Multiply equation 5.8 by $(1-\mu)$</u>

$Y_{t-1}(1-\mu) = \delta\alpha(1-\mu) + \delta\beta P_{t-1}^e(1-\mu) + \delta\gamma X_{t-1}(1-\mu) + \delta\theta_{t-1}(1-\mu) + (1-\mu)(1-\delta)Y_{t-2} + \omega_{t-1}(1-\mu)$ ....(5.9)

Then, subtract equation 5.9 from 5.7

$Y_t - Y_{t-1}(1-\mu)$

$= \delta\alpha + \delta\beta\mu P_{t-1} + \delta\beta(1-\mu)P^e_{t-1} + \delta\beta\varphi_t + \delta\gamma X_t + \delta\theta_t + (1-\delta)Y_{t-1} + \omega_t$ – [$\delta\alpha$(1- μ) $+\delta\beta P^e_{t-1}$(1- μ) $+\delta\gamma X_{t-1}$(1- μ) $+\delta\theta_{t-1}$(1- μ) +(1- μ) $(1-\delta)Y_{t-2} + \omega_{t-1}$ (1- μ)]..........(5.10)

Y_t = ~~$\delta\alpha$~~ $+ \delta\beta\mu P_{t-1} +$ ~~$\delta\beta(1-\mu)P^e_{t-1}$~~ $+ \delta\beta\varphi_t + \delta\gamma X_t + \delta\theta_t + (1-\delta)Y_{t-1} + \omega_t$ –

~~$\delta\alpha$~~ + $\delta\alpha\mu$ - ~~$\delta\beta P^e_{t-1}(1-\mu)$~~ $-\delta\gamma X_{t-1}$(1- μ) $-\delta\theta_{t-1}$(1- μ) $-$(1- μ) $(1-\delta)Y_{t-2} - \omega_{t-1}$ (1- μ) + $Y_{t-1}(1-\mu)$

Y_t = $\delta\alpha\mu$ + $\delta\beta\mu P_{t-1} + (1-\delta)(1-\mu)Y_{t-1} -$ (1 - μ) $(1-\delta)Y_{t-2}$ $+\delta\gamma X_t - \delta\gamma$(1- μ) X_{t-1} + $\delta\beta\varphi_t + \omega_t - \delta(1-\mu)\theta_{t-1} - (1-\mu)\omega_{t-1}$ + $\delta\theta_t$...(5.11)

The final expression is as follows;

$Y_t = b_0 + b_1 P_{t-1} + b_2 Y_{t-1} + b_3 Y_{t-2} + b_4 X_t + b_5 X_{t-1} + \varepsilon_t$..(5.12)

Where

$b_0 = \delta\alpha\mu$;

$b_1 = \delta\beta\mu$,

$b_2 =$ (1- δ) + (1- μ);

$b_3 =$ -(1- δ) (1- μ);

$b_4 = \delta\gamma$;

$b_5 = -\delta\gamma$(1- μ) and

$\varepsilon_t = \omega_t$ - (1- μ) ω_{t-1}+ $\delta\theta_t$ - δ(1- μ) θ_{t-1}+ $\beta\delta\varphi_t$

Equation 5.12 is a distributed lag model and it includes a lagged dependent variable. However, it is mostly expressed in natural logarithms to interpret the coefficients easily as the elasticities (Ogundari, 2018). From equation 5.12, using the coefficient of each independent variable, one can estimate the short run price response directly, and to obtain the long run price response one can divide the short run elasticities by adjusted coefficient (Leaver, 2004;Aksoy, 2012).

5.2 Estimation

Using the variables selected in the previous chapters, the following function will be estimated:

Supply = f (exchange rates, inflation, world prices of wheat, price of barley, price of wheat (t-1), wheat out-put (t-1) , wheat output (t-2), rainfall (t-1), acreage (t-1), land reform policy, time trend)

The final equation used is expressed in logarithmic form, this is to ensure the normality of the residuals. Logarithmic transformation ensures that the errors are normally distributed and homoscedastic (Maddala, 2001). As highlighted previously, using the logarithmic form allows also for an easy interpretation of the coefficients as elasticities.

From the correlation matrix in the previous chapter we noted that $output_{t-1}$ and $acreage_{t-1}$ are highly correlated (0.93) and this led $acreage_{t-1}$ variable to be dropped from the final model.

Therefore, wheat supply response equation is expressed as:

$Loutput_t = b_0 + b_1 Lrealprice_{t-1} + b_2 Loutput_{t-1} + b_3 Loutput_{t-2} + b_4 Lexchangerate_t + b_5 Linflation_t + b_6 Lworldprice_t + b_7 Lrealpricebarley_t + b_8 Lrainfall_{t-1} + b_9 landreform_t + b_{10} time + \varepsilon_t$ ....(5.13)

Where:

$Loutput_t$	= log of total wheat output produced in year t, and measured in tonnes
$Lrealprice_{t-1}$	= log of the real wheat price, measured in US dollar per tonne
$Loutput_{t-1}$	= log of total wheat output lagged by one year
$Loutput_{t-2}$	= log of total wheat output lagged by two years
$Lexchangerate_t$	= log of the exchange rate in year t
$Linflation_t$	= log of the inflation rate in year t
$Lworldprice_t$	= log of the real world wheat price, measured in US dollar per tonne
$Lrealpricebarley_t$	= log of the real barley price, measured in US dollar per tonne
$Lrainfall_{t-1}$	= log of the rainfall lagged by one year, expressed in mm
$landreform_t$	= dummy variable for land reform (1 for the years when the policy was implemented and 0 for the years with no policy)
$time$	= simple time trend which captures technological change
ε_t	= error term

Chapter 6: Results

Introduction

The purpose of this chapter is to present the results of the model. The first section discusses stationarity of the variables in the model. The second section explains if there was a significant structural change due to the land reform policy. The third section presents and discusses the estimation results. The fourth section displays the diagnostic tests carried out and their conclusions. Lastly, this chapter concludes by presenting short and long-run price elasticities.

6.1 Stationarity testing results

The final equation of the Nerlovian model was estimated in Stata using the OLS method. All variables were tested for stationarity for the period 1965 to 2018. For this test, the Augmented Dickey-Fuller(ADF) unit root test was used. The stationarity test results are presented in Table 6.1 and 6.2.

Table 6.1: ADF stationarity testing results before differencing.

Variable	ADF test statistic	1% critical value	5% critical value	Probability	Conclusion
Acreage	3.441	4.141	3.497	0.057	Non-stationary
Land-reform	3.161	4.143	3.497	1.000	Non-stationary
Exchange rate	1.731	2.639	1.952	0.977	Non-stationary
Inflation	2.868	3.581	2.927	0.057	Non-stationary
Output	3.139	4.14	3.497	0.108	Non-stationary
Output(-1)	3.139	4.141	3.497	0.108	Non-stationary
Output(-2)	3.074	4.144	3.499	0.123	Non-stationary
Rainfall(-1)	6.390	3.563	2.919	0.000	Stationary
Real price of barley	2.601	3.565	2.919	0.099	Non-stationary
Real price of wheat (-1)	3.181	4.148	3.500	0.100	Non-stationary
Real-world price	2.942	3.565	2.919	0.048	Non-stationary

: all variables are in logarithmic form except the dummy trend (land reform).

Table 6.2: ADF stationarity testing results at first differences

Variable	*Test statistic*	*1% critical value*	*5% critical value*	*Probability*	*Conclusion*
Acreage	7.37	4.15	3.50	0.0000	Stationary
Inflation	8.67	2.62	1.95	0.0000	Stationary
Output	7.58	4.15	3.50	0.0000	Stationary
Output(-1)	7.58	4.15	3.50	0.0000	Stationary
Output(-2)	7.56	4.15	3.50	0.0000	Stationary
Rainfall(-1)	6.39	3.56	2.92	0.0000	Stationary
Real price of barley	8.93	2.61	1.95	0.0000	Stationary
Real price of wheat (-1)	8.54	2.61	1.95	0.0000	Stationary
Real-world price	6.82	2.61	1.95	0.0000	Stationary
Exchange rate	2.21	4.27	3.56	0.4706	Non-stationary
Exchange rate-2nd Difference	6.47	4.263	3.55	0.0000	Stationary

: All variables are in logarithmic form and at first differences.

The results of stationarity tests show that all variables were non-stationary at levels except rainfall (t-1)(Table 6.1). All other non-stationary variables became stationary after first differencing apart from exchange rates which became stationary only after second differencing (Table 6.2). The land reform variable was not corrected for stationarity since it is a dummy trend.

6.2 Chow-test results

A F-test was used to check if there was a structural change after the implementation of a land reform policy in year 2000. Land reform policy was treated as a dummy trend variable in this model. In STATA, the F-test can be carried out using the testparm command. Table 6.3 shows the results.

Table 6.3: F-test results

Year 2000

H_0 : land reform = 0

F- statistic (1, 25) = 6.03	P- value = 0.0213

Table 6.3 shows that the outcome of the F-test is 6.03, with p-value 0.0213< 0.05, so it is shown that we should not leave land reform out from the model. We can reject the null hypothesis. Therefore, we can conclude that there was a structural change after the impementation of the land reform policy in 2000 and afterwards.

6.3 Wheat supply response results

Table 6.4 presents the regression results of the wheat output response for the period 1965 to 2018. The results show that the R- squared is 0.62, which indicates that explanatory variables in the model explain 62% of the variation in wheat output. The P-value of F-statistic for wheat output is 0.0020< 0.05, this suggests overall significance of the relationships in the regression at 5% level.

The coefficient of lagged output (t-1) had a negative sign with a value of -0.53 The coefficient is significant at the 5% confidence level, implying that when the country obtains higher wheat yields, producers tend to reduce the production in the next production season. The law of demand supply might explains this negative sign. Higher yields may tend to lower the prices of the crop instigating farmers to react negatively by reducing production in the next season. The results were similar to those obtained by (Ozkan et al., 2011) who also concluded a negative relationship between lagged output (t-1) and actual wheat output.

Moreover, the coefficient of lagged output (t-2) had also a negative sign but not significant at the 10% confidence level, suggesting that the output for the past two years might not significantly affect the wheat production.

Table 6.4: Regression results for wheat output response from 1965-2018

DEPENDENT VARIABLE: DLoutput

Variables	**Coefficients**	**Std. Error**	**t-statistic**	**Probability**
$Constant$	-4.33	2.56	-1.69	0.103
$Output_{t-1}$	-0.53	0.16	-3.31	0.003**
$Output_{t-2}$	-0.23	0.15	-1.56	0.130
$Real\ price\ of\ barley_t$	-0.04	0.24	-0.16	0.878
$Real\ price\ of\ wheat_{t-1}$	0.79	0.28	2.87	0.008**
$Real\ world\ price_t$	-0.33	0.48	-0.68	0.501
$Exchange\ rate_t$	-0.42	0.31	-1.36	0.186
$Inflation_t$	-0.18	0.12	-1.52	0.141
$Time\ trend$	-0.01	0.01	-1.18	0.249
$Landreform_t$	-0.35	0.14	-2.46	0.021**
$Rainfall_{t-1}$	0.73	0.39	1.87	0.073*
R^2 = 0.62				
F-stat = 4.10 (p-value 0.0020 < 0.05)				
Observations = 36				

**Significant at the 5% level * significant at the 10 %level

As expected, the coefficient for the real price of barley had a negative value of -0.04, since they are competitive crops. However, the coefficient was not significant at the 10% confidence level. This implies that the real price of barley had no significant effect on wheat production.

The coefficient of the lagged real price of wheat had a positive sign with a value of 0.79. The estimated coefficient is significant at the 5% confidence level, implying that the lagged real price of wheat for the previous season positively influences the wheat production in the next season. These results agree with (Bhatti et al. 2011; Huq et al. 2013) who concluded that there was a positive relationship between the lagged real price of wheat and its output.

The exchange rate, real-world price, and inflation rate negatively affect wheat production but they were insignificant at the 10% confidence level, indicating that they insignificantly influence the production of wheat.

Time trend which was a proxy for technological change. It has a negative sign with the value of -0.02. The coefficient is not significant at the 10% confidence level. This is not as expected. However, the time trend may pickup a negative trend in technology for example disinvestment in irrigation facilities, farm machinery, higher yielding varieties and worse infrastructure.

The dummy trend variable which captures the effect of the land reform policy in year 2000 had a negative sign with the value of -0.35. The coefficient is significant at the 5% cofidence level. During landreform process the country experienced high loss of agricultural expertise and the policy led to the destruction of irrigation facilities and infrastructure (Scoones et al., 2011).

Finally, the results show that lagged rainfall is positively related to wheat output. The coefficient is significant at the 10 % confidence level. This implies that when the country recieves more rainfall in the previous season, water sources for example dams and water resevoirs will have enough water for wheat production in the following season.

6.4 Diagnostic tests

Table 6.5 presents diagnostic tests which were employed to validate the quality of the model. These tests include a White test for heteroskedasticity, Jarque- Bera test for normality, the Ramsey RESET test for the stability of the model, and Breusch-Godfrey LM test for autocorrelation. The table also shows the mean of the variance inflation factor which also shows the sign of multicollinearity.

Table 6.5: Diagnostic tests results

Testisting for:	Method	Null-hypothesis	Outcome	P-value	Conclusion
Heteroskedasticity	White test	Constant variance	1.88	0.1709	No sign of heteroskedasticty
Normality	Jarque-Bera test	Normality	0.36	0.8362	Shows residuals are normally distributed
Stability	Ramsey RESET test	Model has no omitted variables	3.48	0.1332	No sign of misspecification of the model
Autocorelation	Breusch Godfrey LM test	No serial autocorrelation	8.38	0.0786	No sign of autocorelation
Multicollinearrity	Mean VIF	1.98			No serious problem of multicollinearity

Multicollinearity

To check for severity of multicollinearity, the Variance Inflation Factor (VIF) was obtained from the STATA output. When there is no collinearity among the explanatory variables VIF will be equal to 1. VIF index ranges from 1 up to infinity. However, explanatory variables are said to be highly collinear if their VIF exceeds 10 (Ketema and Kassa, 2016)**.** Table 6.5 shows that the computed VIF is 1.98 which is very small and the author concludes that there is no serious problem of multicollinearity. Table 6.6 support that there is no serious correlation among the explanatory varibles after taking their first differences. However, acreage and lagged output(t-1) remain highly correlated hence it was dropped from the final model.

Table 6.6: Correlation matrix after first differencing.

	Land-reform	Exchange-rates	Real world price	Real price of wheat	Real price of barley	Output (-2)	Output (-1)	Output	Inflation	Acreage
Land-reform	1									
Exchange-rates	0.625	1								
Real world price	0.020	-0.052	1							
Real price of wheat	0.259	-0.028	-0.289	1						
Real price of barley	-0.096	-0.543	0.278	-0.106	1					
Output(-2)	-0.037	0.0724	0.156	-0.316	0.135	1				
Output(-1)	-0.202	-0.256	-0.210	-0.092	-0.011	-0.301	1			
Output	-0.263	-0.101	-0.248	0.434	-0.122	-0.176	-0.277	1		
Inflation	0.272	0.273	0.059	-0.075	-0.027	0.077	0.024	-0.307	1	
Acreage	-0.115	-0.084	-0.182	-0.149	-0.104	-0.295	**0.956**	-0.283	0.083	1

Figure 6.1 and 6.2 support that there was no sign of heteroskedasticity and also the residuals were normally distributed.

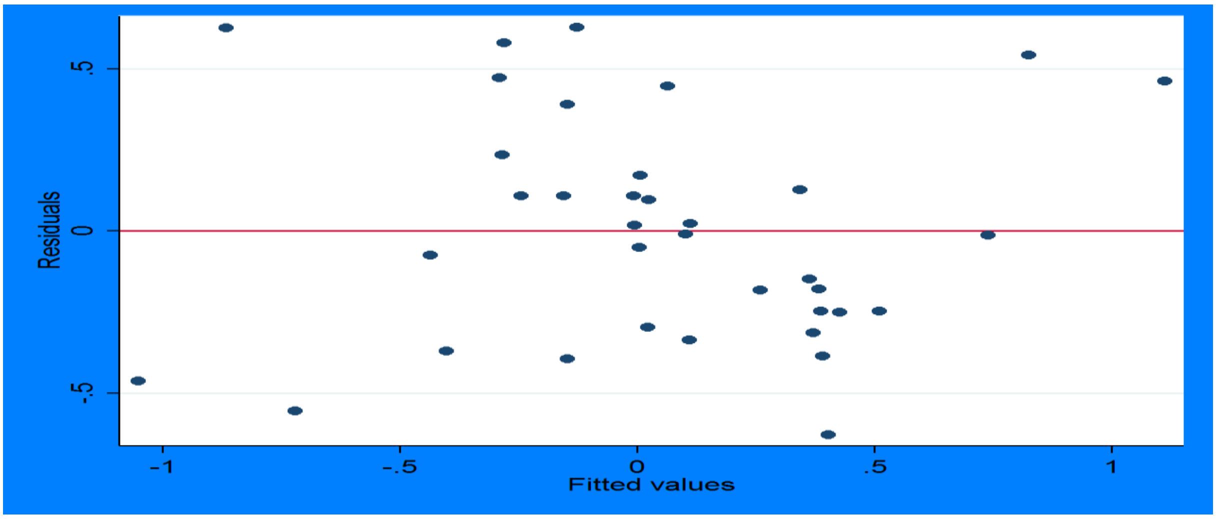


Figure 6.1: No sign of heteroscedasticity

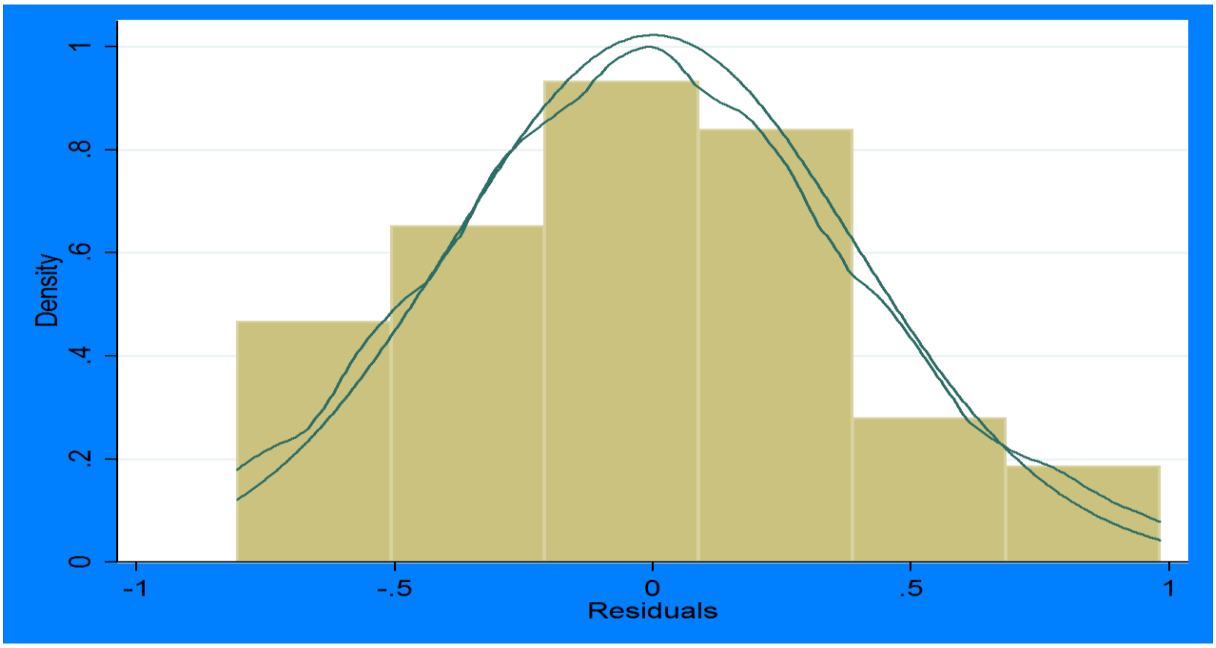


Figure 6.2: Residuals are normally distributed

6.5 Short and long-run price elasticities estimates

Chapter 5 showed that equation 5.12 had to be estimated. However, due to non-stationarity of the variables, the equation was then estimated in first differences with all variables in logarithms.

$$Y_t - Y_{t-1} = b_0 + b_1(P_{t-1} - P_{t-2}) + b_2(Y_{t-1} - Y_{t-2}) + b_3(Y_{t-2} - Y_{t-3}) + b_4X_t + b_5X_{t-1} + \varepsilon_t$$

$$Y_t = b_0 + Y_{t-1} + b_1P_{t-1} - b_1P_{t-2} + b_2Y_{t-1} - b_2Y_{t-2} + b_3Y_{t-2} - b_3Y_{t-3} + b_4X_t + b_5X_{t-1} + \varepsilon_t$$

$$Y_t = b_0 + b_1P_{t-1} + (1 + b_2)Y_{t-1} + (b_3 - b_2)Y_{t-2} - b_3Y_{t-3} + b_4X_t + b_5X_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots (6.51)$$

Where b_1 is the short-run price elasticity equalling 0.79, $(1 + b_2)$, $(b_3 - b_2)$ and b_3 are the elasticities of the Output_{t-1}, Output_{t-2} and Output_{t-3} respectively. Given that $(1 + b_2)$ = -0.53 and $(b_3 - b_2)$ = -0.23 (Table 6.4). Therefore, b_3 becomes 1.30.

Table 6.6 summaries the estimated short and long-run elasticities. The short-run supply elasticity is measured by b_1 and the long-run supply elasticity is obtained through dividing the short run elasticity by the adjustment coefficient. The adjustment coefficient is obtained by subtracting the coefficient of the lagged dependent variables from 1 (Aksoy, 2012): (Cowling et al. 2013). Therefore, to calculate the long run elasticity this formula can be applied $\frac{b_1}{(1-(1+b_2)-(b_3-b_2)-b_3} = \frac{0.79}{(1+0.53+0.23-1.3)} = \frac{0.79}{0.46} = 1.72$

The short-run and the long-run price elasticities are estimated as 0.79 and 1.72 respectively. It is noted that wheat supply is price inelastic in the short run and price elastic in the long run. This implies that wheat producers adjust their production relatively less than the price changes in the short run but more than proportional to the price change in the long run.

Table 6.7: Short and long-run price elasticities

Independent variable	Short-run elasticity	Long-run elasticity
Real wheat price	0.79	1.72

Source: Authors calculation

Chapter 7: Discussion and Conclusion

Introduction

The purpose of this chapter is to present the major findings and critically discuss the research. The first section discusses the major findings of the study. The second section draws the conclusion of the study based on these findings. Lastly, the chapter provides a critical reflection and possible solutions to the challenges faced in the study.

7.1 Major Findings

The first research question on describing wheat production and consumption trends has been answered using literature search. Figure 2.5 in chapter 2, illustrates the trends, showing a widening gap between production and consumption from the year 1960 to 2018.

From 1966-1974, 1980-1986, and from 1990 to the present domestic consumption surpassed domestic supply (Figure 2.5). This ultimately increases the import demand of the commodity which then increases the wheat import bills and further strains the country's budget.

Figure 7.1, shows the area under wheat production for the period 1965 to 2018. The figure shows that from 1966-1978 there was a substantial increase in the number of hectares devoted to wheat production. Thereafter, the area under wheat production started to fluctuate from 1978 to 2006. From 2006 to 2008 the country experienced a sharp drop in the area under production. It fluctuates again from 2010-2014 and lastly stabilises in 2016 onwards (Figure 7.1).

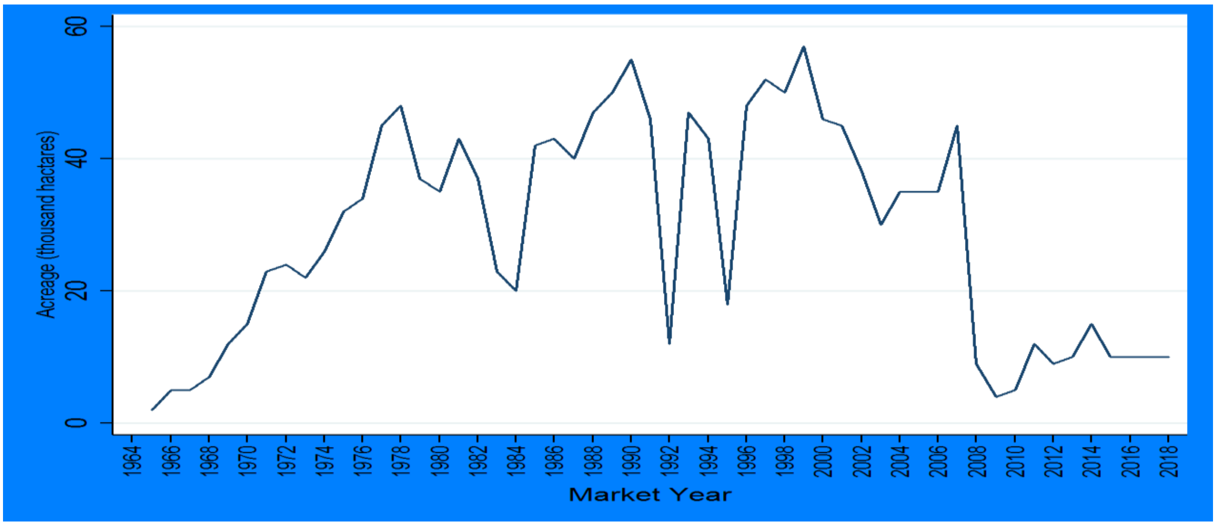


Figure 7.1:Wheat acreage trend from 1965 to 2018

The estimated supply function indicates that wheat production is affected by both price and non-price factors. Therefore, this provides answers to the second research question of the study. The results revealed that lagged real price is one of the factors which affects wheat production.

It has a positive impact on the wheat output with an elasticity of 0.79, suggesting that farmers will venture into wheat production on the basis of the previous price. The results indicate that a 10% increase in lagged real price of wheat results in 7.9 % and 17% increase in total wheat output in the short and long run respectively. This concludes that wheat producers adjust their production relatively more than the price changes in the long run than in the short run. These results concur with the results from other studies such as (Yunus, 1993; Matin and Alam, 2004; Begum et al., 2002). Short-run results are in agreement with the results obtained by (Bhatti et al. 2011) and (Huq et al., 2013). But, the long-run price elasticity results differs.

The lagged output (t-1) is another factor affecting wheat production in Zimbabwe. It has a negative effect on the wheat output with an elasticity of -0.53, implying that a 10 % increase in lagged output (t-1) results in a 5.3 % decrease in actual output. Therefore, it is concluded that the supply conditions of the previous season will affect the production of the next season. However, these results are in disagreement with the results obtained by (Bhatti et al., 2011)) and (Mann and Warner, 2017)). They find that previous output has a positive impact on actual wheat output.

The results show that land reform policy which was implemented in the year 2000 is another determinant of wheat production in Zimbabwe. The results revealed that the policy had a negative impact on wheat output. This implies that the policy disincentives wheat producers to a great extent. The implementation of the land reform policy led to the destruction of irrigation equipment and infrastructure. Moreover, during the land reform process, the land was redistributed to smallholders farmers with no agricultural expertise and enough capital to participate in wheat production.

Lastly, lagged rainfall is another important factor that determines wheat production. Rainfall received in the previous season had a positive impact on wheat produced in the next season. More rainfall received in the previous year suggests that water sources such as dams and water reservoirs will be having sufficient water for irrigation in the next season. Similar findings were obtained by (Mann and Warner, 2017) who concluded that yields are higher in areas with moderate levels of available water for irrigation. However, in the study by (Huang and Khanna, 2010), their findings were uncertain, they cited that changes in rainfall could lead to an increase or decrease in wheat yields.

7.2 Conclusion

The major objective of this study was to estimate the aggregate wheat supply function for Zimbabwe from 1965 to 2018. The output response function derived from profit-maximising was applied to determine the effect of price and non-price factors on wheat production. All variables were in logarithmic form and were tested for stationarity except for the time trend and dummy variable. The function was estimated using the Nerlovian partial adjustment model. Different diagnostic tests applied confirmed the fitness of the model.

As a result, it was established that wheat supply is negatively affected by the output of the previous season and the land reform programme which was implemented in the year 2000. The results of the study showed that wheat supply depends on the rainfall of the previous year, suggesting that sufficient water for wheat irrigation is available if the country receives more rainfall in the previous season. The findings of the study also revealed that wheat supply is price inelastic in the short run, implying that farmers are relatively unresponsive to output prices in the short run, but more responsive in the long run. It is shown that in the long run, the short-run supply limitations will be resolved and farmers can adjust their level of production to a greater extent. This could suggest that domestic wheat price support and price stabilisation policy might influence the wheat supply, but more research is needed to make concrete policy conclusions.

7.3 Critical reflection and possible solutions

This study estimates the aggregate wheat supply function for Zimbabwe using secondary data. Even though the results are important to the policy makers, in themselves they do not command policy conclusions. This is because of the limitations of the study. Firstly, the study could not capture all important variables explained in the theoretical chapter (e.g. fertiliser, labour and electricity costs) due to lack of data.

Secondly, the study uses aggregate data collected from different sources. Some sources display different figures of the same variable for example in case of the exchange rates. In addition, the study focuses only on the aggregate wheat response to price and non-price factors while possibly there could be a difference in response between farm level and national level.

Thirdly, the effect of the transaction costs explained in the theoretical chapter was also not captured in the empirical model. Transaction costs which play a key role in the trading of commodities to determining the implicit and explicit costs of the transaction.

Therefore, considering the limitations of the study highlighted above, the following points for further research were recommended. Instead of using the aggregate data, one can use farm-level data, implying that primary data will be used in the analysis. By using primary data the author gains control over the quality and accuracy of the data. Data can also be collected with the research questions in mind. Moreover, using farm-level data more information can be collected, thereby increasing the number of variables in the analysis. The effect of variables that differ on regional and farm level can be investigated e.g. farmer's expertise. This will enable to formulate regional policies and target specific groups of farmers.

In addition, there is need to study whether Zimbabwe has a comparative advantage of producing wheat. More research is clearly needed on specific aspects of this, such as (i) is it an efficient use of resources for the country to produce wheat? (ii) If it is efficient to produce wheat, what combination of policy incentives and technological change are needed to promote domestic wheat production?

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APPENDIX A:

Table A-1:Zimbabwe Wheat production, Consumption, Imports, Acreage, Yield /ha and Exports

Market Year	Production (1000 MT)	Consumption(1000MT)	Imports(1000 MT)	Acreage (1000HA)	Yield MT/HA)	Exports(1000MT)
1960	1	77	79	1	1	3
1961	1	83	85	1	1	3
1962	1	61	64	1	1	4
1963	2	81	83	1	2	4
1964	4	75	73	1	4	2
1965	4	85	85	2	2	4
1966	10	94	84	5	2	0
1967	15	82	67	5	3	0
1968	25	107	82	7	4	0
1969	40	90	58	12	3	0
1970	54	112	77	15	4	0
1971	89	124	55	23	4	0
1972	85	108	20	24	4	0
1973	86	130	65	22	4	0
1974	97	148	42	26	4	0
1975	126	143	12	32	4	0
1976	145	118	10	34	4	0
1977	173	127	0	45	4	1
1978	212	148	0	48	4	2
1979	161	172	0	37	4	8
1980	162	206	3	35	5	5
1981	201	224	17	43	5	0
1982	213	235	30	37	6	0
1983	124	240	71	23	5	0
1984	99	230	104	20	5	0
1985	205	228	86	42	5	0
1986	225	243	53	43	5	0
1987	215	260	75	40	5	0
1988	257	217	14	47	5	20
1989	284	284	8	50	6	0
1990	325	384	65	55	6	11
1991	259	380	0	46	6	0
1992	57	280	170	12	5	0
1993	275	280	33	47	6	3
1994	240	303	78	43	6	1
1995	67	186	157	18	4	88
1996	263	278	75	48	5	0
1997	250	383	133	52	5	0
1998	300	332	32	50	6	0
1999	324	336	12	57	6	0
2000	255	278	23	46	6	0
2001	325	338	13	45	7	0
2002	150	310	110	38	4	0
2003	90	260	170	30	3	0
2004	105	235	130	35	3	0
2005	120	245	125	35	3	0
2006	135	260	125	35	4	0
2007	135	260	125	45	3	0
2008	38	270	200	9	4	0
2009	12	275	250	4	3	0
2010	18	265	250	5	4	0
2011	23	261	250	12	2	0
2012	17	275	250	9	2	0
2013	25	285	250	10	2	0
2014	34	325	300	15	2	0
2015	20	300	280	10	2	0
2016	20	300	280	10	2	0
2017	20	300	280	10	2	0
2018	20	320	300	10	2	0

APPENDIX B:

Plots of the variables at levels, but in logarithms. The plots shows that all variables were non-stationary at levels except for the lagged rainfall which was stationary (Figure B-III).

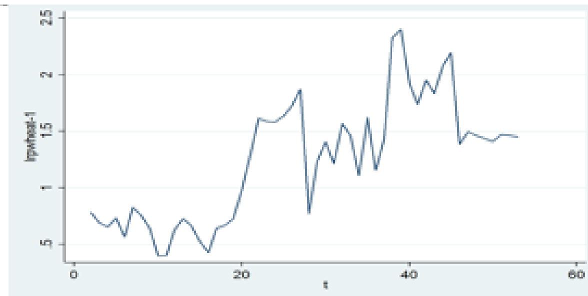

Figure I:Lagged real wheat price

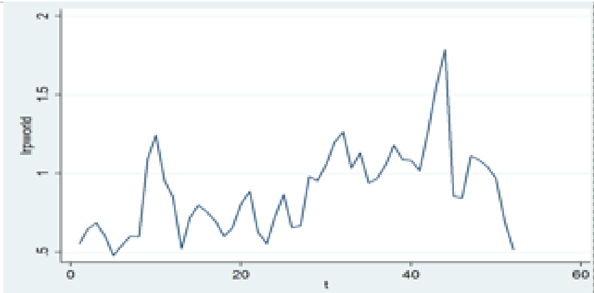

Figure II: World wheat price

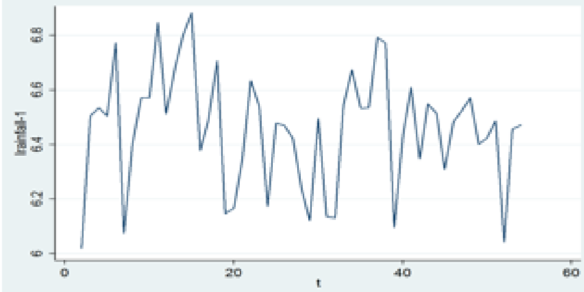

Figure III: Lagged rainfall

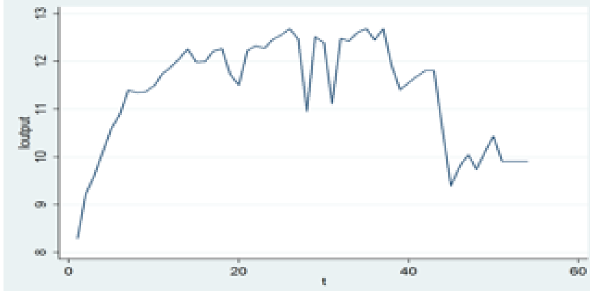

Figure IV: Actual output

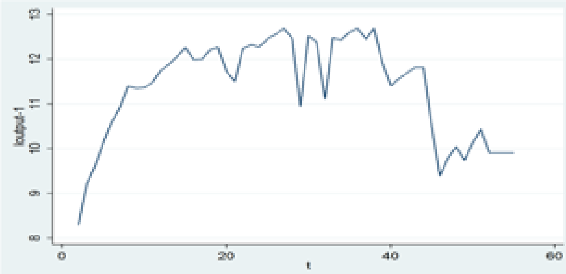

Figure V: Lagged output (t-1)

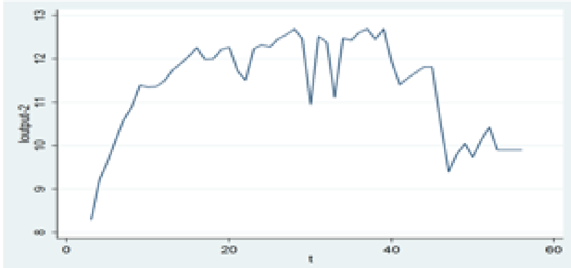

Figure VI: Lagged output (t-2)

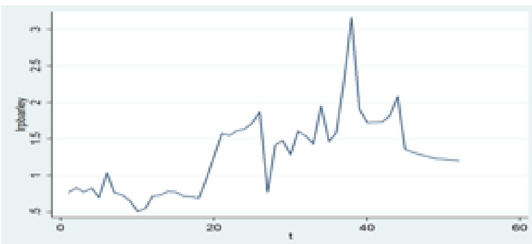

Figure VII: Barley price

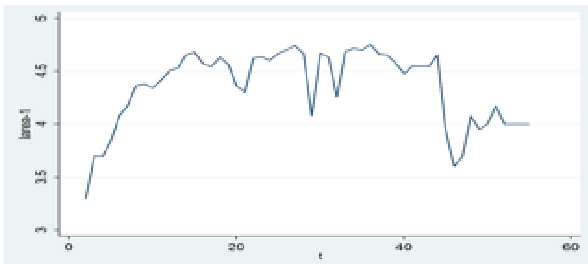

Figure VIII: Lagged acreage

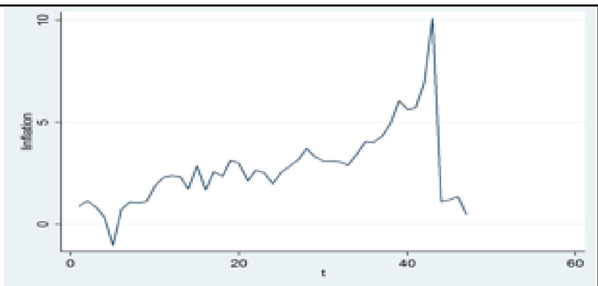

Figure IX: Inflation

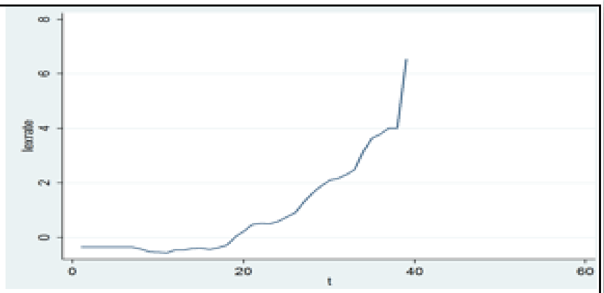

Figure X: Exchange rates

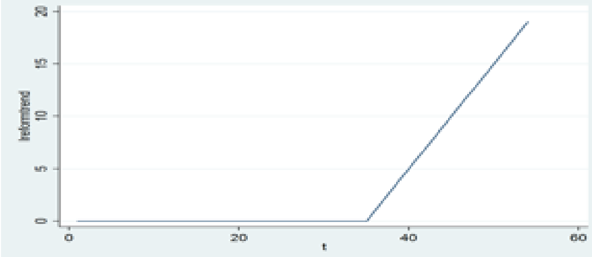

Figure XI: Land-reform trend

APPENDIX C

Soil status in Zimbabwe

By analysing Table I and Figure I, the country is dominated by soils of Order Kaolinitic. The Order comprises Fersiallitic, Paraferrallitic and Orthoferrallitic soils. These soils are mainly formed from granite rocks which is the parent material for the sandy soils. This implies that sand to sandy loam soils mainly dominates the country (Hove et al., 2008). Sandy soils are inherently infertile with low soil organic matter (SOM) and susceptible to leaching. The kaolinite soils dominate in Natura region I, II, III, and IV. Kaolinite soils have low Cation Exchange Capacity (CEC) (Mohanty et al., 2015). CEC refers to a soil chemical property which acts as soil fertility indicator. It shows the ability of the soil to hold and supply plant nutrients. Therefore, soils with high sand content have low CEC, implying that they supply less plant nutrients (Firoozi et al., 2016).

The majority of the smallholder farmers are located in sandy soils and these farmers have limited resources and limited agricultural expertise which hinders effective crop production in the country (Nyamangara et al., 2000). As explained in chapter 2, wheat production is mainly practiced in Mashonaland Central, Mashonaland East and Mashonaland West provinces, these provinces fall in Natural region I,II and III mostly. But, these regions are dominated by sandy to sandy loam soils with less organic content and susceptible to leaching (Hove et al., 2008). Therefore, it is highly recommended to add organic and inorganic fertilisers to boost soil fertility. Nitrogen (N) and phosphorus(P) are the nutrients identified to limit crop production in Zimbabwe (Hove et al., 2008). Hence, to increase crop yields by smallholder farmers appropriate amount of fertiliser or manure need to be applied.

Soil classification in Zimbabwe

Table 3:Soil classification in Zimbabwe

Order	***Description***	***Group***	***Typical soil families***	***Agro ecological zone dominated***
AMORPHIC	Very little or no horizon development	1. **Lithosol**- very shallow soils 2. **Regosol**- deep and extremely low silt/clay ratios	• Derived from mafic rocks • Deep sands derived from Kalahari desert	Region IV western and Northern parts
CALIMORPHIC	Unleached soils with large reserves of weatherable minerals	3. **Vertisols** – moderately deep to deep clay soils and acidic	• Derived from basalt and mafic rocks	Region V

		4. **Siallitic** – shallow to moderately shallow clay soils	• Derived from mafic rocks	
KAOLINITIC	Moderately to strong leached soils. Clay fractions mainly kaolinite together with appreciable amounts of free sesquioxides of aluminium and iron.	5. **Fersiallitic** – soils with weatherable minerals 6. **Paraferrallitic** – mainly sand soils 7. **Orthoferrallitic** – highly porous and truely ferrallitic soils	• Formed on granite rocks	Region 1, II,III and IV
NATRC	Soils contains significant amount of exchangeable sodium	8. **Sodic** – horizons in which the amount of sodium is more than 9 percent.	• Soils with excess salts.	Region V

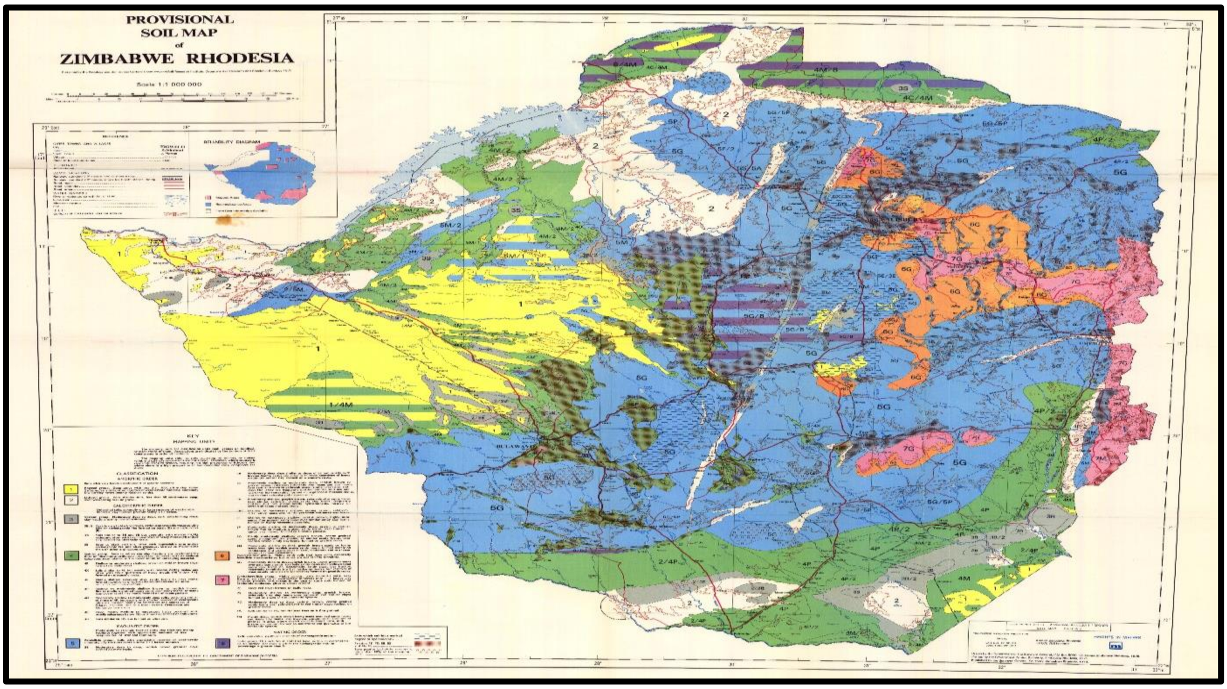

Figure 3: Soil map of Zimbabwe

APPENDIX D

Water availability

Access to water is free only for basic use. Farmers who intend to use water from rivers and dams for irrigation purposes (commercial use) are required to obtain water permits from the Zimbabwe National Water Authority (ZINWA). Water permits help in safeguarding the interests and allocations of permit holders. For example in times of water scarcity, farmers with permits will be given priority to use water before new water users are taken. However, farmers holding water permits are required to pay for the water use and this affect winter crop production to a greater extent because most smallholder farmers are not able to pay for the water bills for irrigation (ZINWA, 2014).

Figure 2 below shows the water catchment areas in Zimbabwe. ZINWA divided the country into seven water catchment areas which includes; Gwayi, Mazoe, Mzingwane, Runde, Sanyati, Save and Manyame. These are considered to be more effective accountability units for water use. Each catchment area comprises of permanent rivers and dams which intend to supply water to local farmers. The provinces where wheat production is mainly practiced are being water supplied by Manyame, Mazoe, Sanyati, Save, and Runde (Figure 2).

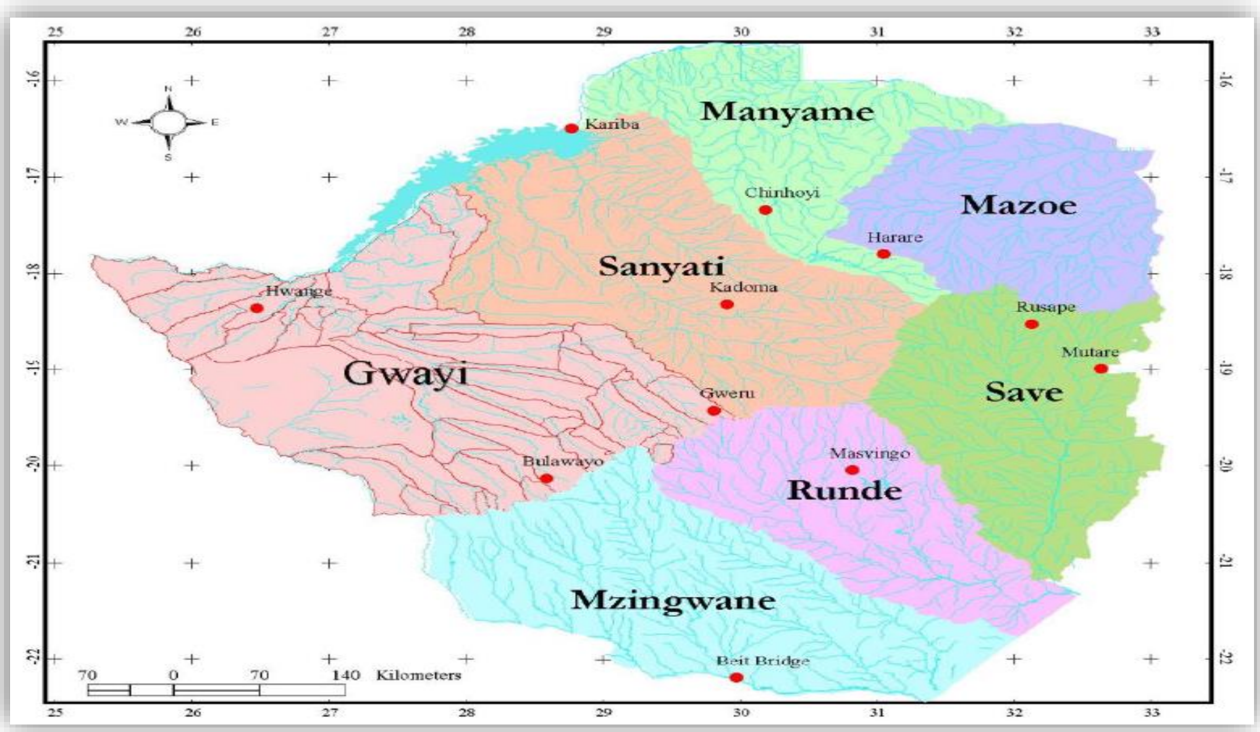

Figure 4:Water catchment areas in Zimbabwe: (Makurira and Viriri, 2017)

APPENDIX E

Money supply

In 2009, Zimbabwe officially adopts the U.S. dollar as its currency. The introduction of the U.S dollar shows a significant change in the stability of the economy (Mpofu, 2015). From 2009 to 2015 Zimbabwean economy started to normalise gradually. But, in the first quarter of 2016, cash shortages re-surfaced and the Reserve Bank of Zimbabwe introduced the bond notes to solve the problem. Bond notes were given the same value as the U.S dollar. However, bond notes were not legalised to be used outside Zimbabwe. The present situation implies that Zimbabwe is trading with two types of currency; the foreign currency and the local currency. The Government officials insisted that the two currency is at par, but, on the black market, they have two different values. The foreign currency shortages worsened to the extent that it is only found on the black market, suggesting hyper-inflation in the country. This causes prices of inputs such as fertilizers, seed and agro-chemicals to rise as the currency loss value. Therefore, this continue to hinder wheat production in the country.