The development of an integrated modelling framework for the dualistic beef sector in Namibia

Thesis submitted in partial fulfilment of the requirements for the degree PhD

By

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DEDICATION

This research work and its outcome is dedicated to my family – my wife, Mariane Grace, and three sons, Jabari, Sean and Barnabas – this is for you, a great reward and accomplishment. We have achieved this outcome as a team.

DECLARATION

I declare that this Thesis, which I hereby submit for the degree of a Doctorate in Agricultural Economics at the University of Pretoria, is my own work and has not previously been submitted by me for degree purposes at any other university.

Parts of this thesis have been published and submitted for publications in journals.

All errors in thinking and omission are entirely my own responsibility.

SIGNATURE: ____________________.

NAME: Kennedy Sean Muzamai Kalundu

DATE: June 2023

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ABSTRACT

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This study develops an integrated model that can capture the dynamics of supply and demand in the dualistic beef cattle market of Namibia. The dualistic nature of the Namibian beef cattle sector is characterised by the co-existence of communal and commercial cattle production sub-sectors.

Against this background and context of Namibia, this study explores the ability of an integrated partial equilibrium model to generate various baseline projections, including the supply and demand variations, off-take rate, pricing and gross margin of the complex dualistic cattle sector.

In the process of evaluating the performance of the model, the study pursued three objectives: (i) to evaluate the impacts of price adjustment mechanisms and relationships in the beef cattle industry in Namibia; (ii) to project a baseline of main aggregate variables for the beef cattle sector that includes the slaughter stock, off-take rates and beef cattle disappearance in the commercial and communal areas; (iii) to quantify the impact of the productivity gain for the beef production, exports, pricing and long-term gross margin of the beef cattle industry in the formal and informal beef sub-sectors in Namibia. In pursuit of the first objective, this study estimated a multivariate cointegration vector error correction model. The findings on the price adjustment indicate that informal beef cattle prices do not adjust rapidly (about 63 percent) to equilibrium, compared with the cattle prices in the formal beef market (about 81 percent).

Further analyses of the disaggregation of the supply responses of live cattle and beef markets indicate that the main drivers of cattle and beef supply responses in Namibia are the off-take rates, veld condition, ratio between the beef carcass price and the weaner price.

Addressing the second and third objectives required the use of an integrated partial equilibrium approach to simulate the demand and supply dynamics of beef cattle in the formal and informal markets. An integrated partial equilibrium model developed in this study was based on the autoregressive distributed lag formulation.

A short-term projection from 2023 to 2030 was assumed in this analysis, which included two shocks. The outlook for cattle numbers in both formal and informal sub-sectors are increasing year-on-year. A productivity gain of 20-percent off-take rate would cause increases in slaughter numbers in the formal commercial sub-sector of 14.88 percent in 2023, about 0.05 percent in 2024, and no increase is expected from 2024 to 2030. While the informal sub-sector, slaughter stock is expected to increase by 0.04 percent in 2023, about 0.12 percent in 2024 and an increase of less than 0.23 percent is expected in 2026 to 2030. During the same scenario shock, the weaner stock numbers are expected to increase by 4.01 percent in 2023, an increase of 0.38 percent is expected in 2024, and 1.36 percent in 2025. Overall, a positive outlook is expected for slaughter stock, weaners and beef production. An increase in supply of slaughter stock and weaner has an impact on the price.

Namibia exports beef, therefore a trade policy shock introduced on the model to capture its implication on slaughter stock, beef production, weaner production, beef cattle price, on-farm supply of beef and gross margin. The shock leads to reduction of slaughter stock and beef production in the 2023 period only. This results in a positive growth in 2024 to 2030. A trade policy restricting access to the EU market means that Namibia would have to export its high value beef cuts to non-EU countries such as Norway, UK, USA, mainland China, Hong-Kong, South Africa and other African markets such as Angola, Ghana and Zimbabwe under the African Continental Free Trade Agreement.

This study shows that an integrated partial equilibrium model that incorporates the dualistic sub-sectors is ideal for capturing the real impacts more appropriately than would a single sub-sector analysis that does not account for the dualistic nature of commercial and communal sub-sectors. Such a single sub-sector analysis may overlook important aspects and implications of the policy by concealing the effects on the productivity and financial and economic positions of the farmers in a dualistic sub-sector. Accordingly, this study provides a modelling tool to be used by policy makers to comprehensively investigate the combined effects of policies on the disaggregated beef cattle sector and to perform scenario analysis. However, it is observed that the simulation outcome presents mixed results on slaughter numbers, beef production, prices, on-farm supply and beef export levels. Furthermore, the model simulates small impacts. This can be attributed to the autoregressive distributed lag approach adopted in chapter 4. An alternative approach is adopted, because developing a model, requires getting the model closure right, and it is just as important as having good supply and demand elasticity estimates. Therefore, to use the model developed in this study for policy formulation, a refinement to the model is required to generate robust and realistic impacts.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AALS	Affirmation Action Loans Scheme
ACP	African Caribbean and Pacific
ADF	Augmented Dickey–Fuller test
AfCFTA	African Continental Free Trade Agreement
AIC	Akaike Information Criteria
AGRIBANK	Agricultural Bank of Namibia
ARDL	Autoregressive Distributive Lag
ARCH	Autoregressive Conditional Heteroscedasticity
BFAP	Bureau for Food and Agricultural Policy
CBPP	Contagious Bovine pleuropneumonia
CE	Co-integrating Equation
CLRM	Classical Linear Regression Model
CPI	Consumer Price Index
CLS	Conditional Least Square
CSA	Central Statistics Agency
CUSUM	Cumulative Sum
CWE	Carcass Weight Equivalent
DVS	Directorate of Veterinary Services
DW	Durbin–Watson
ECM	Error Correction Model
ECT	Error Correction Term
EFTA	European Free Trade agreement
EU	European Union
EPA	Economic Partnership Agreement
FAN-Meat	Farm Assured Namibian Meat Scheme
FAO	Food and Agriculture Organization of the United Nations

GDP	Gross Domestic Product
Ha	Hectare
HQ	Hannan–Quinn
HS	Harmonised System of product classification
IID	Independently and Identically Distributed
Kg	kilogramme
kha	Thousand hectares
kt	Thousand tonnes
LLPs	Livestock and Livestock Products
LM	Lagrange Multiplier
LR	Likelihood Ratio
LWT	Live Weight
MA	Moving Average
MAWF	Ministry of Agriculture, Water and Forestry
Meatco	Meat Corporation of Namibia
MOC	Meatco Owned Cattle
NAP	National Agricultural Policy
NamLITS	Namibian Livestock Identification and Traceability System
NDPs	National Development Plans
NLSS	National Livestock Sector Strategy
NSA	Namibia Statistical Agency
NSIS	North-South Incentive Scheme
N$	Namibia dollar
N-VCF	North of the Veterinary Cordon Fence
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Square
PP	Phillips–Perron

RESET	Regression Specification Error Test
RGDP	Real Gross Domestic Product
RSA	Republic of South Africa
RSS	Residual Sum of Squares
RoA	Rest of Africa
ROW	Rest of the World
SADC	Southern Africa Development Community
SIC	Schwarz Information Criteria
SSA	Sub-Saharan Africa
SPS	Sanitary and Phyto-sanitary
S-VCF	South of the Veterinary Cordon Fence
TAR	Threshold Autoregressive
UK	the United Kingdom
UNAM	University of Namibia
US	United States
USDA	the United States Department of Agriculture
USD	United States Dollar
VAR	Vector Autoregressive
VCF	Veterinary Cordon Fence
VECM	Vector Error Correction Model
WDI	World Development Index
WEO	World Economic Outlook
ZAR	South African Rand (currency)

CHAPTER 1:
INTRODUCTION

1.1 Background and Context

The cattle production system in Namibia is characterised by the existence of the veterinary cordon fence (VCF) that divides the beef cattle production sector into two, namely the viable and more productive disease-free commercial farming sector situated south of the veterinary cordon fence (S-VCF), and the underutilised communal farming sector north of the veterinary cordon fence (N-VCF). Despite this characterisation, a substantial number of communal farmers are also found south of the cordon fence (MAWF, 2015). In fact, the Agricultural Bank of Namibia loan book includes emerging commercial farmers registered in the northern communal areas, as well as south of the veterinary cordon fence. Both these new groups are engaged in commercial cattle production (AGRIBANK, 2019).

Industry data on the Namibia Livestock Identification and Traceability System (NamLITS) regulated by the Directorate of Veterinary Services (DVS) show that the N-VCF is characterised by cattle held among small-holder farmers with a typical low off-take rate and by farmers who raise cattle for other reasons such as a store of value as capital goods (MAWF, 2012). The national cattle herd, comprised of various systems and types of tenure, is presented in Figure 1.1.

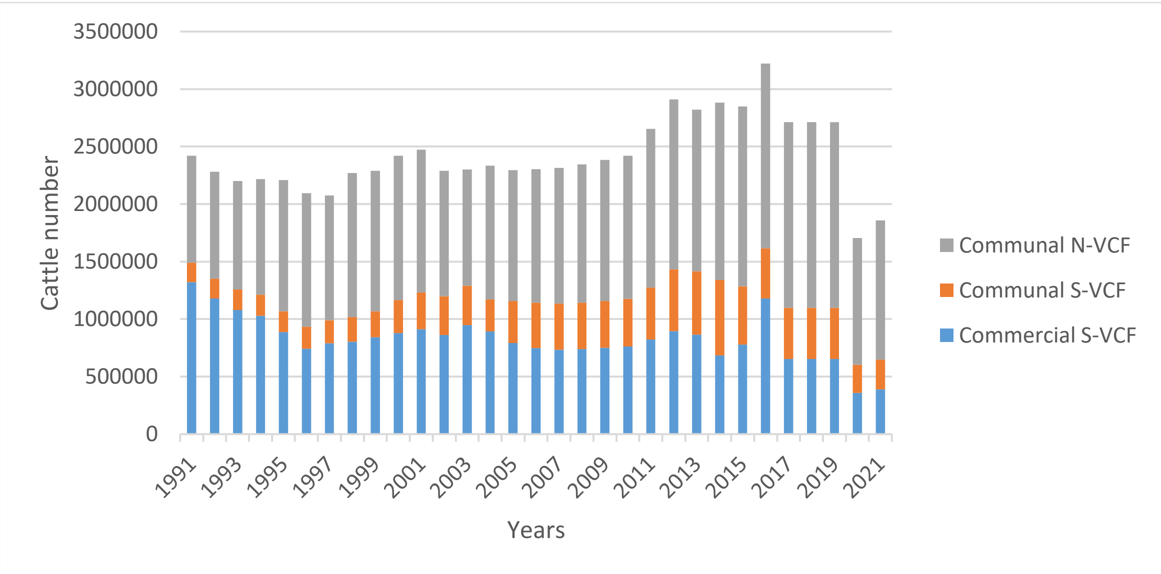

Figure 1.1: Cattle numbers in Namibia

Source: Author’s compilation using Ministry of Agriculture, Water and Land Reform data, 2021.

Given the classification of the farmer groupings, it is important to understand the variation in supply in the Namibian beef cattle production context. Namibian beef producers pursue three main beef production systems, the cow-to-ox production system, the cow-to-weaner production system, and the speculative option of weaner-to-ox system. Under cow-to-ox production, the farmer raises the calf to mature ox (about 2 to 3 years) for slaughter at the abattoir. The cow-to-ox production system is dependent heavily on the quality and quantity of veld, and the slaughter producer carcass price. In the case of the cow-to-weaner system, the farmer raises the calf from 7 to 18 months and auctions it to a feedlot for further feeding. The speculative weaner-to-ox system largely depends on the ratio of weaner price to carcass price (Sartorius von Bach, 2020 and NAU, 2018). Factors associated with the condition of the environment enhance the decision making for most cattle producers. The common denominator for most farmers is to base supply decisions on the prevailing price ratio per kilogram for a 7-month young weaner at live mass, in relation to an ox of about 27 months old. The Meat Board’s data indicate that, on average, the weaner/carcass price ratio is about 62 percent (MBN, 2016; 2017; 2019 and 2020). It is evident that, if the weaner price increases above the 62 percent of the carcass price, in gross margin earning terms per animal, it is not worthwhile to allow weaners to remain on the veld for more than 20 months. The ideal decision for a farmer is to argue against marketing the animal at 27 months, but rather to decide to market the animal as a young weaner at a profitable auction. The reverse position to making this decision is that, if the weaner price is below the said 62 percent, the farmer would then decide to rear and allow the weaners to attain the slaughter mass at 27 months (Sartorius von Bach, 2020 and NAU, 2019). As can be deduced from Figure 1.2 below, the price ratio affects a farmer’s decisions, and equally so, it has implications for the throughput of slaughter animals at the abattoirs.

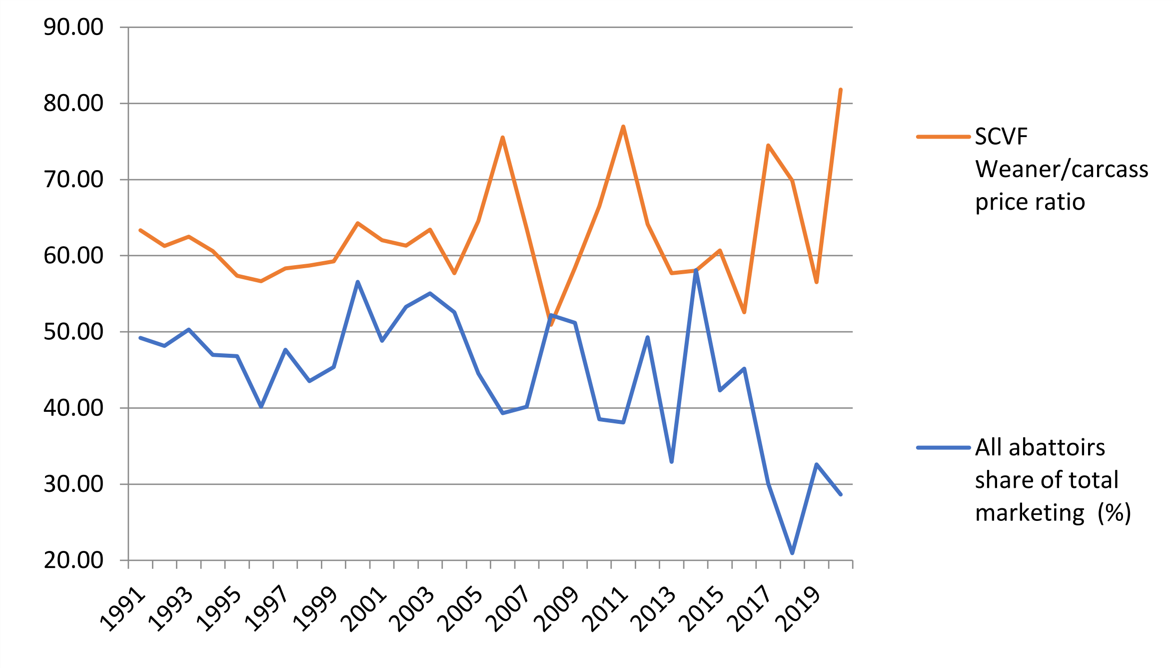

Figure 1.2: Beef and weaner price ratio S-VCF in Namibia

Source: Ministry of Agriculture, Water and Land Reform, 2021 and Meat Board of Namibia, 2020.

These production decisions have implications regarding the supply variation, since about 90 percent of beef cattle production is based on the free-ranging system where cattle graze freely on large grazing lands (MBN, 2020). It is a common practice in Namibia that cattle are fed and finished on the pastures, without any supplementary feeding. The feedlot production system has not been practised by most of the cattle producers in Namibia because it is expensive and escalates the cost of production, since the major ingredient in feedlot feeding is imported.

The Meat Corporation of Namibia (MeatCo) became a state-owned enterprise in 2001 after the amendment of the Act a decade ago and it is empowered to buy, process and export beef to various markets (MCN, 2015). Prior to the amendment of the Act, SWAMeat Co-operation which was established in 1988 as a producer based abattoir with overarching influence and authority from the Ministry of Agriculture. Over the years of its operation, Meatco was influential in the livestock industry to point where the Okapuka feedlot was introduced in the 1996/97 financial year, after the 1995 drought, and the Ekwatho Financing Scheme in the 2007/08 financial year as in-house trial and error schemes for backward integration projects to support the supply channel. Over the ensuing 19-year period, other supply channels, such as the veld cattle production system, proved to be cheaper than the feedlot system was (MCN, 2019). Meatco has since embarked on a backward integration system (MCN, 2015), referred to as Meatco Owned Cattle (MOC). This backward integration accounted for about 10 908 slaughter cattle in the 2016/17 period, while Meatco feedlots accounted for 23 662 slaughter stock during the same period. These slaughter numbers decreased to 2 518 and 19 202, respectively, in the 2018/19 financial year (MCN, 2019 and 2020). However, the decrease in slaughter numbers at the export abattoir illustrates the impact of the severe and extended drought experienced in Namibia during the 2012/13 to 2018/19 period.

Being a small country in the world beef market, Namibia produces an excess of beef cattle and beef products. Therefore, Namibian beef cattle and beef products, through a computer-based tracking systems and distinctive symbol for each cattle to allow identification of the farm of origin achieved through the Farm Assured Namibian Meat Scheme (FAN Meat), have enjoyed access to several markets and with the characterisation of four tiers. These comprise the domestic market (which is composed of both the formal and informal sectors for live cattle and livestock products); the South African market (where Namibia exports live weaners aged between 9 and 27 months, as well as fresh or chilled/frozen carcasses, cuts and processed beef); the rest of Africa (RoA) for beef cuts and processed beef from NCAs and the lucrative European Union (EU) market, for prime boneless beef. For example, Meat Board trade data reveals that, under a unique European Free Trade Agreement (EFTA), Namibia in the past exported 1 600 tonnes of vacuum-packed boneless cuts and chilled beef to Norway (MBN, 2016 and 2019). It is important to mention that the Southern African Customs Union (SACU) is allocated a total quota of 3 700 tonnes by the EU. Namibia and Botswana are allocated about 1 600 tonnes each from the SACU allocation, while Eswatini receives about 500 tonnes. In 2017, the Norwegian annual export value accounted about N$310 million to the Namibian economy.

The importance of the Norwegian beef market is that it has a tariff-free quota shared amongst Namibia, Botswana and Eswatini. Norwegians are known to pay the most for prime beef and consume 17 percent of steak/fillets from the SACU region and, through the activities of Global Protein Solutions (GPS), allows for further beef trade for the SACU-European Free Trade Association, and could include possible quota enlargements, as well as duty-free access to the World Trade Organization for the long-term benefit of Namibia.

At national level, the estimated Namibian beef consumption per capita is about 14 kilogrammes. This represents a total of about 55 000 carcasses. Currently, export abattoirs located south of the VCF slaughter 70 000 carcasses, most traded to RSA, and further.

Typically, live exports are in the region of 200 000 cattle, and beef import carcass equivalents are around 15 000 (Sartorius von Bach, 2020). Local consumption originating from domestic beef production accounts for about 40 000 carcasses (inclusive of cattle from the north of VCF), which equates to about 8 percent, while live exports account for about 65 percent (Sartorius von Bach, 2020). Namibia accounts for 10 percent of beef exports to RSA (DAFF, 2016 and 2017), while beef exports to other markets, which originate only from S-VCF, are at about 17 percent (Sartorius von Bach, 2020).

Based on the Meat Board data, demand variations show that approximately 45 percent of the beef cattle slaughtered is consumed domestically, while the remainder 55 percent is exported. Of the exported beef, South Africa accounts for about 14.30 percent, the UK accounts for 13.53 percent, the Norwegian export market accounts for about 29.78 percent, and the EU accounts for 31.37 percent, while a small percentage goes to Hong Kong (about 0.57 percent), and Réunion receives about 0.65 percent (MCN, 2019; DAFF 2016; DAFF, 2017 and Comtrade, 2020).

1.2 Research Problem and Justification

Understanding the different markets requires a proper tool that analyses the industry through estimating the critical relationships between current supply variation, pricing, trade flows, and profitability of both the formal and informal beef markets. Thus, the standard integrated partial equilibrium model that was developed in this study to improve the ability and to evaluate the full impacts of policy and exogenous shocks in a comprehensive manner.

Studies conducted in Namibia on the livestock industry in the past have, for example, looked at the supply response in the beef industry by using ordinary least squares (OLS). Each of the factors that are incorporated into the ordinary least square regression framework has economic theoretical expectation. For example, Sartorius von Bach and Van Zyl (1990) investigated the supply of live cattle and beef in Namibia through utilising economic, trade, and income factors in their model. Their aim was to investigate the supply of beef in Namibia. The total of the cattle marketed was assumed to have been influenced by the lagged variables of aggregate cattle stock, sum of cattle exported, sum of Namibian carcasses, average carcass producer prices, income per carcass in Namibia, and South African average producer prices. The results from their study showed that average producer prices of beef did not generally play a major role in the supply response of beef in Namibia. The results and signs on the estimated coefficient showed spuriousness in the linearity of the parameters for the dynamics of supply of live beef cattle in Namibia.

Furthermore, comparative advantage, based on a cost–benefit approach, (Chiribonga *et al*., 2007) was found to be not conclusive on the nature of policy directives for the beef cattle industry in Namibia. Other studies have looked at the potential of the livestock industry (Kruger and Lammerts-Imbuwa, 2008), while Van Wyk (2011) used an error correction model (ECM) to analyse the mutton industry in Namibia's formal markets. Although these models are statistically sound, the results on price elasticity transmission do not represent a price formation process that is inclusive of the informal market setup. In addition, these studies have not explored the inclusion of instrumental variables in estimating the demand and supply elasticities of the formal beef cattle markets. These studies have omitted the need to estimate the price transmission elasticities in the informal beef cattle markets. This omission of demand and supply elasticities in the informal beef market undermines the importance of the sector to the mainstream agricultural contribution and leads to the formulation of sub-optimal polices for the industry.

Model tools previously developed for policy formulation for beef cattle in Namibia have ignored the existence of the dualism that exists in the beef cattle markets. These models assumed linear methods of price mechanism (Sartorius von Bach and Van Zyl, 1990), based on average effects that may not explicitly be reflective of the complicated Namibian beef market. The Namibian beef cattle market is influenced by institutions and instruments introduced by the government. These institutions have influences on the supply dynamics in each individual market segment. In fact, institutions have impacts on the process of price formation and discovery in each respective market (Kirsten *et al*., 2009) and Jefferis (2007). The fact that the beef cattle market in Namibia is complex, has major implications for price discovery and formation, integration, and market equilibrium in the formal and informal beef markets, it requires an integrated partial equilibrium model.

Thus far, data has shown that Namibia produces sufficient beef cattle and is an exporter of cattle and beef products to the European Union, the United Kingdom, Norway, and South Africa. In recent years, Namibia has established a market in the USA for its beef (MCN, 2019 and MBN, 2020). The varying changes in regulations in these importing countries have major implications on the price determination, distribution, and beef cattle production in the domestic market. For example, regulations can affect performance directly through government-mandated process and production decisions.

This study explores the ability of an integrated partial equilibrium model to generate various baseline parameters for the projections of supply and demand variations, off-take rate, pricing, productivity gains and gross margin of the complex and inclusive dualistic cattle sector with different health status and market access. It is the premise of this study that this model will support policy formulation in the Namibian beef industry.

The departure point for this study is the fact that previous studies conducted in Namibia failed to adequately address the complexities facing the beef cattle industry. The available literature regarding Namibia has not addressed the dynamism prevailing in the industry and does not address the impact of policy shifts on supply and demand for beef cattle in both the formal and informal beef cattle markets. Furthermore, previous studies have not addressed the long-term profitability of the beef cattle sector. In addition, these studies applied ordinary least squares and cost–benefit analysis methodologies, which did not capture the short-run and long-run policy impacts, and equally did not account for trade policy shifts and their impacts on domestic and international prices. Similarly, these studies did not account for supply and demand responses, institutions, and market instruments shifts.

The existence of the veterinary cordon fence, the dualism in the beef cattle sector, and the existence of the vibrant informal market and the formal beef cattle market all have implications for the supply variation and therefore present a challenge for policymakers in Namibia. It is known that the Namibian beef production system is reliant on the cow-to-ox production system, cow-to-weaner production, and the speculative option of weaner-to-ox system. However, in more recent years, each of these production systems has presented a major debate about the supply variation, pricing, and profitability of each of these production systems. This is because each of these production systems has different demand and supply dynamics, has different objectives for consumers and producers, and has different rules and institutional attributes in the short term and the long term. The perspective views are that, because of these dynamics of the industry, the role players must almost continuously make correct decisions that take account of all the sub-systems so that an overall policy framework will ensure optimal growth of the beef industry in Namibia.

Globally and comparatively, Namibia is a small country in the world beef market. However, it is a surplus producer of weaners, based on the cow-to-weaner production system, and of beef.

Nevertheless, many of the drivers of beef cattle industry performance, such as world prices, subsidisation and protectionism, are outside Namibia's control, although that does not mean that the beef cattle sector should not be guided by better policies and strategies to improve the performance of beef cattle supply, and off-take rates at export abattoirs. Namibia presents a more fundamentally complex industry than elsewhere in world because of the existence of the veterinary fence dividing the livestock sector into two parts, as well as the dynamics of the cow-to-ox production system, the cow-to-weaner production system, and the speculative option of the weaner-to-ox system. A sub-optimal policy framework set by government has led to naive measures of the inefficiency in cattle production and weaner exports, as well as the sub-optimal utilisation of the slaughter facilities in the beef industry (MBN, 2018). The same argument was raised by the findings of Chiribonga *et al* (2007). Support of this can be seen in the annual economic report produced by the Bank of Namibia (BoN, 2019), which indicated that the beef cattle industry only contributed about 5 percent to the gross domestic product (GDP), while the NSA (2018) revealed that the informal beef cattle traders had accounted for about 3.9 percent. Meanwhile, the National Livestock Sector Strategy (NLSS) has stated that Namibia could increase the slaughter off-take rate from the current 400 000 head to about 800 000 head of cattle, annually, at domestic slaughter abattoirs (MBN, 2012 and MBN, 2012a).

Furthermore, it has been argued that, since 1991, a sub-optimal policy framework has resulted in a reduction in the national off-take to 331 768 heads of cattle, annually (MBN, 2021). In addition, Namibia's export abattoirs have sometimes underutilised their Norway export quota allocation of 1 600 metric tonnes per annum (MBN, 2019a). Namibia, under the previous Lomé Convention for African Caribbean and Pacific (ACP) countries, underutilised the quota allocation of 13 000 metric tonnes, which was provided for under the most favoured nations clause (MBN, 2012a, 2011b and MCN, 2020). The Lomé Convention has since expired in 2008 (MBN, 2019a).

Therefore, the determination of prices in a country is dictated by the specific trade and policy framework of its trading partner. In this case, the Namibian domestic market prices are assumed to be integrated with the South African market prices and world prices. Most studies conducted in Namibia have not captured the shift in this basic market fundamental and how these shifts impact on the beef market. Given the existence of different market dimensions and complexities, policymakers should make better decisions concerning the reduction in the supply variation, pricing, distribution, and production policies to allow for better price transmission of elasticity in both the formal and informal beef market segments.

Understanding the different markets requires undertaking a proper analysis of the industry by estimating the critical relationships between the current supply variation, pricing, trade flows, and profitability of both the formal and informal beef markets. Accordingly, the standard integrated partial equilibrium model that was developed in this study improves the ability to evaluate the impacts of policy and exogenous shocks in a comprehensive manner.

The conceptual framework in Figure 1.4 presented below is based on data in the annual reports for the Meatco (MCN, 2020) and the Meat Board of Namibia (MBN, 2021), a large percentage (about 62 percent) of weaners from the off-take rates presented in Figure 1.3 are exported to South Africa on an annual basis. Over the years, the lucrative export of live weaners to South Africa has impacted upon the local export processing abattoirs. Moreover, Figure 1.4 presented below is based on data of the past 9 years (2013 to 2021), which account for the severe and extended drought period, and indicates that the export of live cattle and weaners obtained from the off-take rate presented in Figure 1.3 has created a mismatch in supply and demand for slaughter stock at domestic abattoirs, to the extent that 64 647 head of cattle are short, annually, in the domestic market (MBN, 2021 and MCN, 2021).

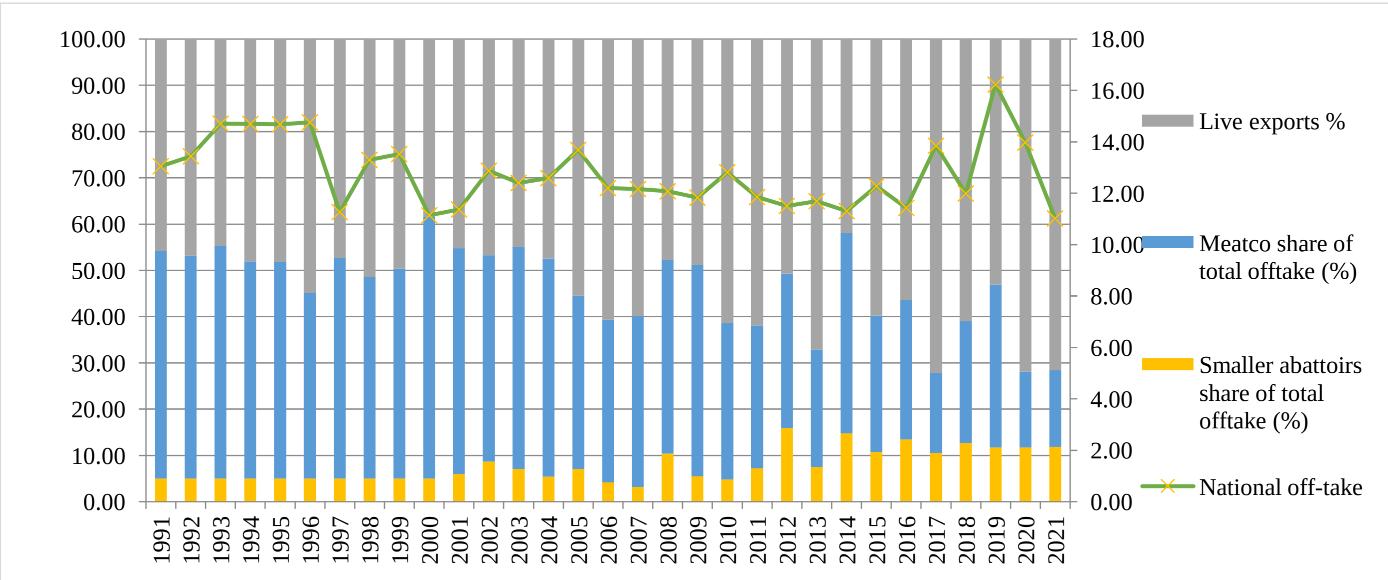

Figure 1.3: Beef cattle off-take rates from 1991 to 2021 period

Source: Based on data from the Meat Board of Namibia (2021).

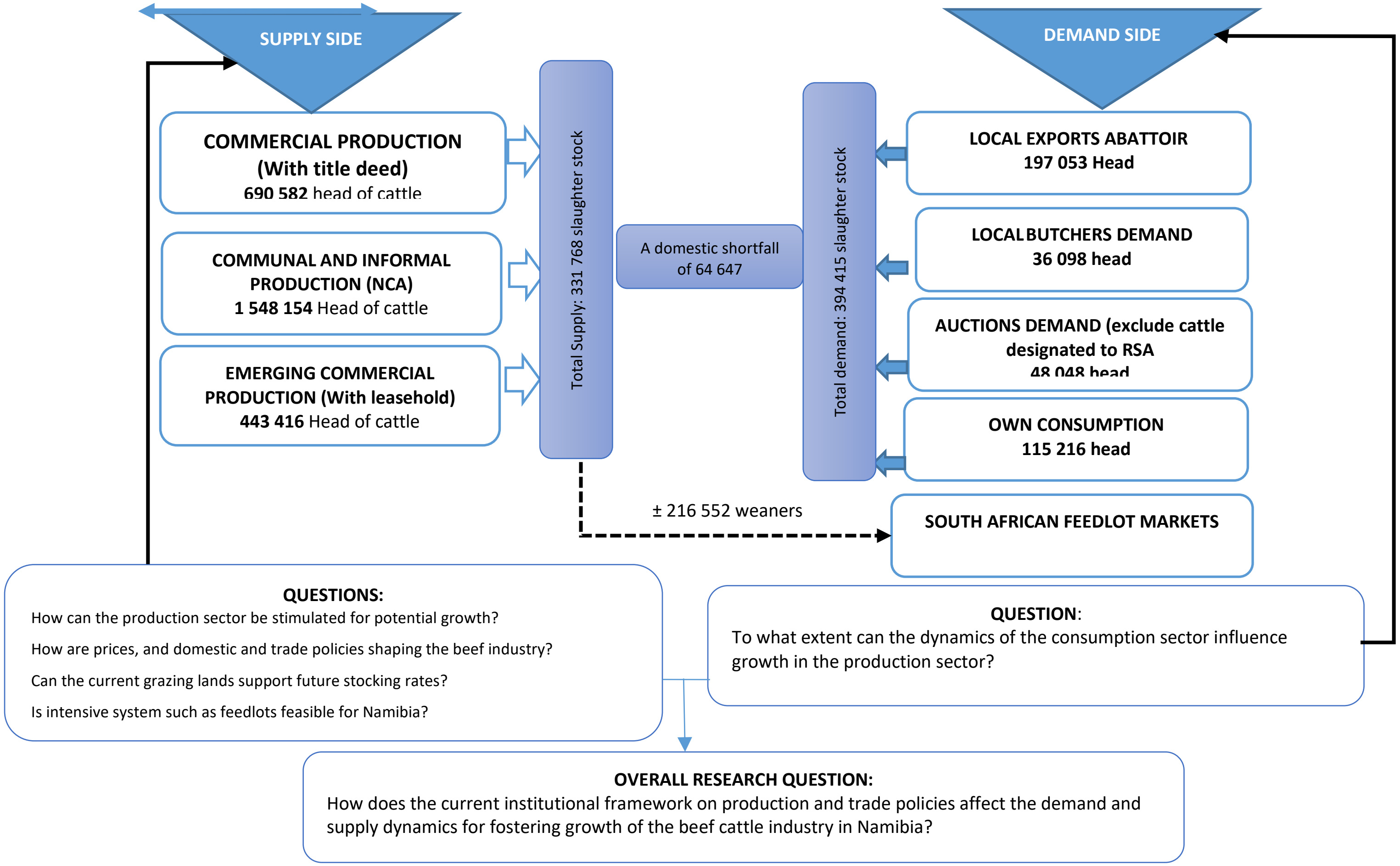

Figure 1.4: Conceptual framework for the study

Source: Author's own elaboration (2021)

1.3 Objectives

The primary objective of this research study is the design of a partial-equilibrium simulation model for the beef cattle industry in Namibia that considers the dualistic realities of commercial and communal farming systems and markets, which is based on an in-depth analysis of the beef cattle industry, to afford the ability to evaluate the impacts of changes in policy shocks that are exerted exogenously. An evaluation of economic policies regarding the agricultural sector, which is based solely on insufficient common indicators, may identify important policy aspects and implications, but might do so by obscuring the effects on productivity, and on the economic and financial status of the farmers. A partial equilibrium model that considers the existence of dualistic markets and sectors is ideal to illustrate the effects of policy more accurately than a single sub-sector assessment would.

The study specific objectives are as follows:

- to evaluate the impacts of price adjustment mechanisms and relationships in the beef cattle industry in Namibia;
- to project a baseline of main aggregate variables for the beef cattle sector that includes
- the slaughter stock, off-take rate and beef cattle disappearance in the commercial and communal areas;
- to quantify the impact of the productivity gain beef production, exports, pricing and long-term gross margin of the beef cattle industry in the formal and informal beef sub-sectors in Namibia.

1.4 Hypotheses

With a correct model specification and formulation, the integrated partial equilibrium model provides the capability to produce various desired baseline projections, including the supply and demand variations, off-take rate, pricing, and profitability of the complex dualistic cattle sector. The integrated model can account for detailed analysis of the supply shifters on cattle production and their impacts on both demand variation and long-term gross margin. Thus, the model can provide better guidance for proper policy formulation for stimulating the growth of the beef industry in Namibia.

The partial equilibrium model developed in this study simulates the supply and demand responses under alternative policies. The study evokes different econometric tools to show how a long-term integrated empirical model for the formal and informal beef cattle markets provides better guidance for policy formulation. This statement is tested by answering the following first hypotheses:

- The partial equilibrium model developed for the formal and informal beef markets provides better projections of the supply and demand variations in the domestic beef market;
- The current productivity status quo in the beef cattle industry has not stimulated long-term gross margin in the informal and formal beef markets;
- The Namibian beef policy regulation and institutional arrangements pursued by the government have been sub-optimal because they have not stimulated long-term growth for the industry.

1.5 Methodology and Data

For the purpose of modelling and addressing the research objectives, the study adopts a combination of econometric models to estimate a set of elasticities, which are then introduced into a partial-equilibrium framework to simulate a comprehensive and integrated demand and supply system for the commercial and communal beef sectors in Namibia. The modelling framework was guided by the formulation of the main equations. These equations include the domestic market equation, further sub-divided into demand and supply equations for both the formal market and the informal market; and the price formation equation, which computed the weighted average export parity price for beef and weaners for Namibia. In addition, South African export equations, subdivided into the market for live cattle and the market for beef carcasses, and the aggregated European market equation, which comprises the market for boneless and chilled beef, were utilised. As a matter of principle, the South African and aggregated European Union equations are formulated based on understanding the long-term relationship between the South African market and Namibia, and between Namibia and European Union beef market, taking into consideration the market integration and price transmission to the Namibian beef cattle market. Finally, the study also uses the simulated prices to compute the profitability of the beef cattle sector in the commercial and communal sub-sectors, as impacted on by the trade policy shifts, regulations and market instruments experienced by the producers in the two sub-sectors.

1.6 Limitations of the Study

The focal point of the study was to formulate an integrated dualistic model that can capture the dynamics of supply and demand in the beef cattle markets of Namibia. The main purpose of this study was to provide an understanding of how structural-related issues cause a decline in the number of marketable cattle stocks in Namibia. The dualistic nature of the Namibian beef cattle sector is not unique to Namibia, but it is not common to other major cattle and beef producers in world. The existence of communal (mostly informal) producers and commercial (mostly formal) producers creates different supply dimensions and demands in both the northern communal areas and the southern commercial areas of the country. Therefore, the modelling approach followed in the analysis does not serve as cure-all, but rather offers descriptive details for the reasons of declining numbers of slaughter stock in Namibia and then provides suggestions for policy directives to remedy the underperformance of the beef cattle industry in Namibia. The animal health status designated by the presence of the veterinary cordon fence has a significant effect on the farms' productivity. The land tenure policy, leaseholds and property rights have impacts on the cattle production system. The issue of tenure systems and their respective implications for cattle production are not addressed in this study, and we acknowledge that the omission of these effects is a major limitation of this study. Attempts were made to include the effects of exogenous macroeconomic variables on price formation and equilibrium formulation of beef cattle supply and market prices by using theoretical and empirical approaches.

1.7 Outline of the study

This study is outlined as follows: Chapter 2 provides a comprehensive summary that helps to understand the beef cattle industry in Namibia, as pertaining to the beef cattle demand and supply, and to the structural and institutional framework of the Namibian beef cattle sector. Furthermore, the chapter provides an overview of the empirical analysis of the global determinants of the demand and supply of beef cattle and guides the formulation of the partial equilibrium model. Chapter 3 describes the dynamics of the partial equilibrium framework, shows the mechanism through which policy effects are translated from broad aggregates to the micro economy, and explains how to better understand the price discovery process in the beef cattle industry. Chapter 4 presents two folds, firstly, is the partial equilibrium framework that captures the market fundamentals of the beef cattle industry – it integrates the aspects identified in Chapters 2 and 3 of this study, thus informing the first and second hypotheses statements. Secondly, it formulates the partial equilibrium model and illustrates how the dynamics of the partial equilibrium framework capture the mechanisms through which policy effects are translated from broad aggregates in the supply-side and the demand-side on the micro economy and describes how better to understand the price discovery process in the beef cattle industry. Chapter 5 presents the results and discussion of supply and demand-side and pricing equations presented in chapter 4. While chapter 6 presents the results from the projection and simulation analysis of the proposed macroeconomic and sector-specific policy shocks to demonstrate the potential policy distributional impacts on the beef industry in Namibia. Finally, Chapter 7 provides a conclusion to this study by summarising all the findings of this study, the conclusion, policy recommendations and future areas for research.

CHAPTER 2:
A REVIEW OF CATTLE BEEF PRODUCTION AND MARKETING IN NAMIBIA

2.1 Introduction

This chapter serves as a foreword to Chapters 3, 4 and 5 of this study. The chapter describes the importance of understanding the key variable selection from the empirical literature and the formulation of an integral beef model for the dualistic beef industry in Namibia. In addition, this chapter offers a contextualised understanding of the performance of the Namibian economy, and an overview of the livestock industry, the structure of the beef industry, and its characteristics. This chapter furthermore discusses previous studies that have examined (i) the determinants of demand for beef cattle analysis, (ii) the supply determinants of the beef cattle production, (v) the policy and measurement of behavioural parameters in livestock and meat industries, and (v) the livestock supply and production situation in Namibia.

2.2 Understanding the Performance of the Namibian Economy

The Namibian economy experienced an average real GDP growth of about 2.16 percent during the 2010 to 2020 period, during which the real GDP growth peaked at over 5.8 percent in 2014, presented in Figure 2.1, (BoN, 2019, 2021). The 2014 spike increase in GDP was attributable to high prices for primary commodities, and the boom in the construction and mining industry sectors. Since the sharp growth experienced in 2014, Namibia went through a meandering average growth of 3.9 percent from 2012 to 2017. However, year-on-year average growths show that the GDP in Namibia grew at about 0.7 percent in 2018, with projections for 2019 and 2020 being dimmed to a negative trajectory (BoN,2019, 2021). Data analyses from the Agricultural Bank of Namibia and the Bank of Namibia suggest that the risks to the domestic economy outlook from 2019 and beyond pinpoint factors that include low commodity prices. Thus, Figure 2.1 below depicts the GDP growth for Namibia from 2010 to 2020 (with GDP growth of -7.3 percent projected for the 2020 period). The GDP growth rate for 2019 was about -1.1 percent, which is indicative of the severe and extended drought affecting the primary sector (BoN, 2020). It can be summarised that GDP growth is trending downwards, and this trend is fairly supported by the foregoing discussion.

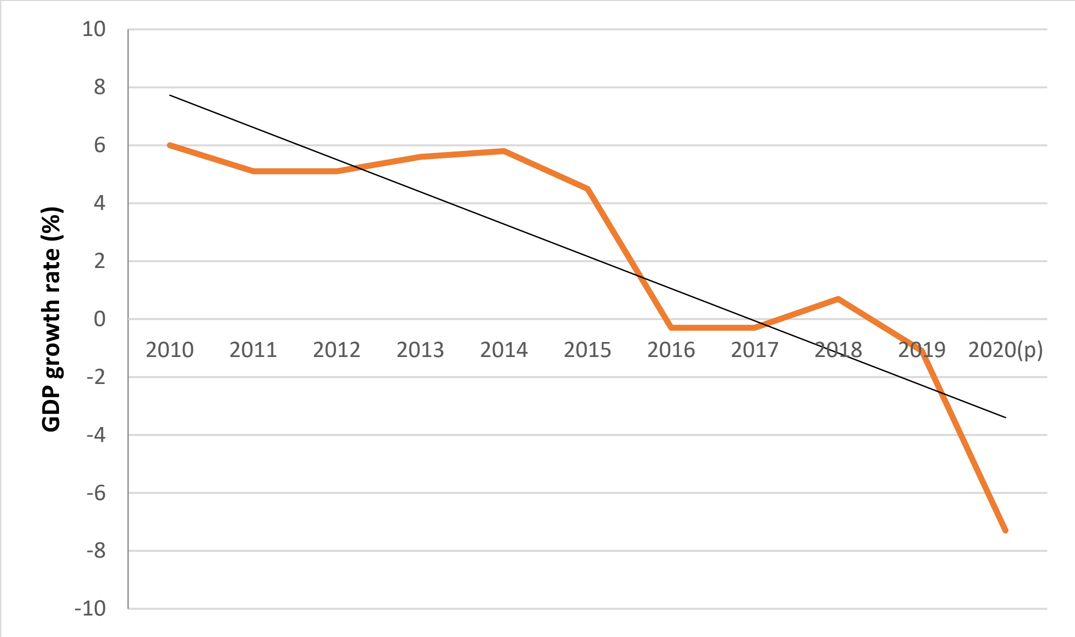

Figure 2.1: GDP growth for Namibia (2010-2020)

Source: Bank of Namibia (2021)

The prevailing drought has implications for the activities of the agricultural sub-sector and its output performance. As expected, the agricultural sector, particularly the livestock stock numbers, meat processing and exports, contracted in the 2019 to 2020 period. This contraction eventually had negative impacts on the livestock sector's contribution to GDP in subsequent years.

2.3 Overview of the Beef Cattle Sector in Namibia

The primary agriculture sector has emerged as a major role player in Namibia because it provides for the livelihoods and sustenance of about 77 percent of the Namibian populace (NSA, 2019 and BoN, 2021). It is reflected in Figure 2.2 below, that the cattle sub-sector experienced growth in 2016 and 2017, although this modest annual contribution to GDP (share of agriculture to GDP) was wiped out by the sluggish and negative growth in 2018. Contrary to the modest performance of the previous period, the 2017 period offered better relief to the economy, with an annual contribution of 14.30 percent. Furthermore Figure 2.2 shows that after showing a good indication of growth, the sector contracted by 2.9 percent in 2018 and decreased by 5.1 percent in 2019 and was projected to decrease by 6.4 percent in 2020. The trough trend in the agriculture sector is largely impacted upon by ongoing drought conditions.

It should be noted that erratic and low rainfall was experienced during the two previous production seasons, notably 2012/2013 and 2018/2019 (BoN, 2020 and Bon, 2021).

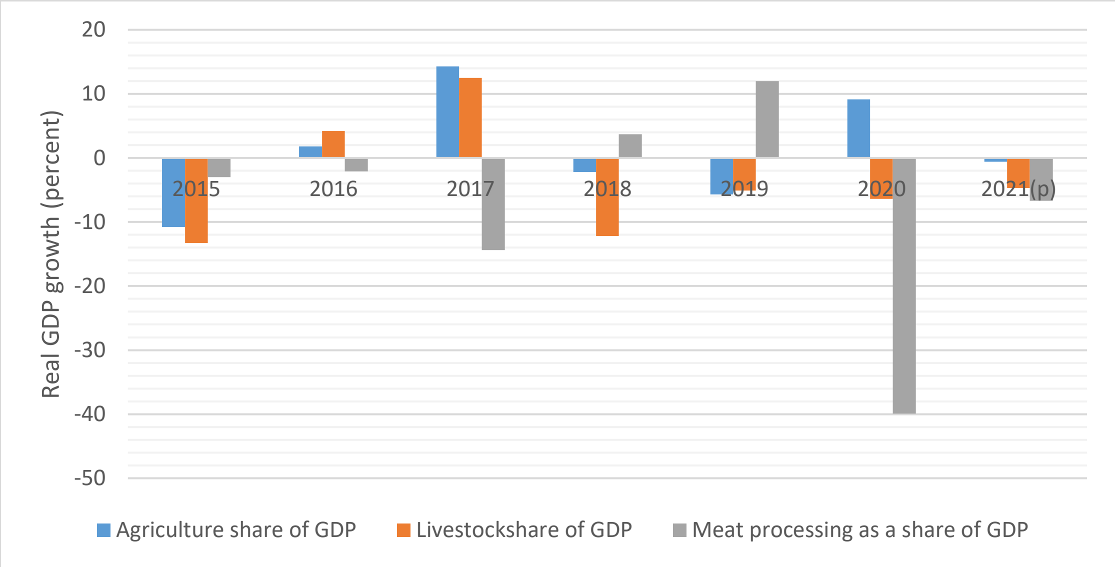

Figure 2.2: Agriculture, livestock and meat processing as share of GDP (2015 -2021)

Source: Author's compilation based on industry data from Bank of Namibia (2021)

It is evident from Figure 2.3 below that most of the revenue in agricultural performance emanated from cattle production in the 2017/18, 2018/19 and 2019/2020 periods. Fruits and vegetables indicated moderate revenue generation through the exports of table grapes to EU markets. The revenue from the small stock sector was subdued because of the unfavourable marketing scheme and the closure of slaughter abattoirs in the south of the country. Poultry and trophy hunting signalled favourable revenue in the period under review (AGRIBANK, 2020).

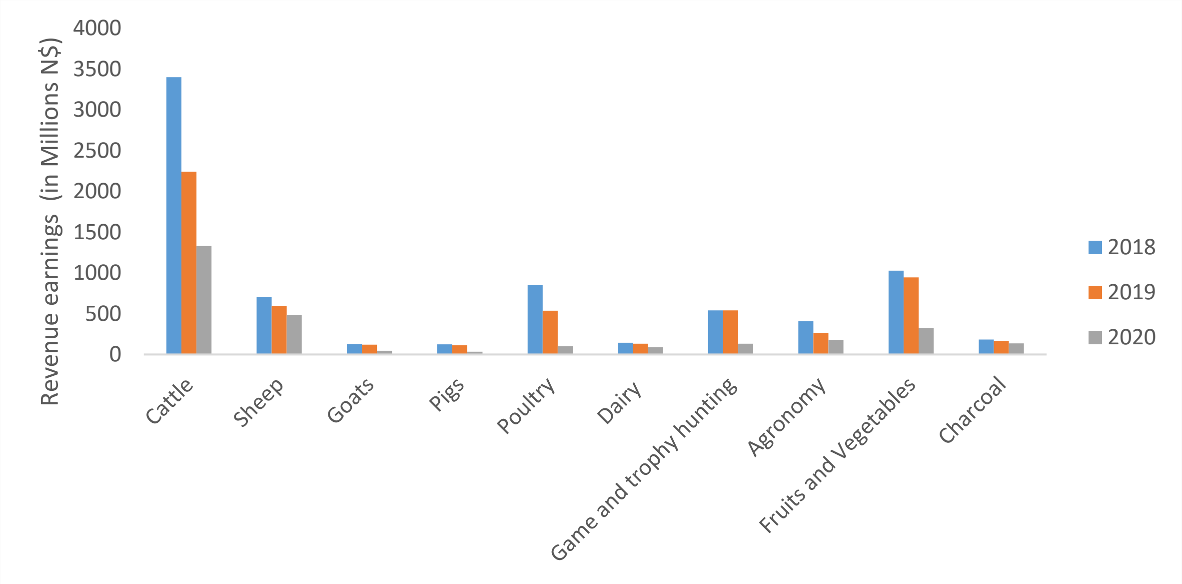

Figure 2.3: Revenue generation by agricultural sub-sector for selected years (2018, 2019 and 2020)

Source: Author's compilation (2021)

In making a comparison of the agriculture sector's performance relative to macroeconomic variables, such as land inflation, it is evident from Figure 2.4 that real farm prices have increased since their major lowest point in 2008, from 0.83 million to 7.89 million Namibian dollars, and farm prices were projected to increase to 8.50 million Namibian dollars in 2020. In similar manner, Figure 2.4 shows that the real prices of weaners and carcasses, year-on-year, trended upward after the sluggish decrease in 2015 to higher levels in 2018 through to 2019, 2020, 2021 and are projected to increase in 2022 to about N\$34.90 per kg compared to N\$32.54 per kg in 2015.

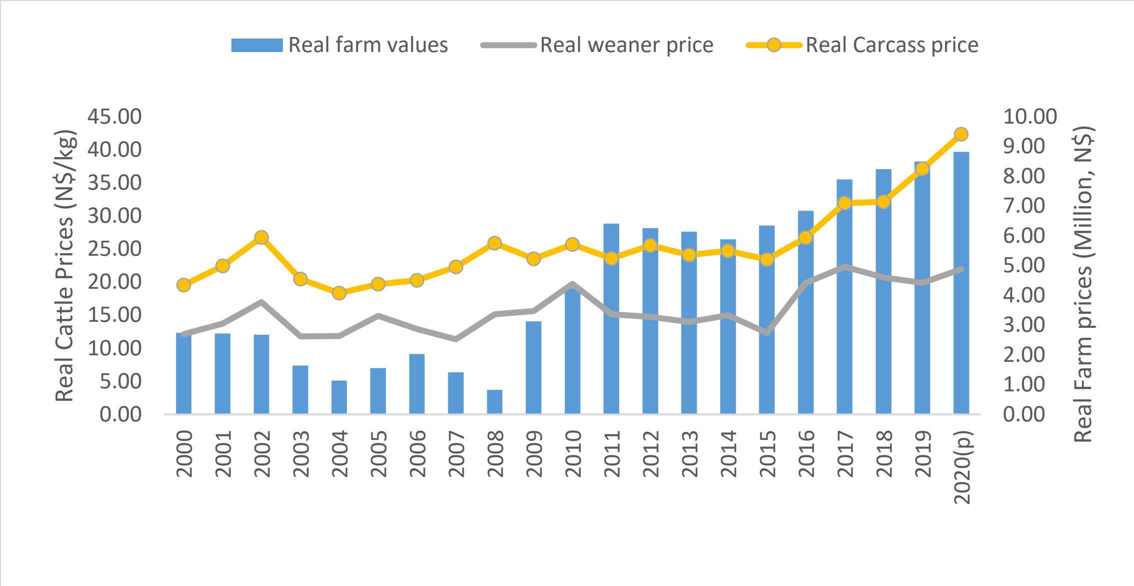

Figure 2.4: A comparison of real farm prices, weaner and cattle carcass prices

Source: Author's compilation based on industry data from Agribank of Namibia (2021) and NAU (2019)

While Figure 2.3 above indicates that most of the sector's revenues strongly emanate from cattle, sheep, poultry, and fruits and vegetables, it can be seen that the trophy-hunting sub-sector, a major component of game farming, is equally deserving of being an alternative for investment. Charcoal production is a new entrant into the farming diversification portfolio, with this sub-sector generating over 184 million Namibian dollars in 2019, up from 134 million in 2017, being an increase of 37 percent. This growth in revenue signals a potential for future investment in agriculture and forestry in the communal sub-sector.

2.4 Structure of the Cattle Industry in Namibia

About 2.7 million head of beef cattle production comes from two major sources of production, with the commercial sector accounting for about 38.86 percent of the cattle population, and the communal sector accounting for most of the cattle population, about 61.14 percent, as depicted in Figure 2.5 below (MAWF, 2017). More precise, Figure 2.5 shows the cattle numbers per production by sector from 2000 to 2020. Beef cattle production in Namibia is carried out by using traditional methods of extensive grazing on 36.6 million hectares, with an average grazing land size of 8 620 hectares, held among 4 200 large-scale commercial farmers (MAWF, 2015). The commercial farming sector is competitive and comparable with modern farming enterprises elsewhere in the world. Until recently, the beef cattle industry advocated for the introduction of intensive feeding of high-quality, grain-fed beef cattle, particularly by Meatco, the major meat processor and exporter, which has a commanding lead in establishing feedlots to support its slaughter capacity and Meatco-owned cattle scheme (MCN, 2019). The Meat Board of Namibia, as the regulator, records that there are several abattoirs available for cattle slaughter and meat processing. These include the abattoirs approved by the European Union market, such as Meatco Windhoek, Meatco, BeefCo and Brukkaros Meat Processors. The abattoirs approved by South Africa include the Farmers Meat Market and Brukkaros Meat Processors (MBN, 2019a). There are several small-scale beef and meat processors that supply the domestic market.

It has been stated already in this chapter that cattle production in the communal areas is undertaken by subsistence farmers with small herd sizes of indigenous, small-frame cattle breeds, with herd sizes varying from less than 10 to more than 500 cattle per household. Communal beef cattle producers operate mostly on communal land, which is often overgrazed and, to some extent, degraded through high stocking rates. Smaller (or emerging) commercial farmers account for 15 percent of cattle produced, and they practise farming under the affirmation action loans scheme (AALS) for the previously disadvantaged black farmers, which is a scheme administered by the Agricultural Bank of Namibia (Agribank) and financially supported by the government.

The figures provided by the UN FAO statistics webpage (FAO, 2015, 2019 and UN Comtrade data 2020) for traded tonnes of fresh or chilled and frozen beef (HS 0201 and HS 0202, respectively) on the world market, indicate that the Namibian beef cattle industry has remained competitive over the years, despite the hardships of drought and outbreaks of foot-and-mouth disease. Namibia’s trade volume of exportable beef ranks 34th in the world for traded beef, trailing South Africa in Africa, and behind global leaders USA, Australia, New Zealand, Poland, Brazil, Uruguay, Mexico and Canada (MCN, 2019, 2020 and UN Comtrade data 2020). It is a well-known fact that, outside their role as sources of income and food, cattle constitute a priced asset, serving as capital goods, a store of value and, more recently, as collateral security for credit, which is an essential safety net during periods of financial distress. Schroeder et al. (2013) and USDA (2020) state that, globally, trade in cattle contributes 15 percent of total food energy and 25 percent of dietary protein, which is a trend that is growing and expected to increase in developing countries, as incomes and populations continue to rise.

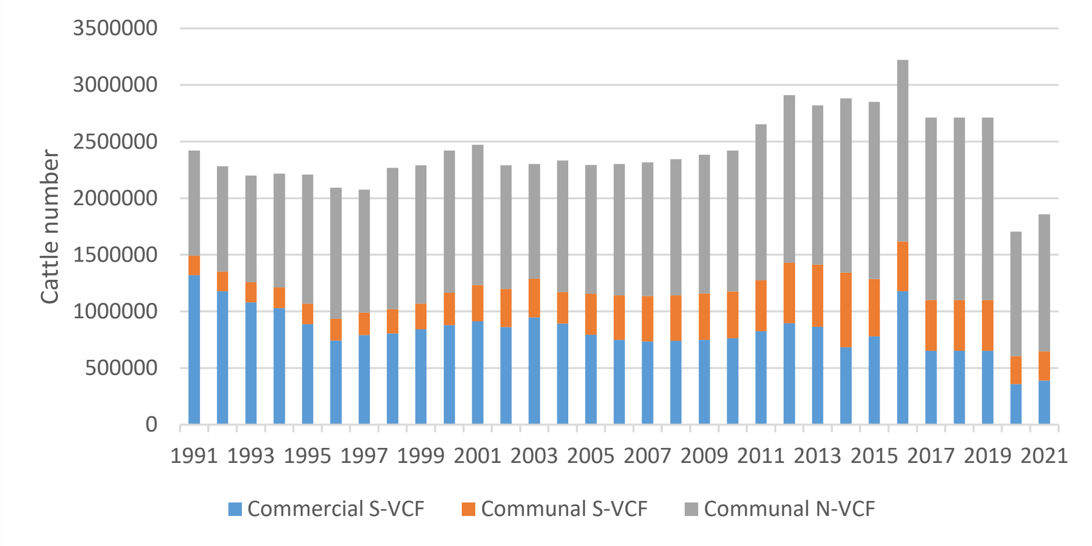

Figure 2.5: Sources of beef cattle supply in Namibia (1990–2021)

Source: Adapted from the MBN (2021) and MAWF (2017).

The NSA (2019) has reported that about 65 percent of the country's population of 2.4 million people are engaged in livestock production, particularly cattle farming. Cattle production has contributed immensely to the agriculture's share of gross domestic production through beef and weaner export earnings. The Bank of Namibia economic outlook statistics indicate that, for 2018, beef and meat processing had accounted for about minus 2.9 percent, which increased to 12 percent in 2019, and was further projected to decrease to 19.0 percent in 2020 (BoN, 2020).

2.5 The Status of Beef Cattle Production and Consumption in Namibia

The cattle industry is cyclical in nature, where a herd size expands and contracts in an 8-to-12-year period due to the biological cycle of cattle and to changes in the market. The cattle cycle in Namibia is vulnerable to several disturbances, such as weather variability, outbreaks of foot-and-mouth disease in northern Namibia, the beef industry structure, export quota allocations, inflation, demand, and, more recently, grain prices and imports. Droughts often extend herd re-building phases through reducing the available pasture areas for cattle. It is noted that during periods of drought, cattle producers either can sell cattle to reduce the number of animals grazing, or they can feed animals on supplemental harvested forages, which increases operating costs. Producers who choose to market cattle are often forced to move more cattle to slaughter facilities than they normally would by selling younger cattle at higher weights, thus reducing the prices they receive. The effects of drought are often, but not always, seen in late spring and early summer.

Apart from the weather-related influences, the industry is often affected by several other variables. First, alterations in the industry structure and technological innovations have changed in recent years. For example, in 2012, the industry structure of Meatco changed, when the government acquired a 30 percent ownership in the meat processing entity, which was previously wholly owned by cattle farmers and producers. The proposed acquisition by the state brought about turbulent debates among the large-scale beef cattle producers, who believed sharing a part of their earnings with the government was unfair, because government had not been proactive enough in supporting large-scale farmers. Technological innovation, on the other hand, which has been pursued by Meatco abattoir, has improved slaughter plant capacity to allow for more and larger animals with higher weights (MCN, 2019). However, Meatco operational inefficiencies are still prevalent, with the closure of abattoirs in Okahandja district. Furthermore, the introduction of the green scheme irrigation programmes for cropping has also affected the industry by providing an incentive to use land either as cropland or as improved pastures. Available literature, for example USDA (2020), shows that cattle numbers are inversely related to changes in the number of harvested crop hectares.

It is argued here that inflation and changes in demand can increase incentives to move from expansion to rebuilding, or vice versa, while more recently, with the introduction of feedlots, grain prices and the quality and quantity of the pastures influence cattle production costs and decisions. Meanwhile, changes in imports and exports of beef and grain can have substantial effects on the cattle cycle by encouraging either herd expansion or herd rebuilding.

The beef cattle cycle observed since the 1990s demonstrates the effects of many of these forces. MAWF report (2009) indicates that the 1990s cattle cycle was affected by surges in drought and disease outbreaks, particularly foot-and-mouth disease. Periods in the 2000s were affected by institutional reforms, drought, diseases and decreased slaughter weights. Moreover, the 2000–2010 cycle experienced an extremely short expansion period, particularly in the commercial sector, where the herd size fell by 20 percent (MBN, 2019a). Average cattle weights decreased and the total number of cattle in the commercial farming sector decreased with the introduction of Witvlei abattoir and processing factory, and with the expansion of Meatco slaughter facilities that allowed the processing of larger animals. At the same time, the period witnessed the closure of slaughter facilities and a moratorium on animal movements in the northern communal areas (NCAs) of the country because of foot-and-mouth disease (FMD) outbreaks (MBN, 2018, 2020).

Furthermore, a year-on-year review covering the years from 2015 to 2020 indicates that more weaners were exported from Namibia, while fewer cattle were slaughtered in the informal and formal markets, and that drought increased the marketing of more numbers of young cattle than before, together with a reduction in the numbers of capital breeding cattle. This has had consequent implications for the slaughter stock quantity at domestic export abattoirs. After the period of severe and extended drought from 2012 to 2019, the capital cattle stock herd began rebuilding, although this exercise has frustrated the main farmers because drought and poor available grazing has hampered their efforts. Severe and extended drought, outbreaks of FMD, particularly in the NCAs, and structural and institutional changes continued to plague the Namibian cattle industry, and producers reduced herds going into 2019 and 2020, which reduced the cattle stock available for slaughter during the same period. This is reflected in Figure 2.6 below, which compares production, domestic consumption, export levels, and shares from 2012 to 2020.

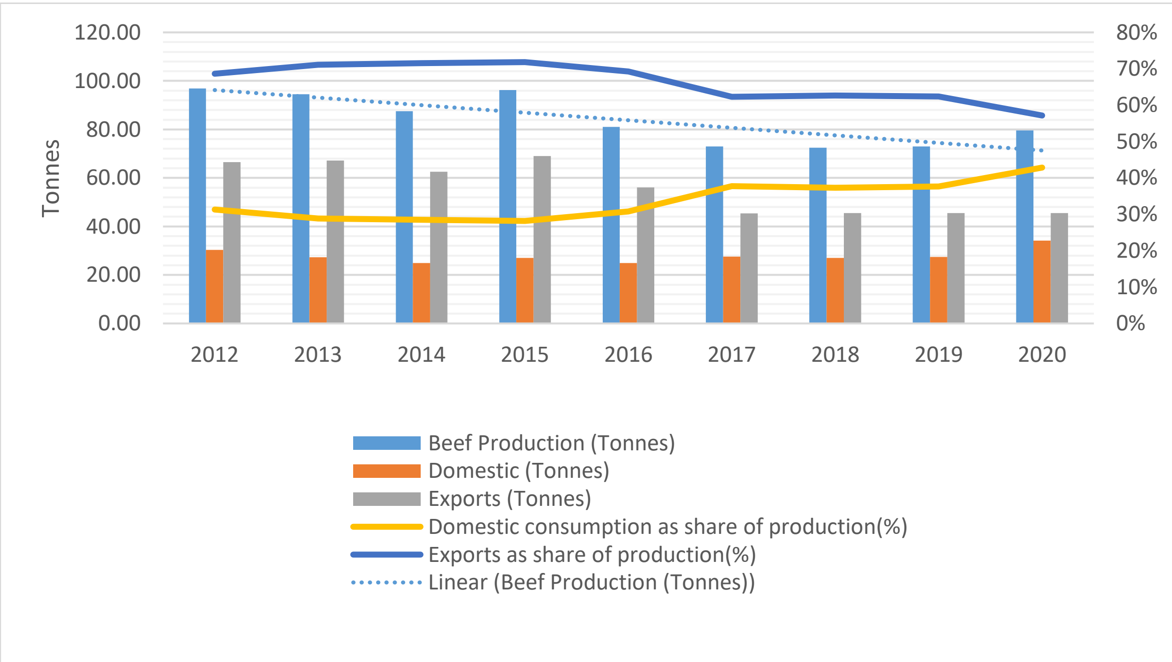

Figure 2.6: Beef production, consumption and exports for Namibia (2012–2020)

Source: Adapted from the MBN (2020)

Cattle herd rebuilding, FMD, import bans by South Africa, feed cost and slaughter mass all appear to have created many changes in production. For example, the ban on receiving Namibian cattle imports imposed by South Africa exacerbated an already over-supplied domestic market for two reasons. First, Namibia has typically relied on the South African market for many of its exportable weaners and beef products. Industry data reveal that in the 2013/14 period, Namibia exported an annual total of 425 388 head (8 months old, with average live mass of 180–240 kilogrammes) to South African feedlots, compared with 140 000 slaughter cattle delivered to export abattoirs in Namibia. Conversely to the marketing of live cattle, Namibia exported 9,400 tonnes of beef to South Africa and about 9,500 tonnes to European markets. These are major markets for Namibian beef and weaners, respectively. In the 2018 and 2019 period, Namibia marketed about 306 700 and 286 880 weaners to South African feedlots (MBN, 2016 and MCN 2013). These values represented about 66 percent of Namibian exports and about 34 percent (inclusive of the value from informal markets) of domestic use. It should be noted that Namibian beef exports account for less than 10 percent of South African beef consumption.

Following the 2012/13 to 2018/19 period, droughts had affected the cattle market for 7 consecutive years, worsening grazing conditions and depleting forage supplies in the commercial farming units and communal areas, the latter of which experiences high incidences of overstocking and overgrazing (MBN, 2019a).

Consumer demand has been steadily trending downwards from 1990 to 2021. This can be attributed to the moratorium imposed by the government, particularly prohibiting the slaughter of cattle in the FMD outbreak areas in the NCAs of Namibia, where there is a large population. Figure 2.7 shows that per capita beef consumption in December 2013 stood at 20 kilogrammes, as compared with 14 kilogrammes in 2010.

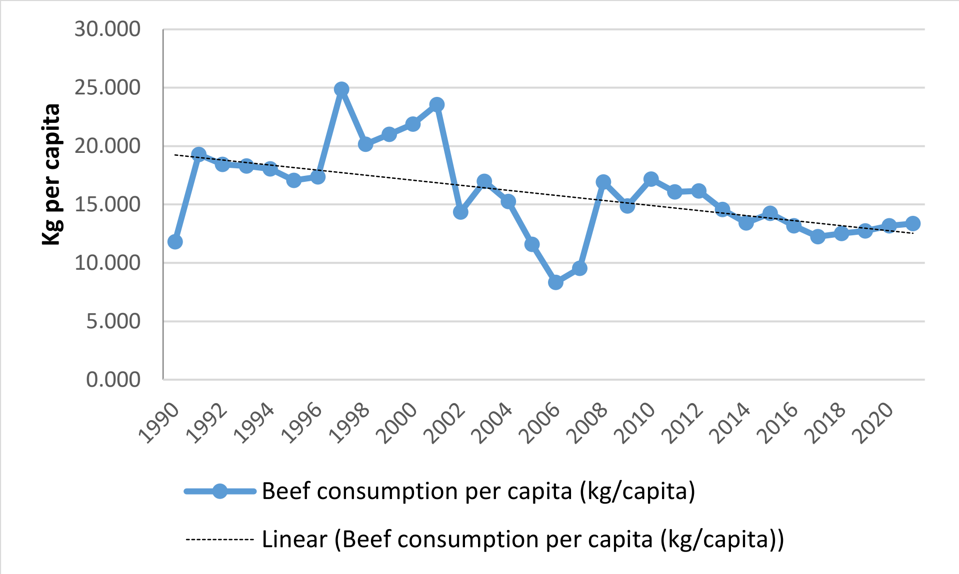

Figure 2.7: Beef consumption per capita in Namibia

Source: Author's compilation using Meat Board data (2021)

2.6 Cattle and Beef Price Movements

Beef price movements in the 2015–2021 period followed changes resulting from the mechanism of supply and demand for beef cattle. During the severe and extended drought period from 2016/17 to 2018/19, producer prices for beef rose by 24 percent in 2016/17 compared with a decline of 10 percent in the 2015/16 period, representing the largest annual gain since 2015/16. Producer prices have trended upwards in the 2020 to 2021 period. Increases in the prices for slaughter cattle are heavily influenced by the rebuilding of herd size after suffering the impacts of drought and decreased slaughter weights during the same period. It is noticeable that, over the years, the prices for slaughter cattle have posted several noticeable gains. Comparatively, the producer and weaner prices for Namibia are, on average, lower than the prices offered by South Africa for the same category of product (see Figure 2.8), while the beef retail prices for Namibia are higher than the retail prices for South Africa. Producer and weaner prices for Namibia are trending below the South African prices because Namibia is a surplus producer of weaners and has limited demand for weaners. The fact that Namibia has less capacity to keep weaners up to slaughter weights requires additional feeding and more forage, and given the occurrence of drought in recent years, Namibia cannot afford to finish weaners on natural veld. It is thus economical for beef cattle producers in Namibia to market live weaners to the lucrative South African feedlots, which is seen as the solution for the surplus weaners in Namibia. For example, Figure 2.8 below shows the average producer prices from 2015 to 2021, and it is evident that the producer prices in Namibia were ZAR 8.92 per kilogramme lower than the feedlot auction market prices were in South Africa over this 7-year period. During this same period, the annual average Namibian weaner prices were ZAR 2.02 per kilogramme lower than the South African weaner prices were, while the average Namibian retail price was ZAR 6.00 per kilogramme higher than the South African price was for the same period. Therefore, regardless of the regulation and policy suggestion in Namibia, the South African beef market is lucrative for Namibian live weaner stock and for beef originating from the zones free of FMD.

Figure 2.8: Beef price spread between Namibia and South Africa (2015–2021)

Source: Author's compilation using industry data (2021)

2.7 Beef Market Value Chain and Policy Issues in Namibia

The state of the cattle stock, being the input in the beef value chain, depends on the quality and quantity of available rangeland, the genetic make-up of the breeding beef cattle, the veterinary support services, and the environment/climatic conditions. Much of the discussion on these factors has been briefly covered in Sections 2.1 and 2.2 of this chapter. It is important to note that it was only in recent years that intensive animal feeding, such as in a feedlot system, has become more prominent in Namibia, particularly for large-scale commercial processors like Meatco.

Figure 2.9 shows the supply chain of the beef industry in Namibia. The supply value chain of the beef cattle industry in Namibia is centred on the quality and quantity of the breeding stock, genetics and available grazing lands, supported by good regulations enforced by the directorate of veterinary services. Cattle production originates from three sources such a large commercial producer, emerging commercial producers and communal producer, who are situated either south-veterinary and north-veterinary cordon fence. Both these types of farmers produce calves, weaners, oxen, culled cows and slaughter cattle stocks represent inputs into the production of cattle sold at auctions, domestic slaughter abattoirs and exported live from the commercial and communal producers. Domestic slaughter abattoirs are characterised as providing primary processing, secondary processing and marketing services. Namibia exports boneless cuts, vacuum packed, and chilled beef to the lucrative international European Union market. Finally, the domestic market is comprised of formal wholesalers, retailers, restaurants and hotels, as well as the informal markets and traders at household level. Therefore, given the existence of these markets, several price transmission information details are important for each exchange point in the supply value chain, with the monthly live slaughter prices being probably the most representative of the market value of beef transmitted back to producers.

Over the years, cattle production in Namibia has enjoyed popularity. Despite its popularity, cattle production has experienced a decline in recent years. However, cattle production retains the potential for substantial impact on growth because of the availability of vast, extensive lands (Dakwa, 2007 and Sartorius von Bach, 2020). The government, through the Ministry of Agriculture acting under the National Agricultural Policy, 1995, stipulates that livestock represent the foundation for the growth of agricultural incomes, exports and rural employment (MAWF, 1995). The regulation states that support to the red meat producers will focus on increasing the productivity and sustainable utilisation of the existing commercial and communal grazing lands. The government has committed to assisting the communal and commercial farming sectors through financial support and incentives for livestock product diversification (MAWF, 1995). In Namibia, the DVS is mandated with the task of controlling the movement of animals. Under the mandate, permits are required for any livestock movement in the infected or buffer zones. Veterinary officials monitor various checkpoints, check truck permits, and help to control areas when there is an animal disease outbreak. Inspections and quarantining are required for livestock moving from the infected zone to the buffer zone. More important to note is that live cattle are not allowed to move from the buffer zone to the free zone, although beef carcasses, after inspection, processing and freezing, are allowed to move from the buffer zone to the free zone. Furthermore, the DVS is responsible in part for the Farm Assured Namibian Meat Scheme ("FAN Meat"), which is the foundation of Namibia's animal traceability system that was implemented to respond to EU regulations after the occurrence of bovine spongiform encephalopathy (BSE) (MAWF, 2015). The EU has passed regulations that require producers and marketers of beef to display information about the origin and birth of slaughtered animals, together with fattening and slaughter information. Under the FAN Meat system introduced in 1999, each animal must bear a distinctive brand symbol and an ear tag containing a unique serial number. Initially using paper-based tracking, all animals, most notably cattle, were tracked on a group basis as they moved from their farm of origin through the various stages of production. Each head of livestock was identified by a particular brand symbol, and permits were required when any movement of the animal took place (MAWF, 2015). In 2008, the government introduced a system that requires all cattle farmers to register their cattle on an electronic database, referred to as the Namibia Livestock Traceability System (NamLITS), through the veterinary directorate. This centralised database allows beef cattle to be tracked back to the farm of origin and has formed part of the beef quality assurance system (MBN, 2018).

The Meat Board of Namibia places trust in the livestock farmers and producers to update the system with accurate information, such that the Meat Board and the EU have since started using this traceability system for validating the eligibility of farms of origin for beef cattle before they are slaughtered at the export abattoirs (MBN, 2016 and MBN, 2018). However, compliance with this system has created a major bottleneck for communal farmers. The integrated supply chain for beef cattle in Namibia in Figure 2.9 indicates the existence of regulatory framework. Through the framework, government has embarked on policy reforms and regulations that were advocated to enhance growth in the meat sectors. Among the policy directives are the value addition in the beef cattle industry, and the regulations introduced include the live cattle export quota, pegged at 120 000 cattle per annum, and an export levy of 30% for cattle whose live mass is 450 kilogrammes as at the date of export. In addition, two levies (the general and special meat classification levies) were introduced in 2010 after the Meat Industry Amendment Act, 1992, which levies a charge of 0.8 percent on the selling prices of cattle, and on beef and beef products sold, imported into, slaughtered in and exported from Namibia (MBN, 2012a).

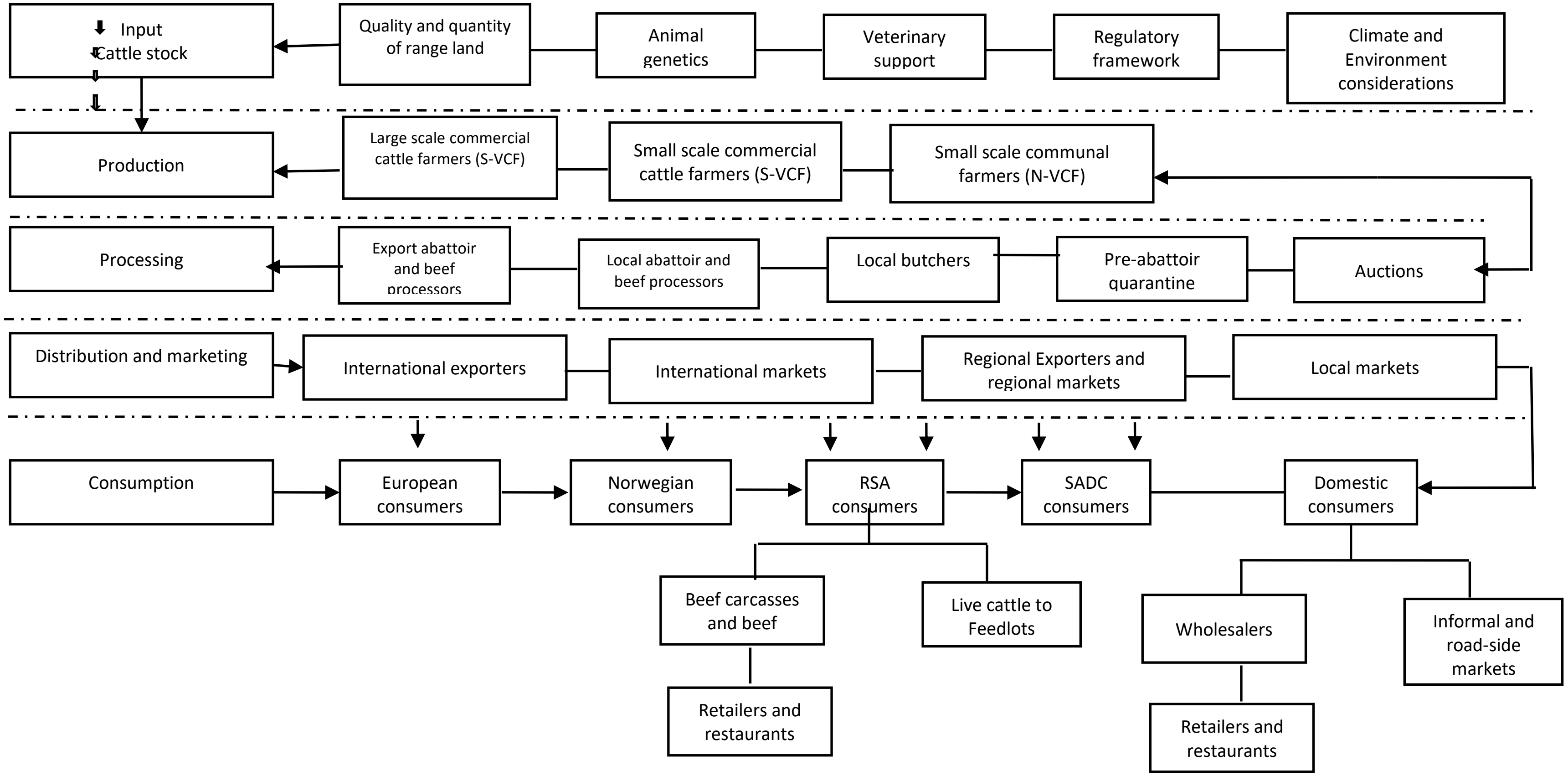

Figure 2.9: Integrated supply chain for the beef cattle industry in Namibia

Source: Author's own compilation

As part of veterinary support, the Directorate of Veterinary Services within MAWF implemented a new regime in 2011 concerning the 90/40-day residency rule as required by the EU. The 90/40-day residence rule stipulates those cattle destined for slaughter at the EU certified abattoirs should be identified on the NamLITS database to ensure that such cattle resided south of the veterinary cordon fences for 90 days and can be traced for the last 40 days in situations when there is a disease outbreak (MAWF, 2009, 2012 and MBN 2012a). EU eligible livestock should not be in direct proximity to livestock that are not compliant. This has implications on the pricing, where compliant livestock are priced higher than the non-compliant. The decrease occurred after cattle producers opted to sell non-compliant cattle to different markets, such as slaughter abattoirs and butchers. Reports further revealed that the 90/40-day residency rule created loss in income amounting to 5.1 million Rand (MAWF, 2009, 2012 and MBN 2012b).

2.7.1 Domestic abattoirs and the EU export market

The traditional view of economic development postulates that Namibia has a comparative advantage in the production of beef. However, based on the industry data provided by the Meat Board, the production and exportation of beef cattle and beef products have enjoyed only modest growth since 1968. This is best substantiated by the underutilisation of domestic export abattoirs. The data show that, since 1968, the annual local slaughter capacity requirements of about 350 000 head have not been fully utilised. For example, in the 2017, 2018 and 2019 periods, slaughter abattoirs accounted for about 83 790, 74 174 and 126 600 slaughtered cattle, respectively (MBN, 2019a). Meanwhile, the local abattoirs accounted for 52 537, 46 924 and 103 204 slaughtered cattle during the same periods, respectively. These numbers are below the annual 350 000 slaughter capacity of domestic abattoirs, and thus create an inability to fulfil the quota of 13 000 tonnes for export to the EU markets (MBN, 2019a). The situation might have been slightly depressed in the industry after the extended drought period of 2018/19, with herd-capital rebuilding taking place among many beef farmers, specifically the emerging commercial producers (AGRIBANK, 2019).

Studies by Kirsten (2002), Kruger and Lammerts-Imbuwa (2008), Negassa and Jabbar (2008), and Teweldemedhin and Conroy (2010) have identified some of the marketing channels and strategies of the livestock industry in Namibia. These studies have not looked at the dynamics of industry and have not mentioned the reason for the modest growth in the beef cattle industry. Industry data reported in MCN (2017) and MBN (2019a) reveal that a large percentage of young livestock (weaners) is exported to South Africa on a monthly basis (DAFF, 2016 and DAFF, 2017). The export of live weaners to South Africa has impacted negatively upon the local export processing abattoirs. Studies commissioned by the Meat Board of Namibia have not used econometric tools to explore the Namibian beef market structure in terms of government regulations and government involvement in the meat processing industry. There is a lack of understanding of how the export quota allocations, the producer prices for weaners in the domestic market (as compared with the feedlot prices in South Africa), and the increasing production costs are shaping the industry. Increasing environmental regulations, the uncertainty arising from the regulations proposed by the EU-Economic Partnership Agreement (EPA) framework, and the veterinary certification proposed by South Africa pose a concern for the comparative advantage of the beef industry.

The duality in the agricultural sector has also compounded the dynamics of the demand and supply relationship. Duality in the Namibian context refers to the two livestock farming sub-sectors, that north of the cordon fence (N-VCF) and that south of the veterinary cordon fence (S-VCF). The context is made further complex by the existence of the formal and informal beef sub-markets within the N-VCF and S-VCF (see Figure 2.10). Data from the commercial farming sector is accessible, but data from the communal farming sector has been insufficient (Meat Board of Namibia's Livestock Sector Strategy, (MBN, 2012a). The performance of the informal cattle sector in terms of beef cattle flows and marketing has not yet been explored, despite the availability of details of animal movement permits and slaughter permits at the regional and national offices of the Directorate of Veterinary Services. This data has not yet been used to determine the share of growth in the informal beef market. In fact, the Meat Board-NLSS Report of 2021 states that one of the strategic issues affecting the proper accounting of the Namibian beef cattle industry is the lack of comprehensive industry analysis because of the disparity and paucity of data (MBN, 2011a). Chiribonga *et al.* (2007) have referred to the environmental regulation and drought impact on the supply side of cattle production. Nevertheless, the Meat Board has acknowledged that drought is known to occur in Namibia every 10 years and that the availability of grazing land is most important for supporting the carrying capacity per large stock unit (LSU).

2.7.2 Supply and demand for slaughter cattle

From industry data made available by the Meat Board, it is observed that there is a widening gap between the beef cattle supplied for slaughter and the demand for beef cattle in the local markets (MCN, 2017). Industry data contextualises the study problem and shows that the numbers of slaughter stock at meat processing abattoirs are declining. The Meat Board reports that slaughter stock numbers are trending downwards, while producer prices have recorded a price increase in 3 years (MCN, 2019a). The disequilibrium in the beef cattle industry is of major concern, and because it occurs, one might think that price theory is not effective for making producer decisions. It is therefore postulated that the principles of demand and supply are being violated.

The Meat Corporation, as the buyer and as a major domestic processor, and the Meat Board of Namibia, as the regulator of the industry, are equally concerned about the declines in the supply of slaughter stock of beef cattle to local formal markets. In addition, other concerns include the severe and extended droughts that hamper proper planning for the emerging commercial farmers, increasing pressures on the profitability of the producers, the future operations of abattoirs, food security, industry investment and growth (MBN, 2018), and the high standards for compliance at Meatco, as an important export abattoir, when compared with others with lower standards. In fact, in theory, local abattoirs could compete with the Meatco business model on price to secure more throughput because of their low-cost structure. However, a proper review of compliance standards and regulation of cattle marketing in the northern communal areas should be done by policymakers for the industry to gain an inflection point towards achieving long-term profitability.

2.7.3 Slaughter stock off-take

The methodological measurement refers to how the off-take values are estimated in Namibia. The Namibian cattle census reported that there are about 2.7 million head of cattle (MBN, 2019b). Despite having a larger cattle population, studies on the marketing of cattle carried out by de Bruyn *et al*. (2001); Kruger, Lammerts-Imbuwa (2008); and Enkono *et al*. (2013) in northern communal areas of Namibia reveal low off-take rates and a low throughput of 3 percent, compared with 60 percent in the commercial sub-sector. The national off-take of slaughter cattle is 14.8 percent (400 000 out 2 700 000 head of cattle), compared with 23 percent for South Africa (MBN, 2019b). The methods used to determine the take-off rate are not comprehensive and cannot be relied upon, given the lack of comprehensive industry data, especially on cattle traded in the informal markets. Figure 1.3 and Figure 1.4 in chapter 1 map the research problem by contextualising the scenario and the dynamics of supply and demand side. The off take from the production sector is about 14.8 percent, compared with 17.4 percent in total requirement in the consumption sector (domestic export abattoirs, butchers and auction markets). This mismatch indicates a deficiency of 166 000 head of cattle, annually, at the domestic market, while more than 235 000 head of weaners are exported to South African feedlots. The available cattle data does not delineate the breeding herd stock, the calf stocks, replacement stock, and slaughter stock (MBN, 2019b). However, the delineation could be done for stock estimations by using the NamLITS data set. Delineating the cattle data is an important service for the industry, and therefore, developing a methodology to determine the cattle stock composition is important for evaluating the dynamics of the slaughter stock growth for the industry.

2.8 Government Interventions and Regulations

The government has intervened in the cattle industry by implementing a regulation of the ownership in the Meat Corporation through a proposed cooperative, where government has proposed transferring a 30-percent share of ownership to a cooperative that is solely owned by farmers (MCN, 2017 and MBN, 2019b). The formal institutional arrangements have done little to solve the economic paradox because of the underutilisation of local abattoirs, the realities of demand and supply, the price relationships in the beef industry, and the continuing need to curb the declining growth. The implementation of the veterinary requirements described in this study is of great importance for evaluating the extent to which the proposed regulations have impacted on the dynamics of supply and demand for slaughter stock in Namibia. Included in this concern, is the inadequacy of information on the national beef cattle herd, the size of the local breeding herd, the replacement stock, producer price effects, the implementation of the EU 90/40-day residency rule by the veterinary services, and the quality of the environment, coupled with weather and food safety regulations (MCN, 2013 and MBN, 2018).

The regulations on beef cattle zoning to mitigate the biosecurity in beef cattle however, the zoning (see Figure 2.10) has led to the unequal market access opportunities for cattle producers.

Nathinge (2011) highlights the point that the basis for beef cattle zoning is the premise of the value of veterinary cordon fence. The designations are such that the area immediately to the south of the cordon fence is the surveillance zone, which stretches for 20 kilometres south of the fence, while the area north of the fence moves towards the Angolan southern border and the Kavango River. This area falls within the buffer zone demarcation (see Figure 2.10). This demarcation arises partly because of the lack of disease control carried out on the periphery of the Angola–Namibia border during the era when the Angolan territory was impoverished by the turmoil of war.

Meat Board data (MBN, 2012a) and DVS data indicates that the eastern Zambezi region is a foot-and-mouth infected zone because of the influx of free-roaming wild buffaloes (Nathinge, 2011). The DVS have always argued that buffaloes are reservoirs of the foot-and-mouth disease virus (Nathinge, 2011). The Meat Board and government regulatory frameworks are such that livestock originating from the free zone (central and southern Namibia) enjoy access to EU and South African markets.

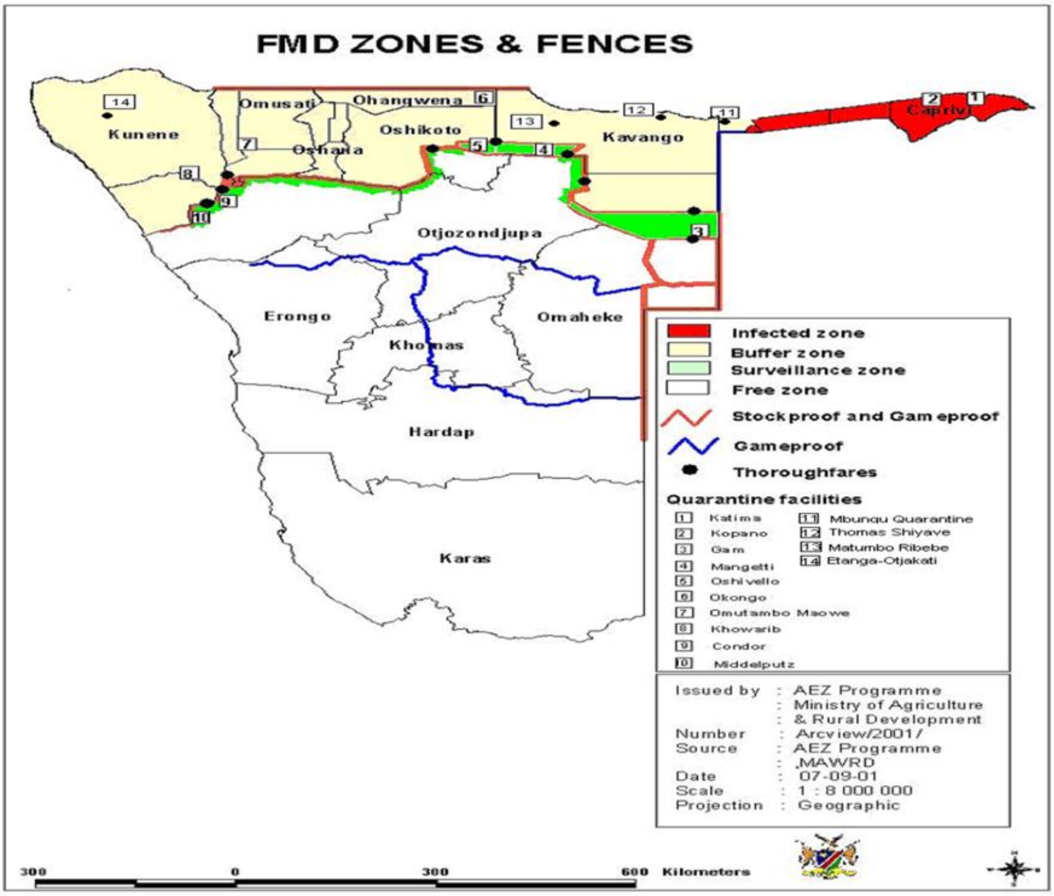

Figure 2.10: Map indicating the location of the veterinary cordon fence and FMD zones

Source: MAWF (2012a)

2.9 The Status of Land Categories in Namibia and the implication for Beef Cattle Production

In Namibia, land is classified into the following categories, state land and freehold commercial land. Crop and livestock production in the communal areas is practised on state land, which is administered by local headman and chiefs in their respective constituencies. The rights to use such communal area land are often only given under verbal agreements and permissions from the traditional authorities. Under the law, these verbal permissions to use such areas of land do not constitute legal title to those land areas, which accordingly have lower capital values (MAWLR, 2017). Thus, the categorisations of land status and land ownership have become a political issue. The two categories are briefly explained in Table 2.1 below.

Table 2.1: Description of land categories in Namibia

Land Category	Description of the category and specific conditions
State Land	• Comprising **protected area,** with the land size of 107 000 km^2 and accounts for about 13% of national land • Protected areas include national parks, game reserves and mines, and are administered by respective government ministries • The Etosha National Park, situated in the north central division, has a land size of 22 270 km^2 and extends along the southern parts of Omusati, Oshan and Oshikoto regions • The communal land accounts for about 43% of state land, comprising about 354 000 km^2 • By gazetted law, communal land is administered and regulated by Communal Land Boards, with support from the Ministry of Land and Resettlement, as guided by the Communal Land Reform Act (No. 5 of 2002). By this Act, the northern central division is proclaimed as communal land, excluding the Etosha National Park and the commercial land described below
Freehold Commercial Land	• The commercial land area accounts for about 44%, comprising about 363 000 km^2 • This land is regulated under the Agriculture Land Reform Act (6 of 1995), which guides commercial agriculture • In the northern central division, commercial farms (mostly livestock farms in the Mangetti area), are in the vicinity south of the Oshikoto region

Source: adopted from MAWLR Northern Crop and Livestock Development Master Plan study (2017) and MAWF (2015).

In terms of cattle numbers and production, the northern communal areas, under the state land, accommodate large cattle herds, when compared with the freehold (title deed) land category.

2.10 Empirical estimation of the Determinants of Demand and Supply of Beef

The supply and demand in beef industries, across the world are shaped by various factors; from beef cattle prices to food safety and traceability, welfare regulation, production and transaction costs, cattle diseases, quality risk, and trade policies (Schroeder *et al.*, 2013). These factors dictate the dynamics of demand and supply relations and have been studied in many of the more-advanced beef cattle markets but have not yet been explored in the Namibian market. For example, Marsh (1999), using econometric estimations, derived a breeding herd equation for the United States and concluded that future beef supply would depend more on changes in technology than on increasing beef herds.

Furthermore, Tsai (1994) and Wahl (1989) employed linearised approximations of the ideal demand systems (LA/AIDS) model to study the economic structures, policy environments and dynamic adjustments in the Taiwanese and Japanese markets, respectively. However, none of these studies introduced instrumental variables in their model that account for the effects of endogeneity. Instrumental variables are exogenous variables that are assumed to be uncorrelated with the omitted or disturbance errors. If the instrument is valid, then the large sample sampling distribution of the estimator is normal, and then inference can proceed (Baltagi, 2008).

Studies conducted in Namibia on the livestock industry have, for example, looked at the supply response in the beef industry through using ordinary least squares. Each of the factors incorporated into an ordinary least square regression framework has some economic theoretical expectation. For example, Sartorius von Bach and van Zyl (1990) investigated the supply of live cattle and beef in Namibia by utilising economic, trade, and income factors in their model. Their aim was to model Namibia's supply of beef by using the figure for total cattle marketed as the endogenous variable, while the exogenous variables were considered as being the lagged variables of total cattle stock, total cattle exported, total Namibian carcasses, average Namibian producer prices, income per carcass in Namibia, and South African average producer prices. The results from their study showed that the producer prices of beef do not generally play a major role in the supply response of beef in Namibia. The study indicated a high adjusted R-squared of 97 percent. However, the results and signs of the estimated coefficient show spuriousness in the linearity of the parameters for the dynamics of the supply of live cattle and beef in Namibia. Furthermore, the comparative advantage derived through using a cost–benefit approach (Chiribonga *et al*., 2007) was not conclusive on the nature of policy directives for the beef cattle industry in Namibia.

Other studies have examined the potential of the livestock industry (Kruger and Lammerts-Imbuwa, 2008), while Van Wyk (2011) used an error correction model to analyse the mutton industry in Namibia's formal markets. Although these models are statistically sound, the results on price elasticity transmission do not represent a price formation process that is inclusive of the informal market setup. In addition, these studies have not explored the inclusion of instrumental variables in estimating the demand and supply elasticities of the formal beef cattle markets. These studies have omitted following the need to estimate the price transmission elasticities in the informal beef cattle markets. This omission in ascertaining the demand and supply elasticities of the informal beef market undermines the importance of the sector to the mainstream agricultural contribution and leads to the formulation of sub-optimal polices for the industry.

Furthermore, the previous models that have been developed for informing policy formulation have ignored the existence of the dualism that exists in the beef cattle markets in Namibia. These models assumed linear methods of price mechanism (e.g., Sartorius von Bach and van Zyl, 1990), but were based on average effects that may not explicitly be reflective of the complicated Namibian beef market. The Namibian beef cattle market is influenced, to some extent, by institutions and instruments introduced by the government. These institutions have influences on the supply dynamics in each of the individual market segments. In fact, these institutions have impacts on the process of price formation and discovery in each respective market. The fact that the beef cattle market in Namibia is complex has major implications for price discovery and formation, integration, and market equilibrium in the formal and informal market beef markets. Thus far, the data has shown that Namibia produces excess quantities of beef cattle and therefore exports excess production to the European Union and Norway, and more recently, to the USA and South Africa. The changes in regulations in these importing countries have major implications for the price determination, distribution and beef cattle production in the domestic market in Namibia. For example, regulations can affect performance directly through government-mandated process and production decisions. Some of the regulations have been discussed in the previous section.

Studies in beef cattle supply and demand have, over the years, focused more on the price establishment and discovery in the formal markets of beef. Previous studies on beef industry demand and supply, such as those by Ollinger and Moore (2008), Ubilava and Foster (2009), Thornton (2010), Tonsor *et al.* (2010), and Peel *et al.* (2011), used econometric tools to model the market fundamentals in the grain-fed beef cattle and feedlot production systems. However, none of these studies explored the use of introducing instrumental variables in the analysis of the dynamics of demand and supply of free-grazing beef cattle. These studies have not unpacked the complexities of formal and informal beef cattle markets. However, these studies have shown their robustness and statistically sound results, and the studies have presented a unique simplification of a more complex beef cattle industry.

2.11 Empirical Studies on the Determinants for Beef Cattle Demand

This section reviews studies that have evaluated the determinants of demand for beef cattle. The determinants of demand have implications for the dynamics of demand for beef. Therefore, in formulating the partial equilibrium model as tool for policy formation, it is important to understand the dynamics of demand-side factors because they have influence on the supply-side dynamics.

Marsh, *et al.* (2005) have argued that the beef cattle industry faces a challenge because of the improper understanding of beef demand. Some studies, for example Capps and Schimitz (1991), have introduced health information as a factor that has an impact on the demand for beef, while Piggot and Marsh (2004) and Ishida, Ishikawa and Fukushinge (2010) identified food safety, diseases and product recall news as demand shifters. Kalwij and Salverda (2007) in Norway and Bilgic and Yen (2014) in Turkey studied consumer demand patterns and found that household characteristics played a part in determining consumer behaviour. However, the long-term impact on the growth of the industry and the factors that have influences on the market dynamics were not adequately addressed. In this study, various factors are identified to cause a shift in demand for beef cattle and are discussed below.

2.11.1 Relative beef cattle prices

Economic theory suggests that "the demand for cattle is derived from the demand for beef", and evidently, beef and cattle prices are also influenced by the trend of demand for beef in the long run. Marsh *et al*. (2005) have demonstrated the dynamic effects of slaughter prices in the

US market. However, their use of a beef demand index to estimate slaughter prices was not popularly received because of the inclusion of beef by-products such as hides and offal. Consumer demand directly affects beef price. However, the use of domestic beef consumption to evaluate demand in a price equation is not a sufficient condition to account for true demand because the consumption of beef is impacted on by the price, and this results in an endogeneity problem in the estimation.

Marsh (2003) evaluated the impact of downward trends in demand for beef at retail level in the USA on the farm-level beef prices and production. Marsh (2003) found that the decline in livestock demand was attributable to changing preference settings among consumers, which were a result of food safety concerns, health attributes, inconsistent quality, demographic patterns, and relative meat prices (Schroeder *et al*., 2013).

Literature shows that the estimation of own, cross-price and income elasticities of meat demand has been the focus of many studies. For example, in 1972, Kulshreshtha and Wilson modelled the beef industry in Canada to evaluate the instantaneous relationships between the demand side, supply side, price vectors, and export variables. The model was based on a two-stage least squares approach. The inferences of the study of Kulshreshtha and Wilson (1972) signal that the elasticities coefficients were greater than the magnitudes of the coefficients estimated in other beef cattle studies carried out in Canada. However, apart from utilising the methodology, the Kulshreshtha and Wilson (1972) study says very little about the extent of the impacts of the estimated elasticities on growth.

2.11.2 Population and income growth

The United Nations Population studies of 2007, 2008 and 2013 estimated that the human population in 2050 would be 9.5 billion, with a range of 7.96 – 10.46 billion. The projected growth in population is described to occur mainly in developing countries, with the population in sub-Saharan Africa set to grow by 1.2 percent on an annual basis. The increase in population could lead to an increase in demand for beef cattle and beef products (UNFPA, 2008). Another important factor that is coupled to rapid population growth is the growth in the numbers of people living in urban areas, with Africa and Asia witnessing large influxes of people into urban areas. As such, urbanisation is believed to accelerate demands for grains and livestock products, including beef. It might be inferred that urbanisation stimulates improvements in infrastructure, which may include cold-storage facilities that allow perishable livestock products to be marketed more widely (Delgado, 2005). Therefore, urbanisation could lead to growth in demand for beef which could accelerate growth in the cattle industry. In Namibia, urbanisation is on the increase, with the recent population census indicating that about 30 percent of the population is now living in urban areas (NSA, 2019), as compared to 80 percent in developed countries (UNFPA, 2008).

Disposable personal income is another key driver that determines the increase in demand for beef cattle. Steinfeld *et al*. (2006) have stated that there is a direct relationship between income and expenditure on livestock products, including beef. Economic growth is estimated to surge upwards, with more growth expected in developing countries than in industrialised countries (van Vuuren *et al*., 2009; Rosegrant *et al*., 2009). The growth in income presents an opportunity for exporters of beef, including those in Namibia.

2.11.3 Food safety and traceability

Food safety and traceability are critical components required for export compliance. For example, Ubilava and Foster (2009) point out that food safety issues are a major concern for developed economies. The requirements for food safety standards are on the rise in developing countries because of the acceleration in household incomes. Ubilava and Foster (2009) conducted their study in Georgia, focusing on attributes of pork, and their findings show that Georgian consumers were aware of quality certification and product traceability as attributes. However, their study did not reflect how important the aspect of food safety is to the growth of the industry.

Ollinger and Moore (2008) examined the economic forces driving food safety quality in meat and poultry. Ollinger and Moore modelled food safety as a function based on the levels of salmonella, a commonly occurring pathogen in meat and poultry products, found in meat products under study after the implementation of regulations such as hazard analysis critical control points (HACCP) programmes at slaughter points in meat processing plants. However, the results derived from their findings of the occurrence of salmonella (though declining) are often generalised to a broader spectrum, and this is misleading. In Namibia, many individuals (small-scale farmers) supply beef to the market, and information about food safety and other important cattle production issues is lost by the time meat reaches a retail outlet. However, the commercial sector represents completely a different scenario, with more organised regulation, and subject to regulations that are enforced by government through the veterinary services, and through the Meat Board of Namibia, which provides quality assurances on both meat quality and safety perspectives through the certification of the brand name 'FAN Meat' (MBN, 2018).

2.12 Empirical Studies on Beef Cattle Supply Dynamics

The determinants of supply have impacts on supply variation in a partial equilibrium analysis. In order to develop a food balance sheet for beef, an understanding of the factors and how they are investigated is important for developing a tool that offers robust conclusions for policy analysis and recommendation. This section looks at the supply-side determinants. Several studies have mentioned the following important factors that determine the supply for cattle.

2.12.1 Profitability and farmers' share of the retail price

Beef cattle producers are concerned about the profits generated from their cattle sales. The share of the retail price received as a margin for producers is seen to be slowly declining, with the middlemen receiving a larger share, as compared with what the farmers receive. During 2011 and 2012, retail beef prices increased by more than the estimated beef quantity did, as price demand and supply elasticities would have predicted, given the reduction in available supplies, signalling that beef demand had increased (USDA, 2013).

For most beef producers, the concept of profitability and producer price is a major concern, although other factors listed here are equally critical in determining the supply dynamics of cattle (Jefferis, 2007). For illustration purpose, Sartorius von Bach (2020) shows that, in 1994, the producers received about 70 percent of the selling price offered at abattoirs, but over the years, the share of producer price declined to less than 60 percent.

In the past 3 decades, producers have witnessed a decrease of about 0.7 percent of share of producer price, year-on-year. Therefore, an important question to be enquired into is "why has the robust share of producer export earnings from export abattoirs decreased in recent years"? (Sartorius von Bach, 2020). It has been argued that slaughter abattoirs in Namibia have different market options to market the premium beef. The options that exist indicate that

Namibia could market different beef cuts through the local markets, particularly at retail level; for example, the retail shops located to the north of the veterinary cordon fence offer an average retail price of about N$48.93 per kilogramme (NSA, 2019). A second option would be to market beef carcasses to markets located south of the veterinary cordon fence, at an average carcass price of about N$45.41 per kilogramme. Sartorius von Bach (2020) indicates that the then current average beef retail prices ranged between N$69 per kilogramme and N$99 per kilogramme, based on the weighted average carcass cuts. On this basis, abattoirs could pay beef producers about N$32 per kilogramme, which would translate to a producer share of about 70 percent. The illustration of pricing shares is derived from an Agribank study assessing the productivity of the livestock sector (AGRIBANK, 2019).

2.12.2 Size of the breeding stock herd and productivity

Marsh (1999) derived the breeding herd size equation for the US and concluded that future beef demand depends more on technology changes than on increasing beef herds. However, it is the use of technology in animal production that has alerted consumers to become engaged in animal welfare and in dictating demands for more safe food. The use of livestock technology in Namibia for production purposes is still at a very cautious stage because of the continuous, rigorous review from the EU markets.

2.12.3 Production and transaction costs

The production costs of beef cattle include veterinary costs, feeding costs and management costs. Transaction costs include those incurred in searching for buyers, drafting contracts, negotiating sales contracts, monitoring contracts, and enforcing contracts (Kirsten *et al*., 2009). More recently in beef cattle production, transaction costs also include costs incurred in ensuring food safety standards, testing for diseases, acquiring certification for quality assurance, identifying the producer (traceability), protecting endangered species, and the preservation of streams (Schroeder *et al.*, 2013). The evolution of these determinants is important in estimating the impact that these factors have on the growth of the beef cattle industry.

2.12.4 Cattle as a store of value

Using cattle as a store of value or a savings account is synonymous with cattle producers in communal areas that are characterised by a lack of responsiveness to cattle prices. For many years, communal farmers have been widely perceived to use cattle as a 'store' of wealth, and that the value of cattle is determined by their derived products such as "use as sources of milk, beef meat consumed during special events and ceremonies, hides, and as draft power (Jarvis, 1980). Jarvis (1980) believes that these owners of cattle are considered to benefit from the security of exchange, based on the value of their cattle, and obtain status or prestige among other persons because of their perceived economic wealth (the Masai people or community in Kenya and the Himba people in Namibia are examples that fit this description). Cattle are only sold under what the need theory terms as 'sale-for-specific-cash'. However, the missing links noticed here are market incentives that are compatible with the cattle producers and lack of productive livestock development programmes. Moreover, the store of value concept becomes irrelevant when the economic value of cattle depreciates because of aging cattle stock and overgrazing, and in scenarios when drought destroys cattle herds.

Therefore, in developing an integrated pricing model, the way the model closes should ensure that the accounting identity, which stipulates that supply be equal to demand, should hold. There are various ways to close a model. However, the right way of closing a model depends on nature of country's markets and policies that have implications on determining the equilibrium pricing conditions.

2.12.5 Animal welfare regulations

Lawrence and Scott (2009) have noted that the EU and the UK have legislation and regulations in place that enshrine the concept of animal welfare in law. Nevertheless, strategies have been navigating away from using legislation as a mechanism for fostering animal welfare improvements to a greater concentration on collective action on behalf of stakeholders in animal welfare. These stakeholders include consumers. However, there is conflicting evidence as to what the potential is for adding value to animal products through setting higher animal welfare standards. In developing countries, the questions regarding consumers' preferences regarding welfare branded are still a mystery and not understood. And, often enough, these items of legislation are perceived to present stumbling blocks for growth, especially when engaged in international trade. Improving animal welfare should not penalise business profitability.

2.12.6 Cattle diseases

Thornton (2010) has affirmed the point that animal diseases generate an array of biophysical and socio-economic impacts that may be direct or indirect and may vary from localised to global. The economic impacts of disease outbreaks have been thoroughly studied since 2003, after the outbreak of Bovine Spongiform Encephalopathy (BSE), commonly known as mad cow disease, in the US–Canada beef trade (Marsh *et al*., 2005; Mattson and Koo, 2007). However, the impacts of disease outbreaks and the extent of the impacts on the growth of the industry have not been fully explored. For example, the significance and extent of the impacts of foot-and-mouth disease (FMD) on the growth of beef cattle in Namibia have not been explored, although the restrictions on the movement of cloven-hoofed animals in the northern part of Namibia have been studied. However, in the UK, FMD-related costs amounted to $18–25 billion between 1999 and 2002 (Mattson and Koo, 2007). The occurrences of FMD have shaped the livestock map for the Namibian cattle production system (MAWLR 2015).

2.12.7 Quality risk and trade

Belasco, Schroeder and Goodwin (2010) point out that the risk in cattle production is comprised of temporal variations in input and output prices, as well as cross-sectional variability in production. Variables in cattle production performance include average daily gain, feed conversion rates, mortality rates, and veterinary costs. Freebairn and Rausser (1975) analysed the US livestock industry by using a model of the production, consumption, trade, and farm prices of fed beef, other beef, pork, poultry and inventories. Freebairn and Rausser (1975) derived a set of reduced form equations from a simultaneous equation model, although their study did not identify a conclusive impact on cattle stock.

However, the important point for cattle producers is that farmers are profit maximisers and jointly manage costs, cattle performance, and carcass attributes. The extent of the impact of quality risk and trade are not thoroughly explored in the livestock industry. The significance of quality risk and beef trade to determine growth in industry should be known (Garcia-Vega and Williams, 1996).

However, it is equally evident that the empirical studies have not explored the inclusion of integrating informal and formal beef markets in modelling. Therefore, a gap exists regarding the formulation of a model that captures both markets to provide an opportunity to measure parameters of importance in improving the sub-sector performance.

2.13 Empirical Studies on the impacts of policy on the Beef Cattle Industry

This section reviews previous studies conducted on the impacts of policies and regulations on the beef cattle industry. Policy reforms and regulations have diversified the beef cattle market and therefore are important for inclusion in model development. The dynamics of the effects differ from country to country and region to region, and according to the state and nature of the stage of development. As more and additional policy regulations are introduced by developed countries, these policy regulations have implications for developing countries that are engaged in trade with those developed countries. The Namibian beef cattle market is also influenced by policy regulations and instruments introduced by the Namibian government. These policy regulations have influences on the supply dynamics in each individual market segment. In fact, policy regulations have impacts on the process of price formation and discovery in each respective market. The fact that the beef cattle market in Namibia is complex has major implications for price discovery and formation, integration, and market equilibrium in the formal and informal beef markets. The changes in regulations in importing countries have major implications for price determination, distribution, and beef cattle production in the domestic market. For example, regulations can affect performance directly through government-mandated process and production decisions. Some of the regulations have been discussed in the previous section. The following section explores the literature on the policy reforms and regulations.

2.13.1 Politics and trade policies

Tsai (1994) evaluated the structure and economic policy environment of Taiwanese livestock, meat and feed markets. The study by Tsai (1994) integrated livestock and feed models with a meat demand system and simulated the impacts of trade liberalisation on the markets. The demand system that was developed was used to test structural change and price endogeneity, where three different specifications were examined, and different complementary specifications were examined because of a complementarity problem. The study concluded that there was evidence of a structural change in the Taiwanese meat demand sector (Tsai, 1994), where prices were treated as independent. The study further indicated that the linearised approximation of the almost ideal demand systems (LA/AIDS) model, with no cross-price elasticity restriction imposed, performed better for simulation purposes. The Tsai study (1994) sets a good example of how to incorporate meat, livestock and feed sector for simulation purposes. However, there is still serious debate about the accuracy of the linearised approximation of the demand systems because demand determinants change over time.

Wahl *et al* (1991) analysed the livestock markets in Japan to investigate the level of adjustments under trade liberalisation. The approach developed incorporates the AIDS model into a supply model. The model was then used to analyse the impacts of the agreement on beef access between the USA and Japan. Wahl *et al* (1991) supply equation omitted feeding cost as inputs in the production process. However, the system of equations, a whole, is acknowledged as a tool to model production and consumption of meat and livestock. It was concluded that the imports into the Japanese markets had limited negative outcomes for the domestic livestock markets.

Bailey (2007) indicates that successful trade development driven by product or market innovations supported by more information and transparency in marketing chains such as additional traceability provided by animal identification systems.

2.13.2 Market regulations

The proposed regulations to be introduced to safeguard the South African livestock industry and the EU regulations on food safety and environmental concerns are examples of market regulations. Several studies have evaluated the impacts of market regulations on industry performance, and a major conclusion is that market regulations are perceived as a form of distortion in the markets (Piggot and Marsh, 2004; Schroeder 2004; Garforth and Rehman, 2006a and 2006b; van Vuuren, 2009; Pacheco and Poccard-Chapuis, 2012 and Mueller and Muller, 2016). However, the extent of their impacts on industry growth is unknown and untested. In recent years, Namibia has also experienced some forms of market regulation imposed by government.

In summary, the determinants of demand and supply dynamics have been well studied in the literature, but the major concern and interesting conjecture is that, despite knowing what these factors are, previous studies have failed to illustrate the impacts of these factors through making growth projections of the beef cattle industry. Their impacts are mostly evaluated on year-to-year bases. Some factors, for example environmental concerns, food safety and price, overlap on both the demand side and the supply side analyses. It is evident from the review of the literature that, although much has been researched on the demand and supply of beef, there is a gap in the research of beef cattle industry analysis, more especially in projecting growth under the scenario of the dynamics of supply and demand relations in the Namibian context.

2.14 Chapter Summary

It is evident from the empirical literature that most of the previous studies have only evaluated the determinants of the dynamics of demand and supply in the beef cattle markets in the formal markets. Several factors are predominant in affecting the production and consumption patterns and preferences of beef. However, it is equally evident that the empirical studies have not explored the inclusion of integrating informal and formal beef markets in modelling. Therefore, a gap exists regarding the formulation of a model that captures both markets to provide an opportunity to measure parameters of importance in improving the sub-sector performance. Furthermore, both the potential growth of the industry and the analysis of the dynamics of supply and demand for beef in both the formal and informal beef markets have not been addressed effectively for the purposes of policymaking. It is argued in this study that, given the identification of the performance of the industry, growth in beef cattle production is important because it enables over 70 percent of the people involved in agricultural activities (in the informal and formal economies) to enjoy their efforts through marketing and trading their products to generate revenue from utilising the domestic market and through export earnings. Thus, this study has developed a tool in the form of a commodity model to aid in evaluating the supply and demand dynamics of beef in both the formal and informal markets to shape the future growth and profitability of the beef cattle industry in Namibia.

Furthermore, this chapter provides a detailed understanding of the agricultural sector in Namibia, by exploring the sector's role in the economy, disaggregating the sector into sub-sectors, and providing details of the performance and contribution to GDP. Furthermore, the dynamics of the beef cattle industry have been shown. It has been emphasised that the cattle sub-sector is a leading contributor to GDP and has potential for future expansion, particularly in the northern communal areas. It is also important to point out that other entrants, such as the poultry and charcoal sub-sectors, are emerging as prominent alternatives for investment portfolios. Real farm prices have, over the years, increased by 34 percent since the 2008 economic meltdown. These increases illustrate the potential of the agricultural sector for diversifying the economic activities in Namibia, expanding from the reliance of the traditional sectors such as mining and services. Game farming, through trophy hunting, has equally evolved to the satisfaction of some farmers, with a growth in revenue of over 306 percent from 2009 to 2017. Acknowledging the implications of drought, some farmers view game farming as an alternative form of land utilisation, although the capital-intensive requirements for building game-proof fencing militate against the investment potential.

Despite the bottlenecks experienced in the whole economy that emanate from macroeconomic factors, the empirical literature points out that the function of demand and supply of slaughter beef cattle at export abattoirs, local butchers and traders is determined by the existence of favourable market conditions in the domestic market and the international market.

The dynamics of land ownership in Namibia contributes to the nature of the agriculture production. This chapter briefly explored the nature and status of land types in Namibia, comprising state land and freehold land. The categories of land status create divergent production capabilities, meaning that producers on state land have different objectives and production dimensions, when compared with producers on freehold land. It is indicated that cattle numbers are high in the NCAs, under state land, as compared with the title deed freehold areas; however, production (cattle for slaughtering and consumption) is lower in the NCAs. Therefore, a proper modelling of the scenarios mentioned in this chapter requires broad consideration to be taken, which should account for the structure of the industry, for the competitiveness of the quantity and quality of environmental resources, and for the support services that exist for the cattle industry.

CHAPTER 3:
MODELLING PRICE ADJUSTMENTS AND RELATIONSHIPS IN THE INFORMAL AND FORMAL BEEF MARKETS IN NAMIBIA

3.1 Introduction

Ben-Kaabia *et al*. (2005) argue that price movements at different points of transaction and along the supply chain may have important implications for producers' and consumers' welfare. The fact that Namibia exports excess beef implies that Namibian beef wholesale prices are expected to trade at or above the export parity price. Market agents and role players follow, analyse, and manipulate prices. Meyer (2006) argues that price control mechanisms are expensive and are worthless measures to implement, when informal traders and butchers transact in the open, unregulated cattle markets. Meyer (2006) states that it is important that consideration should be given to the role played by price in the domestic trade in order to formulate a tool to study the processes of price discovery in a market and thereby inform the making of policy directions.

Here, we investigate the relationship and adjustment of price that is prominent in two markets, the formal and informal beef markets. The analysis focus is placed on the long-run association and dynamics of the speed of price adjustment. The important question, then, is what form of policies would efficiently regulate price relationship, formation, and movement in the formal and informal beef cattle markets, and what kind of measures should be adopted to improve the competitiveness in terms of pricing**.** For example, farm producer prices, retail prices, and export beef price series are considered under the principle of the dynamic price transmission. To achieve the analytical procedure, the analysis invokes the multivariate step-by-step application of Johansen co-integration, followed by the application of a vector error correction model (VECM).

In this chapter, dynamic price adjustment invokes the time it takes for price series to adjust at one level to changes in the prices at different levels. In following the definition of price adjustment, Xing (2012) and Hahn (2010) suggest that price reaction is one where the speed or completeness of adjustment varies depending on whether prices are increasing or decreasing.

In recent years, beef carcass and auction prices have displayed an upward trend (see Figure 3.1). Figure 3.1 shows $IBPRICE$ represents the annual average carcass beef cattle price per kilogramme in the informal market (communal sector), $FBPRICE$ is the formal average carcass beef cattle price per kilogramme in the formal commercial areas; $RBPRICE$ is the annual average retail price per kilogramme in the formal beef cattle market (commercial sector), $PBPRICE$ is the annual average of auction producer beef cattle price per kilogramme in the commercial sector, and $EBPRICE$ represents the annual average price of export carcass beef per kilogramme at the export abattoirs. The price cycles in Namibia emanate from various sources, for example during drought occurrences, when farmers are faced with herd reduction decisions and when making decisions about herd rebuilding.

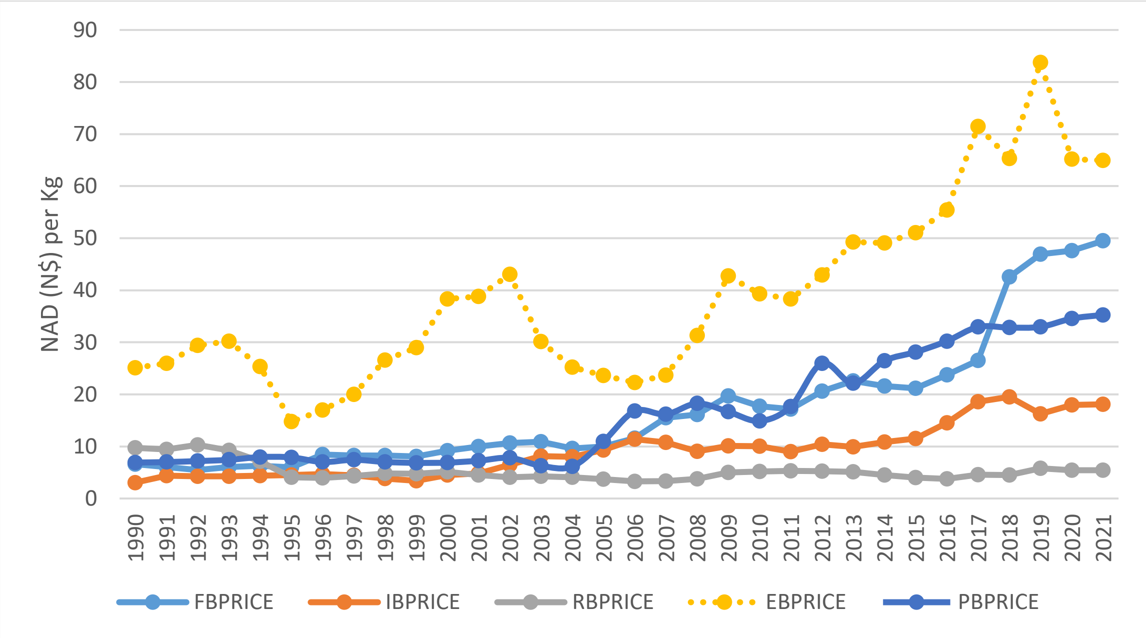

Figure 3.1: Real live cattle and beef prices (base year 2012)

Source: Author's compilation using Meat Board data (2014-2021) and MAWLR, 2021.

Thus, beef cattle producers, whether in NCA or communal areas south of the veterinary cordon fence or elsewhere, face biosafety requirements in marketing cattle in the formal market. They do not have ways of circumventing the sanitary regulations, and nor should they be thinking about doing so. NCA beef cattle producers must meet relevant domestic and developed-country standards to exploit the advantage presented by any carcass price comparative advantage in their beef cattle production. However, two lines of thought are common among the press and policymakers for explaining the recent beef cattle price spikes. One reference is to the high feed costs and prolonged droughts as constituting the primary cause of the extreme reduction of cow herds among commercial producers. To counter the impact of prolonged increases in feed costs and droughts, farmers recently opted to export about 400 000 weaners to feedlots in South Africa (MAWF 2019).

Table 3.1 shows that beef cattle prices in the informal markets in communal areas are high during times of induced supply shocks (such as disease outbreaks), and where the Veterinary Division of the Ministry of Agriculture prohibits animal movements and slaughter during outbreaks of disease. The moratoriums on slaughter usually last for more than 6 months. The closure of abattoirs and slaughter facilities because of the lack of supply generates demand, which eventually is transmitted into beef cattle price spikes in the short run. Table 3.1 sets out the descriptive statistics and shows that price in the communal sub-sector[1] increased by 65.46 percent compared with 91.04 percent in the commercial sub-sector.

Table 3.1: Namibian beef carcass price movements (1990–2020)

Beef carcass price increases in nominal terms (1990 - 2020)					
	Formal price	Informal price	Producer price	Retail price	Export price
Increase:	255.10%	229.82%	377.50%	237.16%	151.94%
Beef carcass price increases in real terms (1990 - 2020), base year 2012.					
	FBPRICE	IBPRICE	PBPRICE	RBPRICE	EBPRICE
Beef price inflation (1990 - 2020):	91.04%	65.46%	94.78%	66.92%	50.01%

Source: Author's compilation, 2021

Regarding export prices, it is important to account for the effects arising from the exchange currency instability. Exchange rate is a determining factor for trading countries. For example, in a scenario where there are currency losses in value relative to the foreign currency in a partner trading export country, an exporter is expected to experience increased short-term value. An appreciation in value of currency has the opposite effect. Currency depreciation is usually not a favoured option for a net importer (Meyer, 2006). For the Namibian beef market, where Namibia has recorded excesses in production and in exported beef and weaners, and where the domestic beef producers are dependent on lucrative export markets, currency

[1] Price data details regarding the informal beef markets (communal sector) are based on a study conducted by Agra Professional Service (Pro-Vision) for the Meat Board of Namibia (2014–2021) and the Directorate of Veterinary Services (DVS), and record sheets from 14 regions of Namibia in the Ministry of Agriculture, Water and Land Reform (MAWLR).

volatility in the European market has negative impacts on beef export earnings. Trade policy movements in importing countries may have consequences on the price at retail and producer level in Namibia. Of importance are the effects of the volatility of the US Dollar and the Euro on the export earnings for Meatco and beef processors, such as Hartlief, in Namibia.

It is argued here that, through the assistance of the government, Meatco has increased its market share of beef cattle slaughtering and processing over the recent years, after the closure of the Witvlei export abattoir. It has been noted that Meatco has state-of-the-art facilities that substantiate its market dominance in the slaughtering and further processing of beef cattle in the domestic market (MCN, 2016). On the other hand, other local butchers have limited slaughter facilities, and while some have no slaughter facilities, they are able to buy carcasses from Meatco for further processing. Meatco pays premium prices for quality beef, therefore attracting most of the beef producers (MCN, 2019). However, the premium paid by Meatco is still below the price of beef, when compared to other beef cattle markets, such as Australia, that have similar production systems and trends that Namibia has. Furthermore, Meatco's mandate, coupled with changes in leadership, management and decision-making biases, has led to discontent among cattle producers and a lack of proper incentive structures for the beef cattle producers. Both the government and Meatco have not succeeded in providing proper price incentives to beef cattle producers.

The setup in traditional cattle production in the small and distant village zones is characterised by a few traders who own cattle and slaughter daily. The slaughtering processes are only allowed after complying with the requirements of permits obtained from the veterinary offices. Further, it is argued that informal beef sellers give little adherence to hygiene and food handling requirements. Therefore, they cannot compete on a par with Meatco on quality and pricing. Meatco has built a reputation of supplying prime beef carcasses at a prime price per kilogramme, as compared with lower carcass prices received by informal producers.

In recent years, the policy focus of the government of Namibia has been on value addition. The value addition requirement by the Namibian government stipulates that market-ready-beef cattle should be slaughtered and processed domestically and be exported as beef cuts. A Meat Board report points out that, under the same requirements, there is, for example, a levy charged on every mature animal that has live mass of about 450 kilogrammes. The levy amount is about 30 percent of the export price (noted in MBN, 2012a and 2016). This levy requirement may distort the domestic price in the long term.

An additional bottleneck to value addition on domestic beef cattle producers is the acceleration of production and feed costs that are required for growing weaner calves on the drought-impacted veld to achieve the 450 kilogramme of slaughter mass. However, with erratic rainfall patterns, the feeding costs required to support the cattle production system and attain the required 450-kilogramme slaughter weight have surged. Government has existing regulations in place that limit the movement of livestock between the two cattle production zones (see Figure 3.2). These regulations typically are derived from the international norms that are diffused through such mechanisms such as the World Trade Organization (WTO), the World Organisation for Animal Health (OIE), the Codex Alimentarius Commission, and other standards-setting bodies for compliance to international markets. No doubt, the N-VCF farmers bear the brunt of these strict regulations (see Figure 3.2 showing the location of the veterinary cordon fence). This form of regulation has caused discontentment among producers of livestock and a disequilibrium in the mechanisms of supply and demand of cattle marketing. Despite the accelerated price increase for beef carcasses in the informal market, beef supply is still weak and constrained by regulations and below-average off-take rates.

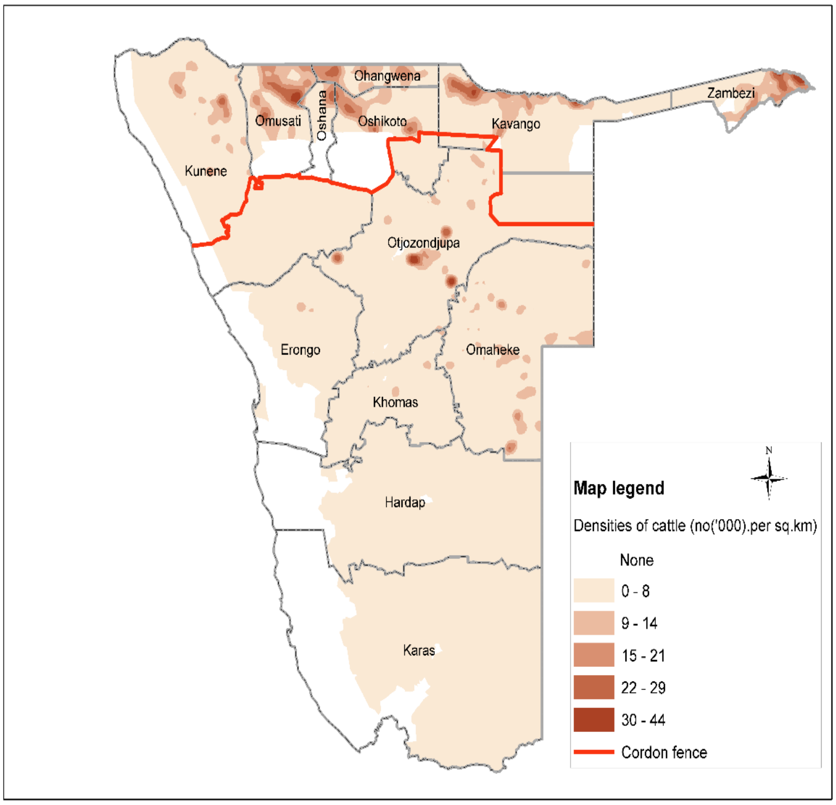

Figure 3.2: Densities of cattle distribution in Namibia

Source: Directorate of Veterinary, MAWF (2015)

3.2 The Theoretical Background on Price Relationship and Adjustment

It is important to state that price is a conduit for interlinking of markets: The nature of price adjustment and speed with which the price shocks are transmitted among beef producers, wholesale and retail channels reflects the actions of market role-players in different market segments. To that extent, to note that the spread in separate price settings can reflect the magnitude of market coordination and the extent of efficiencies that prevail in these markets. There is growing discontent among role players regarding the status quo of the beef pricing efficiency in the country. Producers are of the opinion that the current pricing system pitches producers at the lowest ebb, meanwhile beef processors and retailers are receiving high profit margins. Therefore, it is important to argue that an evaluation of the efficiency of pricing and markets is the key to unlocking the mechanisms that could allow cattle markets to absorb shocks emanating from a set of diverging prices in the domestic and international markets.

A proper understanding of the beef price determination in the Namibian beef sector, as well as the way in which this is associated with trading partners (in this case, South Africa and European markets), has not yet been grasped by key stakeholders in the beef sub-sectors. The lack of studies in price relationship in the beef sector in Namibia has led to inaccuracies in providing important measurement of the degree to which supply and demand shocks arising in one sub-sector, formal, are transmitted to the informal sub-sector, or from the European market and South Africa to the Namibian beef market.

In more recent years, the Namibian government, through its stake in Meatco and the enforcement to government regulations, has transmitted negative impacts to commercial producers of beef through Meatco's operational deficiencies and strategic decisions. The question is whether there is a relationship between the prices of beef cattle in the informal and formal markets, and whether Meatco has offered informal traders' prices to maximise the market value of their cattle. The research works of Saghaian *et al.* (2013); Sarmiento and Allen (2000); Bailey (2007) and Schroeder *et al.* (2013) regarding whether this is a typical example of an oligopoly operation, which may include non-cooperative collusion, strategic price signalling and investment.

A study, by Taljaard *et al.* (2009) on price transmission in the sheep meat sector in Namibia, shows that Namibian small-stock prices were linked to South African sheep prices. Furthermore, the sheep market in Namibia is linked to the South African sheep market, but not vice versa. The findings imply that introducing a shock in the small-stock scheme in Namibia will have an impact on the South African sheep market, but a shock in the sheep market in South African will not have any effect on the sheep market in Namibia. Therefore, the Taljaard *et al* (2009) study has left a mixed interpretation of price transmission and does not provide information on the producer–retail margin spread for small-scale farmers and large-scale sheep farmers, nor on the welfare implications.

There is limited evidence to point to the level of price association in the formal and informal domestic markets trading in beef. However, international literature resources which state that price association and price linkages exist, for example, the study of Saghaian *et al* (2013) evaluated the dynamics of price transmission and market power in the formal Turkish beef sector using a vector error correction model and showed that retail prices tend to rise above equilibrium, whereas wholesale prices tend to fall, therefore, creating an impact on the price margin. Saghaian *et al* (2013) showed that the speed of adjustment was higher for wholesale than for retail, where the adjustment can be attributed to the speed of relay of market information, particularly price information. The study concludes that there exist asymmetric price transmission and a possibility of growing market concentration and inefficiency in the Turkish beef sector.

Furthermore, other notable studies on pricing that involve the vector error correction model include those by El Benni *et al.* (2014), Cutts and Kirsten (2006), and Conforti (2004). The foundation of many of these studies was to use a bivariate approach of the vector error correction (VEC) model. The approach and foundation followed in this chapter is to use the multivariate VEC model representation. In this chapter, we provide examples of the application of the bivariate-based VEC model, such as the formulation in Jaleta and Gebermedhin (2009) for wheat and teff in Ethiopia; the study by Minot (2011) that focused on the transmission of world food price changes to markets in Sub-Sahara Africa; and the study by Kelbore (2013), who based a case study that assessed the world food prices and their transmission to the Ethiopian domestic food prices. Kelbore (2013) used a version of the VEC model that included a threshold aspect to account for the presence of marketing costs.

This chapter reports other beef studies that have based their analyses on co-integration and VEC model specifications to analyse pricing and the level of association in supply chains, such as the Sarmeinto (2000) study that analyses the dynamics of beef supply in the United States of America (USA) in the presence of co-integration testing of backward-bending hypothesis. Furthermore, the studies of Schroeder *et al*. (2013), Mkhabela and Nyhodo (2011), and Worako *et al.* (2008), which formulated bivariate-based models to investigate consumption patterns for beef in South Africa and in the USA. In a similar manner, the study by Cutts and Kirsten (2006) applied a VEC model framed for South Africa to capture price association in the supply chains of selected commodities. This chapter concludes that these studies are similar in the sense that their magnitudes of analysis were set for organised, formal market setups and supply chains.

The structure of the VEC model representation used in this chapter is multivariate formulated, with the ability to capture multiple price series relationships and speeds of adjustment. The informal market or communal market prices are introduced in the model to account for the difference in measurement and approach.

3.3 Empirical Procedures

This section provides the step-by-step methods used in the analysis.

3.3.1 Testing for unit root

A unit root process is conducted to determine if the variables have the same order of integration or not. Trends in data can lead to a spurious correlation that implies relationships between the variables in a regression equation, when in fact none exist. That is why, in using a standard regression technique such as OLS with trending or non-stationary data, spurious regression results are found (where R-squared is approximating unity, t and F statistics look significant and valid). Gujarati (2004) says that this leads to falsely concluding that a relationship exists between two unrelated nonstationary series. If a variable is stationary, for example it does not have unit roots, it is said to be integrated of order zero $I(0)$. If a variable is not stationary in its level but stationary in its first differenced form, it is said to be integrated of order one, $I(1)$. More generally, the series X_t will be integrated if ordered, for example, $X_t \tilde{} I(d)$, if it is stationary after being differenced of d times, so X_t contains d unit roots (Dickey and Fuller, 1981).

Many non-stationarity tests exist, with their main purpose being to test the stated postulations that the variable under investigation has a unit root and is likely to benefit from being stated in its first or second difference form should the first difference be found to contain unit root (Becketti, 2013; Baltagi, 2008; Lütkepohl, 2005; Hamilton, 1994). The Augmented Dickey–Fuller (ADF), Phillips–Peron, and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests are invoked in this study to evaluate the unit root processes, which is done to determine whether the time series is stationary or non-stationary to ensure that spurious results are avoided (Baltagi, 2008). Unit roots are conducted on all key variables by using all the three methods.

3.3.2 Augmented Dickey–Fuller (ADF) test

This test is an improvement of the Dickey and Fuller test, and it incorporates the lagged difference of the predicated variable in Equations (3.1), (3.2) and (3.3) to ensure that the errors are free from autocorrelation. These equations enable the ability to perform a random walk, in cases where there is drift or no drift, such that:

$$\Delta X_t = \alpha + \beta_1 T + \beta_2 X_{t-1} + \sum_{i=1}^{p} \lambda \Delta X_{t-1} + \varepsilon_t \qquad (3.1)$$

$$\Delta Y_t = \alpha + \beta_1 T + \beta_2 Y_{t-1} + \sum_{i=1}^{p} \lambda \Delta Y_{t-1} + \varepsilon_t \qquad (3.2)$$

$$\Delta Z_t = \alpha + \beta_1 T + \beta_2 Z_{t-1} + \sum_{i=1}^{p} \sigma \Delta Z_{t-1} + \varepsilon_t \qquad (3.3)$$

where: Δ is a change in X; Y and Z

- T accounts for time
- P represents the number of lags added to the model
- ε_t is white noise
- Δ, λ andσ are the coefficients of ΔX_{t-1} ;ΔY_{t-1} and ΔZ_{t-1} respectively
- $\alpha$is the intercept term and ε is an error term.

The ADF tests the hypothesis that $\beta_2$equates to 1 against the alternative hypotheses that $\beta_2 < 1$. If the computed test statistic is greater than the critical value at the selected significance level, the null hypotheses of the presence of a unit root cannot be rejected. The rejection of the alternative hypotheses indicates that the time series is stationary whereas non-rejection of the null hypotheses indicates that time series is non-stationary (Gujarati, 2004).

Maggiora and Skerman (2009) state that it must be noted that, to select the optimal lag length for the model, the log-likelihood function must be maximised. That is done by selecting the model with the lowest Schwarz Bayesian Information Criteria (SBIC), confirming the results with the Akaike Information Criterion (AIC) to ensure accuracy.

3.3.3 Phillips–Perron (PP) test

If the data suffers from serial correlation and heteroscedasticity in the error term, then the Phillips–Perron (PP) non-parametric test is used (Phillips and Perron, 1988). PP accounts for this by introducing the lagged difference term of the dependent variable (Baltagi, 2008).

$$\Delta Y_t = \alpha + \beta_1 T + \delta Y_{t-1} + \varepsilon_t \tag{3.4}$$

$$\Delta P_t = \alpha + \beta_1 T + \lambda P_{t-1} + \varepsilon_t \tag{3.5}$$

$$\Delta Z_t = \alpha + \beta_1 T + \sigma Z_{t-1} + \varepsilon_t \tag{3.6}$$

where δ, λ and σ represent the parameters for the lagged values of Y, P and Z, respectively.

The main difference between the two tests is that, while the ADF test uses a parameter autoregressive to approximate the ARMA structure of the errors in the test regression, the PP test modifies the test statistic so that no additional lags of the dependent variables are needed in the presence of serially correlated errors (Phillips and Perron, 1988).

An advantage of the PP test is that it assumes no functional form for the error process of the variable, which means it is applicable to a very wide set of problems. Its disadvantage is that it relies on large samples to give reliable results, and thus it will perform rather poorly with small sample sizes. However, both these methods, PP and ADF are criticised over their failure to determine whether a process is stationary when the root lies close to 1, for example, with 0.95, these tests may incorrectly fail to reject the null hypotheses and find the time series in the equation to be non-stationary (Baltagi, 2008). These tests are also criticised for their low power and size problems.

3.3.4 Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test

In cases where the PP and the ADF test results are contradictory, the KPSS stationarity test can be used. The KPSS statistic uses OLS regression on a trend and random walk. Researchers have noted that standard unit root tests sometimes fail to nullify the stated hypotheses of a unit root when applied to economic data (Phillips and Ouliaris, 1990). Hence, the KPSS can be seen as an alternative to the ADF and PP tests.

The equation is as follows:

$$Y_t = \beta_1 T + (r_t + \alpha_1) + \varepsilon_t \quad (3.7)$$

$$P_t = \beta_1 T + (r_t + \alpha_2) + \varepsilon_t \quad (3.8)$$

$$Z_t = \beta_1 T + (r_t + \alpha_3) + \varepsilon_t \quad (3.9)$$

where: $r_t = r_{t-1} + \mu_t$ is a random walk, $r_0 = \alpha_1$, α_2 and α_3 are the intercepts, and μ_t is [*i i d* (0, σ^2)].

3.3.5 Lag length criterion

In time series data analysis, the influence of past events on the current situation is also of interest. To determine this, a model that involves a number of lag terms is imposed on the data. The coefficients of these lag terms give us information about the effects of past events, and it should help us to predict the future values of the dependent variables under study.

One approach to choosing the appropriate lag length is to perform a hypothesis test on the final lag. Sims (2014) explains that the problem with this *t*-statistic is that such tests would incorrectly reject the null hypothesis of zero coefficients 5% of the time. An alternative approach that counters this problem is to estimate the lag length by using Information Criterion (IC) methods. Sims (2014) identifies the following information criteria: the AIC, the SBIC and the HQIC approaches. These Information Criterion methods are also recommended, as they give the best results when the number of observations used in each model is the same. Moreover, as the sample sizes increase, the performance of the IC improves, and the differences in performance between IC decreases. These information criteria are designed explicitly for model selection. The model selection criteria generally involve the calculation of information criteria functions for each of the models, and we pick a model for which the function is maximised or minimised.

In most cases, a model with the fewest parameters to estimate is chosen, provided that each one of the candidate models is correctly specified, i.e., the most parsimonious model of the set.

However, selecting a higher order lag length than the true one overestimates the parameter values and increases the forecasting errors. At the same time, selecting a lower lag length usually underestimates the coefficients and generates uncorrelated errors. Hence, in this research, following the recommendation by Sims (2014), the lag length provided by most of the selection criteria will be selected.

Davidson and McKinnon (2004) indicate that whenever two or more models are nested, the AIC may fail to choose the most parsimonious one, whereas if they are not nested and only one is well specified, it chooses the well-specified model asymptotically. This is because the model has the largest value of the log-likelihood function. The SBIC avoids such problems by replacing the 2 in the AIC function in Equation (3.10) with log T term, as in Equation (3.11). As T approaches infinity, the addition of another lag would increase the SBIC value by a larger margin. Hence, asymptotically, SBIC would pick the more parsimonious model than AIC might suggest.

The Hannan-Quinn Information Criterion (HQIC) is often used as a criterion for model selection among a finite set of models. The HQIC introduces a penalty term for the number of parameters in the model, but this penalty, together with the SIC penalty, is larger than the penalty imposed by the AIC. The term Ln (Ln (n)) in Equation (3.12) ensures that, unlike the AIC, HQIC is strongly consistent. It follows the law of the iterated logarithm, that any strongly consistent method must miss efficiency by at least Ln (ln(n)) factor. So, in this sense, HQIC is asymptotically very well behaved.

Following the unit root tests, is the determination of the lag length of the series. This is accomplished by using the Akaike Information Criterion (AIC), the Schwarz Bayesian Information Criterion (SBIC) (Schwarz, 1978) and HQIC. The equations are as follows:

$$AIC = \frac{-2l}{T} + \frac{2K}{T} \tag{3.10}$$

$$SBIC = \frac{-2l}{T} + \frac{KlogT}{T} \tag{3.11}$$

$$HQIC = -2Lmax + 2Kln\big(ln(n)\big) \tag{3.12}$$

where T is the sample size, K is the number of parameters, and l is the log likelihood. The main differences between the two tests are that the AIC selects the model that will predict the best values and is less concerned with having too many parameters. In contrast, the SBIC and HQIC are designed to select the true values of p and q (lag lengths). However, both can be used to compare the in-sample or out- sample forecasting performance of the model.

For example, Becketti (2013) states that the unit root test procedure is conducted by making use of the Augmented Dickey–Fuller (ADF) test to establish the process of stationary, in which case the variance and mean is constant, over time. The unit root test is specified as follows.

$$Y_t = \alpha + \rho Y_{it} + \varepsilon_{it} \qquad (3.13)$$

As defined by Becketti (2013), ε accounts for disturbance among observed variables which are assumed to have homoscedastic properties and are assumed to exhibit normality. Becketti (2013) suggests that the choice of the number of lags (p) to be included in the unit root test is based on the significant lag of the autocorrelation function (ACF) and the partial autocorrelation function (PACF) plots of the correlogram and partial correlogram. Becketti (2013) states that the value of p is taken to be the number of lags at which the ACF cuts off or the number of lags of the PACF that are significantly different from zero. Becketti (2013) suggests that the rule of thumb is to compute ACF up to one-third to one-quarter of the length of the time series. The ACF and PACF show different lags that are correlated and compared with the confidence bounds, mostly at 95 percent level (Becketti, 2013). Abitante (2008) suggests that performing this step will lead to AR process in cognisance of the properties of the residual. Becketti (2013) states that in Equation 3.13, the parameter ρ is the order of the autoregressive, α is an intercept, and Y_i represents the lagged dependent variables considered in the model. Becketti (2013) states that the unit root process will evaluate the following postulation:

$H_0: \varphi_i = 0,$ variables are not following a unit root process

$H_1: \varphi_i \neq 0,$ variables are following a unit root process

A key decision needs to be taken when the result shows that $\varphi < 1$ at a 5% significant level, where Becketti (2013) then advises a researcher to nullify the stated postulation of the unit root process, implying that the time series of all the variables are demonstrating unit root process, where the effects of external shocks would decay.

On the other hand, if$\varphi > 1$, Becketti (2013) advises not to nullify the stated postulation that there is a unit root process, hence the time series are nonstationary and that the shocks affect growth over time (Becketti, 2013). If we cannot reject the stated postulation, the next step would be to identify the appropriate lag structure. In that position, Becketti (2013) suggests using the Akaike information criterion (AIC).

This sub-section provides an overview of the procedures and importance of unit root testing. The multivariate Johansen co-integration, the VEC model, and Granger Causality (GC) provide important provisions for handling time series observation. The work of Dickey and Fuller (1979), and the approach and usage of ADF and Phillips–Perron (PP) provide a technical way of testing unit root process. The works of Johansen (1988; 1992), the Johansen co-integration test for ranking matrix of co-integrating price series. Co-integration describes a long-run, or equilibrium relationship between the variables (Sims, 2014). In adopting the suggestion of Sims (2014), the definition makes co-integration an ideal analysis technique to ascertain the existence of a long-term relationship between the formal and informal beef cattle price series in Namibia. The dynamic behaviour of the variables can be better accounted for properly in the representation of an error correction modelling approach. To aid the necessity of the error correction model, the two superior tests of Johansen multivariate co-integration should be performed first. The maximum eigenvalue abbreviated as **λ**-*Max* and the *Trace* denoted as **λ**-*Trace* statistic tests are the two superior tests of Johansen multivariate co-integration. Enders (1995) and Hamilton (1994) offer more information about the tests and the importance of determining the number of co-integrating relations among variables. The *Maximum eigenvalue* evaluates the null postulation, which suggests that *r* co-integrating relations against the alternative of *r* + 1 co-integrating relations for *r* = 0, 1, 2…. *n* – 1, in this case, *r* account for the position of vectors in a matrix. According to Enders (1995) and Hamilton (1994), the test statistic is calculated as:

$$LR_{max}\left(r \; / \; (n+1)\right) = -T * log\left(1 - \hat{\lambda}\right) \tag{3.14}$$

Enders (1995) and Hamilton (1994) define λ as the maximum eigenvalue and T is the sample size, while the $Trace$ statistic tests the null hypothesis of r co-integrating relations against the alternative of n co-integrating relations. Enders (1995) and Hamilton (1994) show that, in Equation 3.14, n accounts for number of variables, such that r can assume $1{,}2 \ldots n\!-1$. Enders (1995) and Hamilton (1994) give the Trace statistic equation to take the following form:

$$LR_{tr}\left(\frac{r}{n}\right) = -T * \sum_{i=r+1}^{K} log\left(1 - \hat{\lambda}\right) \quad (3.15)$$

Enders (1995) and Hamilton (1994) argue that *Trace* and *Maximum eigenvalue* statistics give the same outcomes. However, in scenarios where there is divergence in the outcome, the *Trace* statistic offers more plausible inferences. In addition, Enders (1995) and Hamilton (1994) suggest that the Johansen tests embedded in Equations (3.14) and (3.15) could account for unrestricted model (with a trend) and restricted model (without a trend).

Enders (1995) and Hamilton (1994) suggest that the choice of the number of lags (p) to be included in the unit root test should be based on the significant lag of the autocorrelation function and the partial autocorrelation function plots of the correlogram and partial correlogram. Becketti (2013) suggests that the value of p is taken to be the number of lags at which the ACF cuts off or the number of lags of the PACF that are significantly different from zero.

3.3.6 Tests for co-integration

After determining the lag length, the next step is to test for co-integration amongst the variables. Becketti (2013) notes that co-integration is generally defined as a concept that reveals the presence of a long-run equilibrium relationship amongst the variables. It indicates convergence to some equilibrium in the long run. However, if all variables are integrated of order zero, then only a short-run relationship exists. Co-integration is a statistical property of time series variables (Hamilton, 1994). Two or more time series are co-integrated if they share a common stochastic drift. If two or more series are individually integrated, but some linear combination of them has a lower order of integration, then the series is said to be co-integrated.

To analyse time series with classical methods like OLS, the assumption that the variance and the mean of the series are constants that are independent of time, such that they are stationary, holds. Non-stationary time series (unit root variables) do not meet this assumption, so the results from any hypothesis test will be biased or misleading. They will have to be analysed with a different method, and one of the methods is use co-integration. For example, Granger and Newbold (1974) argued that the use of linear regression, in a similar manner as to what was done by economists later in the 1980s, was to be regarded as being most inappropriate and misleading because such linear regression formulations result in spurious correlations.

Granger and Newbold showed that when two non-stationary time series variables are tested together, they could produce results that are statistically significant, even though there are no significant underlying relationships between the two. Much of the theory developed earlier was able to interpret the relationship between variables in levels, but not differences. On the contrary, later research has shown that many economic time series data is non-stationary at levels testing, and so new approaches to estimation have had to be developed for allowing greater accuracy in the interpretation of results. The following sub-section discusses the procedure for testing for co-integration.

3.3.7 The Engle-Granger two-step method

Becketti (2013) suggests that the next step after co-integration is to use the Granger Causality test. It is worth noting that the Granger Causality test is an option that is subject to the results derived from Equations (3.16) and (3.17) presented below.

$$Y_t = b_0 + \rho_0 X_t \sum_{i=1}^{m} \rho_i X_{t-i} + \sum_{i=1} b_i Y_{t-i} + \mu_t \qquad (3.16)$$

$$X_t = \gamma_0 + \omega_0 Y_t + \sum_{i=1}^{m} \delta_i X_{t-i} + \sum_{i=1} \omega_i Y_{t-i} + \varepsilon_t \qquad (3.17)$$

Becketti (2013) and Enders and Granger (1998) suggest that Equations (3.16) and (3.17) represent the Granger Causal model which is typically captured in an ordinary least squares approach. Becketti (2013) offers the advice that a study should always conclude with diagnostic or post-estimation tests to validate the robustness of the results. The robustness tests suggested are the heteroskedasticity test by Breusch-Godfrey and the Durbin–Watson test to capture the presence of serial correction auxiliary terms.

The model invoked in this analysis is a multivariate form. The proposed hypothesis is that beef carcass price series in the informal markets is derived from the beef carcass prices function originating from the formal market. Formal prices include prices at the levels of retail outlets, auctions, and export markets.

$$IBPRICE_t = f(FBPRICE_t, RBPRICE_t, PBPRICE_t, EBPRICE_t) \qquad (3.18)$$

Where price series are already defined in Figure 3.1. The variable t denotes the time trend for period 1990–2014. The methodological approaches adopted in this analysis follow the steps of Conforti (2004) to conduct a logarithmic transformation of the prices so the outcome coefficients from the model output are explained as price elasticities.

VEC model is a standard vector autoregression (VAR) and possess p lags, following the Engle and Granger illustration:

$$Price_t = v + A_1 Price_{t-1} + A_2 Price_{t-2} + \cdots + A_p Price_{t-p} + \epsilon_t \quad (3.19)$$

The variables in the representation as follows: $Price_t$ is $K \times 1$ vector of variables (price series), v is a $K \times 1$ vector of intercept terms, $A_1 - A_p$ are $K \times K$ matrices of parameters, and ϵ_t is a $K \times 1$ vector of disturbance terms where ϵ_t has a zero mean and covariance matrix $\sum$, and is independently, identically distributed (*i.i.d*) normal over time (Becketti (2013). Accordingly, the VAR model set out in Equation (3.19) can be transformed as a VEC model presentation as:

$$\Delta Price_t = v + \Pi Price_{t-1} + \sum_{i-1}^{p-1} \Gamma_i \Delta Price_{t-1} + \epsilon_t \quad (3.20)$$

Becketti (2013) further states that the $\Delta Price_t$ is a matrix conforming to $K \times 1$ matrix of price series, representing $Price_t - Price_{t-1}$; v is a K × 1 vector of intercept terms; and $\Pi = \sum_{j=1}^{j=p} A_j - I_k$ represents a matrix that captures the long-run relationships among the price series. Becketti (2013) suggests that if we assume that Π has reduced rank that varies $0 < r < K$ so that it can be expressed as $\Pi = \alpha\beta'$, where α and β are both $r \times K$ matrices of rank r, then α is matrix describes the speeds of the adjustment, where each price series returns to long-run equilibrium and the β matrix captures the cointegrating vectors in a long-run relationship (Enders and Siklos, 2001; Lütkepohl, 2005; Becketti, 2013).

Becketti (2013) shows that the $\Gamma_i \Delta Price_{t-1}$ terms capture the short-run relationships among the elements of $Price_t$ matrix, while the v and ϵ_t in Equations (3.19) and (3.20) are homogenous. Becketti (2013) provide an exposition where a multiple variable representation delivers 2 co-integration vectors and discounting v and ensuring that $\Pi = \alpha\beta$.

3.3.8 Data and description of variables

The analysis in this chapter relied on multiple datasets obtained from the Meat Board of Namibia (MBN, 2012) and the NamLITS database held by the DVS. For example, the 2005 and 2009 bulletins contain livestock prices (MAWF, 2005, 2009), while the CPI figures are based on National Planning Commission and National Statistical Agency provisions (NPC, 2012 and NSA, 2012). As a standard process, a deflating of all prices was carried out. Therefore, the prices in this chapter are expressed in South African rand per kilogramme. It should be mentioned that the South African rand is a legal tender and widely used, on 1-to-1 basis, in Namibia (BoN, 2013, 2014, and 2015).

As shown in Figure 3.1, price data express a sturdy but inconsistent trend, which may lead to the prospect of 1st order one $[I(1)]$ process. The time trend in the price series appears to be approximately linear, implying that there is a need to specify trends (constant) when modelling these price series. Retail price series displayed a positive slope in the observed period, while the export price had an upswing in early periods, after which it displayed a negative trend in 2008. This widening in the price series is not indicative of buying power, because supply shocks such as production costs, for example feed costs and severe droughts may be the cause for this phenomenon.

Outcome presented in Table 3.2 gives the account that the average of the informal beef cattle price is lower than that of the prices offered in other markets and about 3 times lower than the retail beef price and about 4 times lower than the export price. It is important to point out that the valuation of live cattle is based on their live mass in all markets; however, differences lie in the type of breed. Traditionally, informal markets commonly trade in small, framed cattle with an average live mass of about 218 kilogrammes compared with larger framed cattle stock with live mass of about 280 – 325 kilogrammes in the formal markets.

Table 3.2: Real price series descriptive statistics (1990 - 2021)

Variables	Obs	Mean	Std. Dev.	Min	Max
IBPRICE	25	6.73	2.76	3.05	11.88
FBPRICE	25	8.48	3.45	3.84	14.98
RBPRICE	25	21.64	7.52	10.55	35.57
PBPRICE	25	13.30	7.09	6.16	29.41
EBPRICE	25	29.18	10.37	14.87	46.72

Source: Author's compilation, 2021.

3.4 Empirical Results and Discussion

In this section, we offer and discuss the results of the unit root testing, the multivariate Johansen Co-integration procedure, the VEC model, and the Granger-Causality outcomes.

3.4.1 Unit root test

Figure 3.1 presented earlier displayed the behavioural patterns of prices. The price series that possess first-degree association are deemed to have unit root process. Table 3.3 presents the outcome of the unit root process. For all the price series, the stated postulation is nullified at 1st difference because the outcomes of the ADF and Phillip–Perron (PP) values are more than the 1 percent and 5 percent critical levels of significance, respectively. This outcome implies that price series are associated and indicates that co-integrating relationships exist among the price series. The outcome therefore requires the application of a multivariate Johansen co-integration procedure.

Table 3.3: Outcome of the tests for Unit root process

Augmented Dickey–Fuller Test (ADF)			Phillips–Perron test statistic (PP)	
Data in levels				
Variables	Constant without a trend	Constant with trend	Constant without a trend	Constant with trend
L_IBPRICE	-1.2643	-1.8379	-1.2643	-1.9668
L_FBPRICE	-1.3935	-2.0083	-1.4139	-2.0083
L_PBPRICE	0.2952	-2.7663	2.1807	-2.6449
L_RBPRICE	-0.8389	-1.4136	-1.1990	-2.7086
L_EBPRICE	-1.2066	-3.8564	-1.2067	-1.9674
Data in first difference				
L_IBPRICE	-4.9678**	-4.7761**	-4.9678**	-4.7761**
L_FBPRICE	-4.8969**	-4.7255**	-4.8789**	-4.7393**
L_PBPRICE	-5.9128**	-4.8644**	-6.6350*	-11.9568*
L_RBPRICE	-4.4697**	-4.8517**	-5.0914**	-5.2299**
L_EBPRICE	-3.3132**	-3.3969**	-4.5794**	-4.7500**

Source: Author's compilation, 2021.

Note: * denotes that the null hypothesis of stationarity is rejected at 1% level of significance, and ** is rejection at 5% level of significance, based on the Akaike Info Criterion (AIC) and the Phillips–Perron (PP) test, respectively.

3.4.2 Determination of the rank and co-integrating results

The lag length is based on the outcome of the information criterion. The information criteria seek to handle the trade-off between a parsimonious model and a comprehensive model. Furthermore, the results suggest that the inclusion of one lag for correlogram for autocorrelation and the autocorrelation is tested at the confidence level of 5%. Based on the output, no serial autocorrelation was encountered. In terms of exhibiting lag length, the Schwarz and Hannan–Quinn information criteria produced 1 lag, while the AIC and Final FPE presented 3 lags.

Table 3.4 below presents the co-integrating outcome. The explanation is based on the mathematical expositions described earlier about the association of beef cattle price series. According to Table 3.4, *Trace* and *Maximum eigenvalue*, the tests that $H_0: r = 0$) is nullified until where $H_0: r = 1$, because 118.73 is greater than the critical values of 69.82, at the level where $r = 0$; similarly, 56.21 is greater than the critical value of 47.86 when $r = 1$). This implies that we nullify the stated postulation of zero co-integration at $r = 0$ and $r = 1$ and accept that there are 2 degrees of association among the beef prices in Namibia, where $H_0: r = 2$ where 28.90 is less than 29.78 at the 5% level of significance.

Table 3.4: The outcome of the multivariate Johansen co-integration

Hypothesised number of co-integrating equations	λ-Trace statistic	Critical value (5%)	λ-Max –Eigen statistic	Critical value (5%)
$r = 0$	118.73	69.82	62.52	33.87
$r \leq 1$	56.21	47.86	28.30	27.58
$r \leq 2$	28.90**	29.78	19.47**	21.13
$r \leq 3$	9.43	15.49	9.40	14.26
$r \leq 4$	0.03	3.84	0.03	3.84

Source: Author's compilation, 2021.

***note: the Trace and Max eigenvalues show that there are 2 co-integrating long-run relationships.*

It is evident from Table 3.4 that both the Trace and Max eigenvalues indicate that there are 2 co-integrating long-run relationships between the beef cattle price series. This implies that we reject the null hypothesis of no co-integration at r = 0 and r = 1 and accept that there is 2 (where H_0: r = 2(28.90 < 29.78 for Trace, and 19.47 < 21.13 for Max at 5% level of significance, respectively) co-integration relationship among the beef cattle price series in Namibia.

3.4.3 Vector error correction model results

Sims (2014) suggests that the term EC_t as the speed of adjustment parameter or feedback effect is derived as the error term from the co-integration models whose coefficients are based on the normality of the equation on X_t in the equation (Price in Equation 3.14) and Y_t (price in Equation 3.15), respectively. The EC_t shows how much of the disequilibrium is being corrected, that is, the extent to which any disequilibrium in the previous period is being adjusted in y_t. A positive coefficient indicates a divergence, while a negative coefficient indicates convergence. If the estimate of EC_t = 1, then 100% of the adjustment takes place within the period, or the adjustment is instantaneous and full, while if the estimate of EC_t = 0.5, then 50% of the adjustment takes place each period/year. EC_t, shows that there is no adjustment, and to claim that there is a long-run relationship does not make sense anymore. Therefore, obtaining the ECT requires estimating a VEC model replication of Equation (3.20).

The VEC model output is a confirmation of the adequacy of the model, based on stable and possession of correct signs. Table 3.4 indicates the a priori expectation on the sign of the estimated parameters. The expected positive signs illustrate the mild to rapid adjustment toward equilibrium (Lütkepohl, 2005). Table 3.5 indicates that when the predictions from the co-integrating equations are positive, informal beef cattle price is above its equilibrium value and drifts away from the equilibrium (Lütkepohl, 2005).

The Output presented in Table 3.5 shows that the outcomes from the co-integrating equations possess positive signs, meaning that the informal beef cattle price is above its equilibrium value and drifts away from the equilibrium, which implies that when the average beef cattle price in the informal market is high, it quickly falls back toward the formal auction beef cattle price per kilogramme. The VEC model outcome illustrates that, for the informal beef cattle price to be in long-run equilibrium, it will have to adjust by 63% based on the error-correction terms of the ECT, or alternatively, about 63 % of disequilibrium is corrected each year by changes in log of informal beef cattle price, similarly, for formal beef cattle price should adjust by minus 81% based on the error-correction terms. The estimation outcome is represented by the following two equations:

The first co-integrating long-run outcome:

$$L\_IBPRICE_{t-1} = -2.655 - 0.9908L\_PBPRICE_{t-1} + 4.5885L\_RBPRICE_{t-1} - 2.0788L\_EBPRICE_{t-1} \quad (3.21)$$

And the second long-run, co-integrating outcome:

$$L\_FBPRICE_{t-1} = -2.3191 - 0.9696L\_PBPRICE_{t-1} + 4.4439L\_RBPRICE_{t-1} - 2.0035L\_EBPRICE_{t-1} \quad (3.22)$$

The explanations of the outcome parameters were found to be according to guidelines proposed by Becketti (2013), Baltagi (2008), Lütkepohl (2005), and Hamilton (1994). The parameters in Equations (3.12) and (3.13) indicate stability among all the price series in the study (average beef cattle price series for the formal auction beef cattle price, and the average price series for producer and export prices). In Equation (3.15), the formal beef cattle price series was to be omitted because it was found to be insignificant, although significant in Equation (3.16), while the informal beef cattle price series was similarly not significant in Equation (3.16), but significant in Equation (3.14). The ECT represents the short-run relations. The outcome of the study follows those found by Becketti (2013), Baltagi (2008), Lütkepohl (2005), and Hamilton (1994). The coefficients displayed in Equations (3.12) and (3.13) identify important relationships and findings for policy consideration.

3.5 Granger–Causality Test

The results shown in Table 3.5 indicates that the log price of beef cattle in the informal market does not Granger-cause log of beef cattle price in the formal market, log of producer beef cattle price, log of retail beef price and log of export beef price unidirectional at the 1% level of significance. Furthermore, the log of producer beef price Granger-cause log of informal beef cattle price and log of formal beef cattle auction price. The log of retail beef price does not Granger-cause log price of beef in the informal market, log of beef cattle price in the formal market and log of producer beef price unidirectional at 1% level of significance.

Table 3.5: Granger causality results based on VECM model

Dependent variables	**Independent variables**						
	χ^2-statistics of lagged 1st differenced term					**ECT_{t-1} coefficient (*t*-ratios)**	**ECT_{t-1} coefficient (*t*-ratios)**
	ΔL_IBPRICE	ΔL_FBPRICE	ΔL_PBPRICE	ΔL_RBPRICE	ΔL_EBPRICE	Eq.4.6	Eq.4.7
ΔL_IBPRICE	--	0.8304 [0.3621]	1.2505 [0.2635]	0.1779 [0.6732]	0.0268 [0.8699]	0.6394 (0.6982)	-0.8105 (-0.8748)
ΔL_FBPRICE	1.0905 [0.2964]	--	2.3606 [0.1244]	0.1210 [0.7279]	0.0796 [0.7778]	1.6969* (2.0429)	-1.9189* (-2.2839)
ΔL_PBPRICE	4.3553* [0.0369]*	3.6217* [0.0570]*	--	0.0056 [0.9402]	1.7480 [0.1861]	1.2763* (1.5670)	-1.3188* (-1.6001)
ΔL_RBPRICE	0.0181 [0.8931]	0.0305 [0.8613]	0.0047 [0.9451]	--	0.0086 [0.9261]	0.3730 (0.6820)	-0.2761 (-0.4990)
ΔL_EBPRICE	0.4371 [0.5085]	0.7107 [0.3992]	0.1565 [0.6924]	0.0136 [0.9071]	--	-1.0583 (-1.5351)	1.0321 (1.4801)

Source: Model results, 2021.

*Note: *denotes significant at 5% level. The figures in parenthesis (...) denote t-statistics and the figures in square brackets [...] represent p-value.*

3.6 Chapter Summary

This chapter analysed the interrelationships and transmissions experienced among different prices series – informal beef cattle price, auction beef cattle price, producer beef price, retail price and export price – in the domestic beef cattle market. The results show that informal beef cattle prices do not adjust rapidly (about 63% adjustment compared to 81%) to equilibrium compared to the beef cattle prices in formal (81% compared to 63 %) beef market. The lack of rapid adjustment to equilibrium can be attributed to the characteristics of informal beef markets and objectives of the producers of beef cattle in the informal markets. The outcome of this study is consistent with the findings of El Benni, Finger and Hedinger (2014), that looked at transmission of beef and veal prices in different marketing channels that prices in downstream sectors do hardly depend on producer prices. Likewise, there is no empirical evidence that a downstream industry creates price relationships. Therefore, the price relationships prevailing in the dualistic markets of the Namibian beef cattle sector should be properly understood to properly inform policy formulation. Beef cattle producers, whether in NCA or communal areas south of the veterinary cordon fence or elsewhere, who wish to market their produce in the formal market or export to developed markets, do not have ways of circumventing the sanitary regulations, and nor should they be thinking of ways to do so. NCA beef cattle producers must meet relevant domestic and developed-country standards to be able to exploit the advantage presented by price carcass and Namibia's comparative advantages in beef cattle production in the formal sub-sector.

CHAPTER 4:
A BEEF CATTLE PARTIAL EQUILIBRIUM MODEL FOR NAMIBIA

4.1 Introduction

This chapter affirms that the basis of the model is to obtain realistic estimates that are ideal for making forecasts that are imperative for proper policy formulation and implementation. The model developed in this chapter is specified within the partial equilibrium framework, which encompasses an annual, simultaneous equation in terms of the live beef cattle number supplied for slaughter, cattle demand, cattle stock, beef cattle exports and beef for both the formal and informal market segments. The analysis accounts for several policy regulations that have impacts on the industry. The approach of the analysis draws from using the basic theory of the competitive market. In addition, the study considered the domestic beef carcass prices prevailing in the formal and informal sub-sectors, weaner auction prices, and export parity prices. It was further assumed that no separate price equations were to be included in the model because of the assumption of competitive equilibrium. Although equilibrium price and quantity are determined by both supply and demand, model shocks to live cattle markets primarily arise from the supply side (Sartorius von Bach *et al*., 1998; Sartorius von Bach and Van Zyl, 1990). The quantities demanded are determined by the market clearing identities, with the three basic explanatory relationships being specified in terms of neoclassical theory. Beef cattle supplies are defined as a function of current prices, cattle stocks as functions of expected prices, and beef cattle demand as a function of both current prices and household income. Demand, supply, cattle stocks and on-farm supplies of beef cattle are determined simultaneously within the model.

In this chapter, cattle marketing refers to live export numbers only. Therefore, it is imperative to understand cattle market cycles and to examine their features. It is a belief that the improved knowledge of the cattle inventory cycle can be of great importance for long-term planning because this enables informed evaluations to be made of the future direction of the cattle business and its long-term profitability.

The work of Ferris (2005) and the study of Nerlove (1956) has generated a sense of enquiry to address supply responses for agricultural commodities, and variations in findings have come about from the differences in methodological approaches used to investigate the commodity supply responses. However, the impetus has not diminished in efforts to provide accurate and useful information to policymakers, which effort is attributable to the changing dynamics within the agricultural commodity environment. Ogundeji *et al* (2011) state that the dynamism of the agricultural commodity environment has led to the formulation of dynamic models, with specifications that capture the willingness of producers to adjust their production practices to respond to changes in the agricultural commodity environment.

Figure 4.1 illustrates a model representing a cattle farmer, who produces cattle in period *t*, and must make decisions whether to sell in period $t + 1$, or to retain the cattle stock in period $t + 1$, and then sell in period $t + 2$. However, decisions to sell are influenced by production, disease prevalence, and policy and market issues. The importance of cattle pricing in the domestic market and international market encourages the supply of cattle.

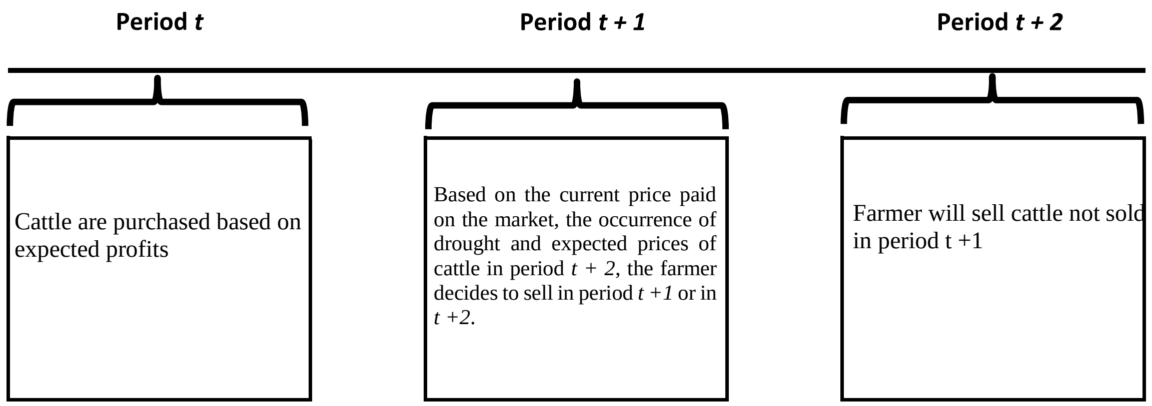

Figure 4.1: An illustration of the farmer marketing decisions for cattle in commercial sub-sector

The adaptive expectation model developed by Nerlove (1956) prescribes the inclusion of the unobservable expected price P_{t^*} to determine the quantity supplied, $Q_{t^{\cdot}}$. However, the application of the Nerlove (1956) approaches has been criticised for their lack of providing short- and long-run relationships between the exogenous and endogenous variables, and the inability to be econometric sound. For example, most studies that have applied the Nerlove supply response (NSR) have reported results that are spurious in nature, such as Sartorius von Bach *et al*. (1998) and Sartorius von Bach and Van Zyl (1990). Conclusions drawn from such results are bound to display biasness and mislead policy decision making. Accordingly, better models have since been developed to correct the omissions and accuracy of NSR. One such model is the dynamic approach to the error correction model (ECM), as incorporated into an autoregressive process.

To understand the formulation and specification of the integrated partial equilibrium framework, the next section provides a discussion about the model development, the data sources, and the variable definitions.

4.2 Understanding the Partial Equilibrium Model Specification and Model Closure

This section briefly discusses the development of the partial equilibrium model that accounts for the nature of the cattle farming, production, and cattle enterprises in Namibia. The nature and structure of the cattle production industry have had a significant impact on marketing patterns in the industry in Namibia. Cattle production consists of a series of operations, involving breeding, rearing calf crops, and feeding these cows up to market weights.

The diversity of the farming units contributes to the difficulty of organising livestock farmers for collective market actions. As a result of long production periods, and the tendency to adjust future production to current prices, cattle production is subject to output and price cycles. Farmers periodically produce too many cattle to obtain what they consider to be reasonable prices, but the cattle prices are frequently below the costs of production. This supply expansion, thus, increases beef prices in the short run. Conversely, when low prices and profits signal cattle producers to reduce production, the herd off-take increases beef supplies and further reduces prices in the short run.

The biological lags involved in cattle production prompt farmers to adjust cattle production often, and this results in unexpected market effects (see Figure 4.1 presented earlier). To expand future meat supplies in response to anticipated profits, cattle farmers hold animals back from the market in the near term to build up their breeding herds. Cattle characteristics influence the prices and marketing patterns. Cattle are bulky and expensive to transport, although cattle sales can be deferred to some extent. By varying the finishing and weights of cattle, farmers have alternatives to immediate sale. However, there are limits to these options, because when deferred sales eventually come to market, there might be weight and age price discounts in place.

The concept of the partial equilibrium modelling is founded on the notion that total demand is equal to total supply (Ferris 2005). A typical partial equilibrium commodity model is based on the principle that a market clearing price equates total supply and total demand, where the total supply, consisting of cattle, is broken down into beginning cattle stocks equation, production and imports (Ferris 2005). The total demand is also broken down into individual equations for exports (live cattle), domestic consumption, and ending stock.

Meyer (2006) provides an exhaustive methodological review of investing price formation under different market regimes through using price data and export volume. Figure 4.2 below sets out an excerpt of a diagram from Meyer (2006). Few modifications needed to be added to suit the beef cattle operation in Namibia; however, the principles and application are similar to those in the work of Meyer (2006). By way of explanation, the domestic price is mathematically estimated by using a price linkage equation that considers the import and export parity prices. For true representation of the domestic price formation, the price linkage equation considers the exchange rate. This is more important for a commodity that is traded over borders.

The Namibian beef market has demonstrated, over the years that it is an excess producer and exporter of beef (MBN, 2013). Most of the beef produced is exported to the EU and South Africa, and therefore, the ZAR and Euro fluctuations (depreciation and appreciation) have impacts on the domestic price formation.

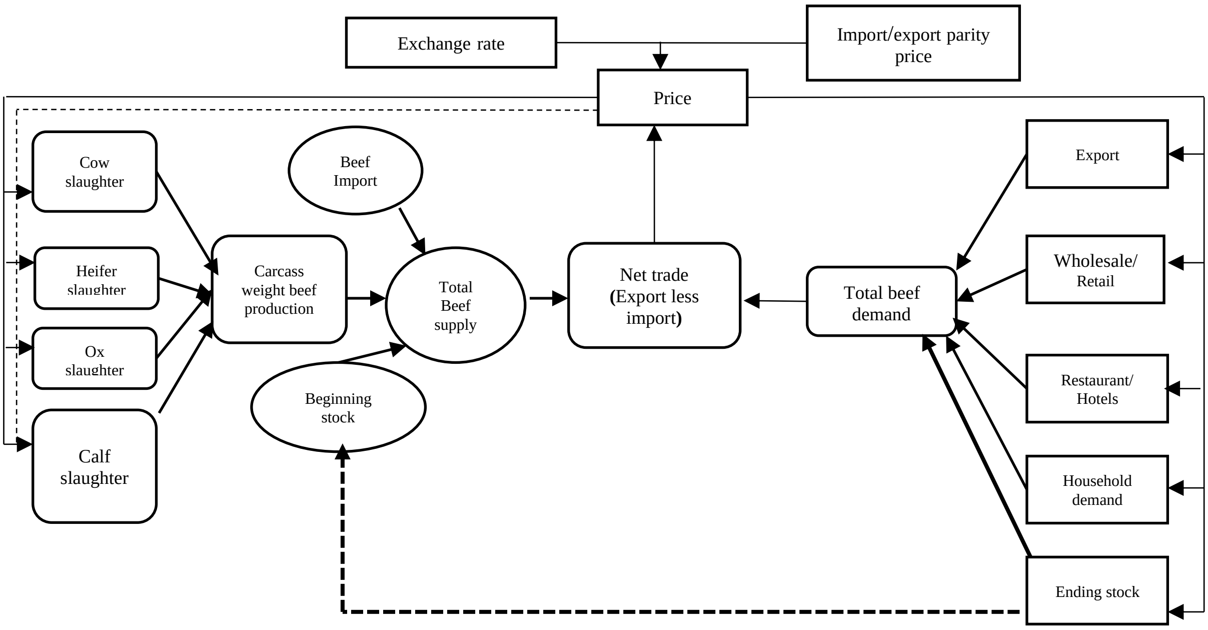

Figure 4.2: Flow diagram depicting the beef market in Namibia

Source: Adapted from Meyer *et al*. (2006).

Figure 4.2 illustrates the flow of beef, considers the price formation in the domestic market. The supply side comprises the sources of beef (cows, heifers, oxen and calves for veal), slaughtered at desired carcass weights. These are complimented by beginning stock (calves and heifers plus culled stock from production, thus forming part of the ending stock from the previous year), plus in any imports sum as total beef supply identity. On the other hand, the demand side is comprised of demands at the wholesale and/or retail levels, and by restaurants, hotels, households and exports. A summation of all these levels of demand accounts for the total demand identity. Net trade is an identity that captures the difference between export and imports; thus, a positive difference indicates that a country is a net exporter and a surplus producer of a traded commodity, while a negative net value indicates that a country is a net importer and deficit producer of a traded commodity. The relationships among these identities are important in determining the model formation and closure.

It is important to mention that Figure 4.2 shows the inclusion of exchange rates in the price formation process. Nevertheless, the exchange rate and other macroeconomic variables are already captured in the export parity price, as stated by Ferris (2005); Barrett (2001), cited in Meyer (2006). On average, it is expected that the domestic price should be trending below the export parity price. For a country such as Namibia, a net exporter, the retail domestic price is expected to be trending above the export parity price, and the producer price below the export parity price, for trade to occur. Therefore, the numerous price variables may be collapsed into two variables such as firstly, the price in a given exporting nation translated in into an average price for the importing nations and secondly, the price in each given exporting nation translated into an average price competing exporting nations face. With the first option, the purpose is to estimate product prices importing nations face. While the second approach, the purpose is to assess the competition represented by the prices at which other competing nation could transact. This relationship is particularly important on the beef relative to Namibia, a small country, an exporter of premium beef to several markets.

4.3 Data Sources and Model Formulation

To fulfil the mandate of answering the hypotheses of this study, time series data obtained from the Meat Board and Meatco are used. Specifically important is the data on the supply of live cattle, beef quantities in kilogrammes; beef traded export quantities, average beef carcass producer prices, and average weaner auction prices. Annual average observations from 1990 to 2019 are used. For comparison purposes, details of further beef prices, weaner prices, and carcass prices for South Africa for same periods were obtained from the Bureau for Food and Agricultural Policy (BFAP) baseline and projection of agricultural outlook of 2018-2027 and 2020-2029 (BFAP, 2018 and BFAP, 2020). For accuracy, further beef prices, particularly at retail level, for Namibia were obtained from the Namibian Statistical Agency (NSA) in Windhoek (NSA, 2014 and NSA, 2019), while data on population of inhabitants were obtained from the National Planning Commission (NPC, 2012).

Some of the data details were obtained from the Bank of Namibia for the exogenous variables originating outside the beef cattle industry, for example macroeconomic variables such as exchange rates (BoN, 2017, 2019, 2020 and 2021), while details of trade policy instruments were obtained from the Ministry of Trade, Small Enterprise and Industry Development and the Ministry of Agriculture, Water and Land Reform, respectively. Serving as a repository of livestock data, NamLITS is a traceability database, under the Directorate of Veterinary Services and Food and Agriculture Organisation (FAO) of the United Nations (FAO, 2019); United States Department of Agriculture (USDA) database (USDA, 2020). The database ideally should contain updated versions of the lists of all the livestock registered on both commercial and communal farms in Namibia. Thus, details of all livestock that is born, has died, or has been marketed should be updated on the NamLITS database. It was an idea of this researcher to explore this database for analysis; however, it was concluded that the stock numbers are not well updated, and that the disaggregation of the cattle stock is weak and, to some extent, misleading. Thus, the sources of data for the informal beef cattle transactions were reconciled from DVS data of cattle movement permits issued and collected by the DVS.

All prices at producer and retail levels were normalised by using an index to account for price fluctuations over the 31-year period of observations. The variables were classified as: 1) endogenous variables; 2) lagged endogenous variables that were determined within the model, but at a previous period; and 3) exogenous variables, which were determined outside of the model. Essentially, the purpose of modelling is to capture the underlying processes by using the observed time series so that we can predict what the likely realisation would be at a time point in future. Thus, Equations (4.1) through to (4.8) are formulated and used in a regression methodological approach to answer the hypothesis statements formulated in the study.

To provide a better understanding of the price formation for beef cattle and to validate the effects of government policy interventions on beef cattle prices, it was necessary to develop a partial equilibrium model for the beef cattle market that accounts for the duality that prevails in the Namibian beef cattle production sector. The beef cattle market model formation is comprised of three tiers: production and usage blocks, and the closing of the model. The partial equilibrium model developed for the Namibian beef cattle industry combines fourteen disaggregated individual equations and four identities.

Literature has proposed several methods to capture the behaviour of single equations when modelling agricultural commodities. For ease in estimating impact factors, the ordinary least squares method has been preferred. However, criticism has been made of the tendency of the OLS method to produce spurious results for time-variant variables. It is important to note that violations are common in regressions that use nonstationary variables (Dougherty, 2011). To account for time-variant variables, procedures were carried out in this study to allow the detection of the presence of non-stationarity on dependent and independent variables (Dougherty, 2011). To perform the detection, the unit root test developed by Dickey and Fuller is used (Dickey and Fuller, 1979). Beef cattle production, cattle numbers and ending stock equations were estimated by using the Autoregressive Distributive Lag (ARDL) based on unit root tests.

The ARDL is used particularly to resolve the high dependence of the endogenous variable on the exogenous variables. It is attractive because it can accommodate a broad range of dynamic patterns, with few lagged values and parameters (Dougherty, 2011). ARDLs are standard least squares regressions that include lags of both the dependent variable and explanatory variables as regressors (Dougherty, 2011). The ARDL model has been used for many years to illustrate the association between variables of economic nature in a one-equation, time-series framework. Engle and Granger (1987) and Hamilton (1994) offer the popular version of co-integration of nonstationary variables which considers error-correction (EC) process, while the ARDL model has a re-parameterisation in EC form. Sims (2014) suggests that the existence of a long run / co-integrating relationship can be tested based on the EC representation. Pesaran *et al*. (2001) suggest that a bounds testing procedure is available to draw conclusive inference, without knowing whether the variables are integrated of order zero I(0) or one I(1). Subsequently, inferences concerning the long-run properties of the model are carried out by using standard asymptotic normal theory (Pesaran *et al*, 1999). However, a large volume of alternatives for estimation and hypothesis testing has been developed for analysing series that are integrated of order 1 or order 0.

The one benefit of the ARDL representation is its one-approach feature that has the ability to assess the long-run relations among variables (y_t and X_t) that are first order I (1) and no order I (0) integration. This study makes use of an ARDL representation that accounts for cattle markets that are then integrated into a partial equilibrium framework.

Engle and Granger (1987) and Hamilton (1994) offer advice that the equations should be developed in such manner that the independent variables are expressed as a representation of past changes and present truncation of the dependent determinants and one-period-lag error correction term to capture the deviations from the long-run equilibrium (Sims, 2014). The representation of ARDL (*p*, *q*) is given mathematically as:

$$y_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{p} \emptyset_i y_{t-1} + \beta' X_t + \sum_{i=0}^{q-1} \beta_i' \, \Delta X_{t-i} + \mu_t, \qquad (4.1)$$

$$\Delta X_t = P_1 \Delta X_{t-1} + P_2 \Delta X_{t-2} + \cdots + P_s \Delta X_{t-s} + \varepsilon_t, \qquad (4.2)$$

The variables are denoted in the mathematical equations as: X_t is the *k*-dimensional I (1) exogenous variables (for example, dependent and independent variables) that are not co-integrated among themselves, μ_t and ε_t are serially uncorrelated disturbances with zero means and constant variance-covariance. Where P_i are $k \times k$ coefficient matrices such that they assume vector autoregressive process where ΔX_t is stable, *t* denotes the max (*p*, *q*), . . . ,*T*, in simple form, the lag order of q is the same for all variables in the $K \times 1$ vector x_t dimension (Sims, 2014). In a lag polynomial, where L assumes lag operator status and is defined as $\emptyset(L)$ and $\beta_j(L)$ as follows (as described Sims, 2014):

$$\emptyset_t = 1 - \sum_{i=1}^{p} \emptyset_i L^i \wedge \beta_j(L) = 1 - \sum_{l_j}^{q} \beta_{j,l} L^{l_j}$$

Therefore, equation 4.1 presented above can expressed as:

$$\emptyset(L) y_t = \alpha_0 + \alpha_1 t + \sum_{j=1}^{k} \beta_j(L) x_{j,t} + \varepsilon_t \qquad (4.3)$$

The mathematical representation of the ARDL equations allows for an assumption that the roots of $1 - \sum_{i=1}^{p} \emptyset_i z^i = 0$ fall outside the unit circle and there exists a stable unique long-run relationship between y_t (endogenous variables) and x_t. $\alpha_0, \alpha_1, \beta, \ldots \beta^*{}_1, \beta^*{}_{q-1}$ and $\emptyset = (\emptyset_1, \ldots, \emptyset_p)$ are parameters to be estimated (Pesaran *et al.*, 2001). Following this general representation, three alternative formations are established. While all three can be used for parameter estimation, Pesaran *et al*. (2001) suggests that the first is preferred to invoke intertemporal dynamic estimation. Furthermore, Pesaran *et al*. (2001) equally mention that the second exposition is suitable for the post-estimation derivation of the long-run relationship, while the third representation illustrates a reduction of (equation 4.1) into a representation of the conditional error correction in equation 4.3 to account for the Bounds test formulated by Pesaran et al (2001). All three alternative formulae are the foundation of the Beveridge–Nelson decomposition (Pesaran *et al*., 2001). For the sake of brevity, none of the three alternative formulations are explored further in this study. Thus, in this analytical work, the adoption of the ARDL is preferred because it offers more leverage for a small sample size (Pesaran *et al.*, 1999) and integrated variables.

For continuity, the ARDL equations for cattle stock numbers in both the formal and informal sub-sectors, cattle off-take rates, available slaughter cattle stocks, the average slaughter weights, beef production in the formal and informal sub-markets, beef demands, price linkages, and beef exports, were estimated. While estimating these equations, shift variables to account for policy dynamics were introduced into the model. An assumption on shift variables is that they invoke the effects of changes in policies, for example, they can account for bans on exports of beef attributable to bans on cattle movements imposed by a moratorium after an outbreak of foot-and-mouth disease, a common trend in the northern Namibia, or a government ban on the marketing of live cattle to South Africa.

It is stated in the literature that biological cycles of production and time lags are important because they lead to the nature of data generating process. Thus, the data-generating process of time variant observation, such as cattle production, generates a nonstationary trend, which results in non-robust model results. Variables become trend stationary after differencing. Pesaran *et al*. (2001) cautions that the usage of differenced data leads to loss of relevant long-run properties of data. A researcher should identify mechanisms that allow for the retention of properties in the variables to maintain the long-run properties. Therefore, Pesaran *et al*. (2001) suggest that co-integration has built-in properties and advantages that allow the retention of long-run properties that are lost after differencing because it invokes short-run dynamics with the long-run equilibrium.

From the modelling perspective, Labys (1973, 1975) and Pindyck and Rubinfeld (1998) suggest that, after examining every possible scenario, the standard procedure should include the estimation of the disaggregated single behavioural equations, and then validate the results for accuracy (Labys 1973, 1975; Pindyck and Rubinfeld, 1998). The robustness of the model result is important in developing a sector outlook and for conducting scenario analysis (Labys, 1975). Moreover, Labys (1973, 1975) suggests that validating a model for robustness helps to improve the reliability of the model. For proper forecasting and policy impact evaluation, robust model results are key outcomes and inputs. In this study, model adequacy tests were based on graphical representations and statistical methods. The graphical method was preferred because it provides a comparison of the actual and fitted values that are tracking each other. For a good sign of proper prediction, it is always accepted that the estimated value tracks the actual value (Pindyck and Rubinfeld, 1998). Pindyck and Rubinfeld (1998) distinguish between the actual values as being the values that represents the true observed values of the dependent variable, whereas the fitted values are the predicted values from the estimated regression model. Pindyck and Rubinfeld (1998) explain that the two values are separated by the existence of unexplained, normally distributed residuals in forecasting, which are the result of the model underestimating or overestimating the predicated values. Therefore, the analytical part of this chapter used annual data of domestic average beef prices, export parity prices, export supplies and export demands for 1990–2016 for Namibia, the European Union and South Africa.

4.4 List of Variables and their Explanation

This section provides a summarised Table 4.1 containing the endogenous and exogenous variables used in the study's model. A set of macroeconomic variables are included in the construction of equations. The major models are classified in the following blocks of equations: Supply side block, demand side block, and price block. All variables carry standard units of measurement.

Table 4.3: List of endogenous and exogenous variables in the model

Variable acronyms	Description	Source and method
EUEXP	Beef exported to the EU	MeatCo and Meat Board of Namibia Export expressed as 1000 kilogrammes or tonne equivalent
BCEX	Beef carcass exported	MeatCo and Meat Board of Namibia

		Export expressed as 1000 kilogrammes or tonne equivalent
BHF	Breeding herd number in commercial area	Ministry of Agriculture, Water and Land Reform Meat Board of Namibia A larger breeding herd is likely to increase in the numbers of calves produced, expressed in 1000 head
BHI	Breeding herd number in communal area:	Ministry of Agriculture, Water and Land Reform Meat Board of Namibia A larger breeding herd is likely to increase in the numbers of calves produced, expressed in 1000 head
BIM	Amount of beef imports	Ministry of Agriculture, Water and Land Reform Meat Board of Namibia Quantity of beef imported into Namibia, expressed in 1000 kilogrammes
TBPN	Total Beef produced in Namibia	Meat Board of Namibia Meat Corporation of Namibia Amount of beef produced in Namibia and expressed in 1000 kilogrammes
TBEF	Total beef equivalent produced in the commercial area,	Meat Board of Namibia Meat Corporation of Namibia Expressed as the number of cattle for slaughter (per 1000 head) multiplied by the carcass weight as provided by the Meat Board of Namibia
TEBI	Total beef equivalent produced in the communal area,	Meat Board of Namibia Meat Corporation of Namibia Expressed as the number of cattle for slaughter (per 1000 head) multiplied by the carcass weight as provided by the Meat Board of Namibia
CSF	Cattle slaughter stock number in the commercial area:	Meat Board of Namibia Meat Corporation of Namibia This expected to increase with increases in the size of the breeding herd, in the quality of grazing, in rainfall and in cattle price, while a negative relationship is expected with increases in feed costs. Expressed in 1000 head
CSI	Cattle slaughter stock numbers in communal	Meat Board of Namibia

	area:	Meat Corporation of Namibia This is expected to increase with increases in the size of the breeding herd, in quality of grazing, in rainfall and in cattle price, while a negative relationship is expected with increases in feed costs. Expressed in1000 head
AICF	Input cost index in commercial area	Agra and Namibia Agricultural Union (NAU) Meat Board of Namibia Meat Corporation of Namibia Higher costs of feed (maize) will reduce the sticking rate; however, for Namibia, this is less important because most of the cattle are naturally fed – meaning they graze extensively on the pasture, expressed in R/kg
BCPF	Beef carcass price in the formal area	Meat Corporation of Namibia Average carcass prices, expressed in 100 cents per kg
BCPI	Beef carcass price in the informal area	Meat Corporation of Namibia Average carcass prices, expressed in 100 cents per kg
BBPF	Average producer prices in commercial area:	Agra Meat Board of Namibia Meat Corporation of Namibia Auction producer prices increase more production and calf retention rate, R/kg
BBPI	Average producer prices in communal:	Agra Meat Board of Namibia Meat Corporation of Namibia Average producer prices increase more production and calf retention rate, R/kg
WPNAM	Average weaner price	Agra Meat Board of Namibia Average weaner prices increase more production and calf retention rate, R/kg
DUB	Domestic use of beef	NSA The consumption capturing variable and is expressed in per head (in kilogrammes per head)
DUM	Dummy variables:	Dummy variables are introduced into the model to capture structural shifts due to policy and disease outbreaks in time periods when disease outbreaks occur,

		for example, DUM2014 would imply an outbreak recorded in 2014, or when there are a policy shifts, such as trade restrictions and border closures to exports of live cattle, with the restrictions as suggested by the South African government.
EUCP	European Union beef carcass price	Meat Board of Namibia Meat Corporation of Namibia BFAP Is the import price for beef set by European Union countries importing beef from Namibia. Prices are converted to domestic equivalents by considering the exchange rate. Euro/kilogramme of chilled boneless beef.
AICI	Average input costs in communal area:	Agra Meat Board of Namibia Meat Corporation of Namibia Higher costs of feed (maize) will reduce the sticking rate; however, for Namibia, this is less important because most of the cattle are naturally fed – meaning they graze extensively on the pasture, expressed in R/kg higher costs of feed (maize) will reduce the stocking rate; however, for Namibia, this is less important because most of the cattle are naturally fed – meaning they graze extensively on the pasture. This is expressed in R/kg
POPF	Namibian population south of veterinary cordon fence,	NSA Expressed in 1000 inhabitants each year
POPI	Namibian population north of the veterinary cordon fence,	NSA Expressed in 1000 inhabitants each year
ARFF (RSVCF)	Rainfall in commercial area:	Namibia Meteorological Service Higher and sustained rainfall improves the quality of pastures and, therefore, the possibility of improving the stocking rate of breeding cattle, with increases in the numbers of calves born per breeding season. Rainfall figure is the recorded annual average, in mm
ARFI (RNVCF)	Rainfall in communal area:	Namibia Meteorological Service Higher and sustained rainfall improves the quality of pastures and, therefore, the possibility of improving the stocking rate of breeding cattle, with increases in the numbers of calves born per breeding season. Rainfall figure is the recorded annual average, in mm.

RBP	Real Retail beef price,	NSA Expressed real terms as the average deflated price of beef in R/kg/CPI*100
RBPP	Real beef producer price,	Meat Board of Namibia and NSA Expressed as the average price received by beef producers, RBPP/Deflator *100 in R/kg
RCKP	Real chicken retail price:	Meat Board of Namibia and NSA Competition in consumption warrants the incorporation in sub-sector decisions in the model, expressed in R/kg / deflator *100
RGDP	Real gross domestic product,.	NSA and BoN Expressed in per capita terms, R/capita, base year 2012
RSP	Real retail price of sheep/mutton,	Meat Board of Namibia Expressed in R/kg/deflator *100. Competition in the use of resources, mainly land, grazing and in consumption warrant the incorporation in sub-sector decisions in the model
SAP	The South African beef import price, in R/kg.	BFAP It is important to note that South Africa and Namibia are members of the Monetary Common Area; therefore, the currencies of the two countries (Rand and Namibia dollar) are equated at 1 to 1 ratio. The differences only exist in interest rates and commodity pricing
TBS	Total quantity of supply of beef in Namibia,	Meat Board of Namibia Expressed in kg and is an identity that captures domestic-produced beef, plus all imported beef
NWF	Number of weaners in commercial areas:	Meat Board of Namibia The larger the number, the more likely is the total number marketed, expressed in 1000 head, equivalent to the calf crop
NWI	Number of weaners in communal areas:	Meat Board of Namibia The larger the number, the more likely is the total number marketed, expressed in 1000 head, equivalent to the calf crop
WMARK	Number of weaners marketed	Meat Board of Namibia Expressed in 1000 head
CHEN	Cattle herd numbers in	Meat Board of Namibia The larger the number, the more likely is the total number

CHENF CHENI	Namibia, in thousands Cattle herd numbers in the formal area Cattle herd numbers in the informal area	marketed, expressed in 1000 head
ASWF	Average weight of slaughter stock in commercial areas	Meat Board of Namibia Expressed in kg per head at slaughter date. Not more than 2 to 3 years old.
ASWI	Average weight of slaughter in communal areas,	Meat Board of Namibia Expressed in kg per head at slaughter date. Not more than 2 to 3 years old.
OTRF OTRI	Off-take rate in the formal market (commercial) area Off-take rate in the informal market (communal) area	Calculated as a percentage of number of cattle marketed /available slaughter stock.
EXOGENOUS VARIABLES		
Variables acronyms	**Description**	**Source and method**
EXCH	Exchange rate	Bank of Namibia (BoN) and NSA Exchange rate in local currency*U.S. Dollar
RGDPN	Real GDP per capita	Namibia Bank of Namibia (BoN)
INCF	Household Income in the formal areas	Namibia Statistical Agency Expressed as N$1000/household
INCI	Household Income in informal areas	Namibia Statistical Agency (NSA) Expressed as N$1000/household
BCPPF	Beef consumption per capita in the formal (urban) areas	Meat Board of Namibia and NSA Expressed as total beef disappearance /population in the formal areas -kg/per capita
BCPPF	Beef consumption per capita in the informal (rural) areas	Meat Board of Namibia and NSA Expressed as total beef disappearance /population in the informal areas -kg/per capita
Trend	Time variant	
WPRSA	Weaner price RSA (average	Meat Board of Namibia

	price)	BFAP Expressed as average price c/kg
WPNAM	Weaner price in Namibia (average price)	Meat Board of Namibia NAM weaner price = c/kg
EUQR	European Union quota restriction	Meat Board of Namibia/MAWF Quantity expressed in toones/ kg
Levy	A charge on cattle marketed	Meat Board of Namibia/MAWF Expressed as levy amount charged on marketed live or exported beef cattle, c/kg*
TARF	Tariff charged on weaner import	Meat Board of Namibia/MAWF Expressed as dollar amount charged per head, i.e., 0.08c/Head = c/kg*

***Note:** Meat Board Levies are charged for every head of cattle marketed in commercial areas and communal areas. The levy amounts are R10.85 per head of cattle and 0.8% of income earned from all cattle sales, which collected amounts are administered by the Meat Board of Namibia.

4.5 Specification of the Beef Cattle Model

4.5.1 Beef supply block

The dynamics of the beef production system in Namibia are founded on the cow-to-ox production system, the cow-to-weaner production system, and the speculative option of the weaner-to-ox production system. Thus, the Namibian beef cattle supply system includes slaughter cows, weaners, store cows, culled cows, and slaughter oxen. Figure 4.2 illustrates the beef sub-sector in Namibia and enables the derivation of the different equations and identities for the commercial and communal sub-sectors. However, although the supply is known, the cattle stock composition and cattle censuses have not delineated the cattle stock according to slaughter cows, weaners, store cows, culled cows, and slaughter oxen.

A shortcoming, however, is that the current NamLITS and FAN Meat data do not represent and delineate the cattle composition in terms of breeding stock, calving stock and replacement stock, while the slaughter stock is determined as an off-take rate from the current cattle population. More importantly, the foundation research undertaken by Jarvis (1974) suggests a principle for assuming cattle inventories as constituting "capital goods" and farmers as being "portfolio managers". Within this context, Jarvis (1974) suggests that cattle producers base their decisions about breeding herd size on the expected profitability of raising cattle. In support of this view, Jarvis (1974) found that farmers determine their breeding herd size on the assumption that the herd size will shift slowly to the level believed to be optimum in a long-run level, and farmers have beliefs that gross margin expectations are in tandem with profit in each period, while taking into account the error in forecasting the returns.

For the modelling perspective, the following series of simultaneous equations have been formulated. The breeding beef cattle herd stock model was developed as follows:

$$BHS_t = f(\pi^e_{t-1}, Z_t) \tag{4.4}$$

where BHS_t is the "breeding herd size at the end of period" t, while π^e_{t-1} accounts for the expected probability of rearing livestock in the subsequent period, and Z is a vector of other observed exogenous variables occurring in time t, with all the observed variables dictating the level of desired cattle stock.

When assuming a partial adjustment framework and adaptive price expectations, Equation (4.4) may be expressed as follows:

$$BHS_t - BHS_{t-1} = \tau\left(BHS_t - BHS_{t-1}\right) \qquad (0 \leq \tau \leq 1) \tag{4.5}$$

$$\pi^e_{t-1} - \pi^e_t = \gamma(\pi_t - \pi^e_t) \qquad (0 \leq \gamma \leq 1 \tag{4.6}$$

where the coefficient τ is the herd adjustment and γ captures the expectation. Jarvis (1974) suggests that Equation (4.5) implies that the producing herd of cattle inventory is expected to adjust in each period on account of both biological restrictions and adjustment costs. Equation (4.6) assumes that a change in expected profit in time period $t + 1$ is proportional to the current error in forecasting (Jarvis, 1974).

Under a linear assumption, Equations (4.4), (4.5) and (4.6) may be used to derive a breeding herd equation, as follows:

$$BHS = a_0 + a_1\pi + a_2 BHS_{t-1} + a_3 BHS_{t-2} + a_4 Z + a_5 Z_{t-1}, \tag{4.7}$$

where $a_0 = \tau\gamma\alpha$, $a_1 = \tau\gamma\beta$, $a_2 = [(1-\tau) + (1-\gamma)]$, $a_3 = (1-\tau)(1-\gamma)$, $a_4 = \tau\epsilon$, and $a_5 = \tau(1-\gamma)\epsilon$.

The model shows that the intercept is α while β and ϵ are the coefficients of the variables in Equation (4.7).

The weaner beef cattle inventory for each year depends on the number of calves available in the current and the past periods. Generally, a productive cow produces one calf per year. Calves represent the new cattle stock and are dependent on the current cow herd and the calving rate.

4.5.1.1 Calf and weaner equations

The calves born and the weaner stock may be modelled as follows:

$$CS = BHS * CR \tag{4.8}$$

$$WS = f(CS, CS_{t-1}), \tag{4.9}$$

where CS represents the calf stock born, CR is the calving rate, WS is the weaner stock, and BH is the breeding herd.

Farmer make decisions on cattle supply, based on profit expectations. If the prices of beef at retail level are relatively high, farmers tend to sell more slaughter cattle than they would otherwise have done. Thus, the slaughter equation is specified as follows:

$$TBCS_1 = CS_1(BRP, CFP, WS_{t-1}) \tag{4.10}$$

where $TBCS_1$ is the total number of beef cattle slaughtered, BRP is the beef retail price, CFP is the cattle farm price, and WS is defined as previously.

The market clearing condition requires that the total supply should equate the total demand. Jarvis (1974) states that, in the beef cattle industry, the total supply in each period consists of the breeding cows, store cows, and slaughter oxen, calves born during the period, and cattle imports. The demand for beef cattle is the summation of slaughter cattle, ending stock, and exports. Beef cattle loss and the statistical discrepancy account for the residual of the identity.

$$BHS_{t-1} + WS_{t-1} + CS + M = TBCS_1 + BHS + WS + X_1 + LSD \tag{4.11}$$

where M and X represent imported and exported cattle, respectively, LSD refers to such as loss and statistical discrepancy in beef cattle stock, while the other variables retain their above definitions.

4.5.1.2 Calf crop determinants in the commercial sector

Calves are predominately the off spring of breeding activities carried out in the previous year. The calving rate is influenced by the management practices adopted by the farmer.

$$CCF = f(BHF, CPF, CIC, RFF, CDOF) all\ lagged\ one\ year \tag{4.12}$$

4.5.1.3 Total beef cattle marketed and weaner exports

In estimating the total number of cattle marketed and supplied in Namibia, the model accounts for the slaughter cattle and weaner cattle. The South Africa-Namibia weaner price ratio is calculated as ratio between South African weaner prices per kilogramme and Namibia weaner prices per kilogramme. This South Africa-Namibia weaner price ratio competes with the domestic market weaner-to-carcass price ratio (carcass producer price per kilogramme and the Namibia auction weaner price per kilogramme). These two ratios have impacts on the decisions of the beef producers, while the carcass prices for slaughter oxen dictate the decisions made by the beef producers. It is clear to beef cattle producers that auctions are important for fattening weaners for the domestic market and for exports to feedlots in RSA feedlots, or to attract slaughter animals for the local slaughterhouses. In most scenarios, guided by the current or expected price and the duration of payment, cattle producers tend to choose between the two market options, for example, auction and abattoir. For illustration purposes only, take into consideration where a producer is offered a carcass auction price for an ox of about N$22.51 per kilogramme of live mass, and the same price is equivalent to about N$42 per kilogramme at an export abattoir. Thus, taking consideration of other parameters in the decision-making process, such as dressing percentage, the costs of transacting, transport and handling, and commission, a producer will choose an ideal option for profit maximisation. However, this scenario is a mere glimpse of the entire pricing system and does not account for the implications of the production systems.

The first component of the weaners marketed includes estimating the weaner equation, and the specification is given as follows:

$$WEXPRSA = f(WRPRSA/NAM\ , BDCP/WPNAM\ , TRFF, CHERD) \tag{4.13}$$

Equation (4.13) accounts for weaner exports to South Africa (WEXPRSA), the ratio of the South Africa weaner price per kilogramme to the Namibian weaner auction price, the domestic ratio of beef carcass price to the weaner auction price, the tariff, transportation, handling and commission (TRFF), and the cattle herd in Namibia (CHERD).

The total slaughter cattle include the domestic slaughter in the formal market (weaners exported to South Africa and oxen slaughtered at the export abattoirs) and in the informal market, comprised of cattle from the various production systems (cow-to-weaner production system, cow-to-ox production system, and the speculative production option). The identity is represented as follows:

$$BSC = CCF + CCI \tag{4.13a}$$

The variables are as defined in Table 4.1 presented earlier, meaning that this identity accounts for beef cattle emanating from the formal production systems (cow-to-weaner production system, cow-to-ox production system' and speculative production option) and beef cattle emanating from the informal sector (cow-to-ox production system).

The total beef production in Namibia (TBS) is therefore an identity that captures the beef stock from the commercial sector (*TCEF*) plus the beef stock from the communal sector (*TCEI*) and imported beef. The identity is given as follows:

$$TBS = TCEF + TCEI \tag{4.14}$$

4.5.1.4 Total beef supplied for Namibia

The total beef production in Namibia (TBSN) is therefore an identity that captures the beef stock from both the commercial sector and communal sector (TBS), imported beef (IMB) and inventory beef stock equivalent (INV). Therefore, the identity is given as follows:

$$TBSN = TBS + IMB + INV \tag{4.15}$$

4.5.2 Demand for Beef Functional Forms and Identity

4.5.2.1 Beef per capita consumption

The demand function for beef is expressed in per capita terms and measured on a carcass weight basis. Beef output and consumption are disaggregated into commercial and communal categories, similar to the disaggregation formulated in the supply functions. It is expressed as follows:

$$DUB = f(RBP, RCKP, RSP, RGDP, T) \tag{4.16}$$

4.5.2.2 Beef exports

The beef export equation is estimated as a representation of the average real beef carcass domestic price, ratio of real beef carcass producer price and parity price and DUM, and is expressed as follows:

$$BEX = f(RBP, (RBPP/IMP), DUM\ for\ trade\ restrictions) \tag{4.17}$$

4.5.2.3 Farm supply stock or Inventory

The farm supply stock is taken as an identity, calculated by adding the total beef exports and total beef domestic use, and then deducting all the production and imported beef in both commercial and communal areas. The farm supply stock for each respective year equalises the beef stock supplied and demand for the subsequent year in succession.

$$FSS = BEXP + BDU - BPROD - BIMP \tag{4.18}$$

4.5.2.4 Beef total domestic use

The domestic use is derived from using the per capita consumption that was estimated as a function of real beef price, real chicken producer price, real pork auction price, real GDP per capita and Trend-health (introduced in the equation as a dummy variable) in the commercial and communal sub-sector levels. Thereafter, the beef total domestic use is derived as an identity expressed by the following equation. The definition of variables is explained in Table 4.1 (presented earlier).

$$BDU = (BPCF * POPF) + (BPCI * POPI) \tag{4.19}$$

4.5.3 Price block equations

The pricing block consists of three equations, comprising the weaner export equation, the average domestic beef carcass price equation in the formal market, and the average beef carcass price equation in the informal market. The derivation of these equations is illustrated as follows:

4.5.3.1 Weaner price

The average weaner price (WAPN) function is represented by the lagged average weaner auction price in Namibia, current and lagged numbers of weaner cattle marketed (WEMT), current and lagged beef carcass prices in Namibia (BCPN), and current and lagged weaner auction prices in South Africa (WPRSA), and is represented as follows:

$$WAPN = f(WEMT, BCPN, WPRSA) \quad (4.20)$$

4.5.3.2 Beef price linkage equation

The price transmission equation for the domestic average beef carcass price, DBCP, is specified as a function of beef carcass export, average EU carcass price (EUPRICE) and tariff, handling and commission (TRFF), and appears as follows:

$$DBCP = f(BCEXP, EUPRICE.TRFF) \quad (4.21)$$

4.5.3.3 Beef price in the informal market

The informal sub-sector carcass price for beef is derived from the functional relationship between the current and lagged average beef carcass prices in the formal sub-sector. It is expected that the relationship will exhibit a positive relationship. The functional form is given as follows:

$$BPPI = f(BPPI_{t-1}, BCPN) \quad (4.22)$$

4.5.4 Model Diagnostic

Becketti (2013) explains that the Jarque–Bera (JB) test is a goodness-of-fit test of whether sample data have the skewness and kurtosis matching a normal distribution. For example, Becketti (2013) states that, if the data observes symmetrical generating process, the distribution of JB statistic asymptotically has a chi-squared distribution with two degrees of freedom, such that the outcome statistic value can be used to test the claim that data observation originates from a symmetrical distribution (Becketti, 2013). Furthermore, Becketti (2013) suggests that the null hypothesis is a joint hypothesis of the skewness being zero and the excess kurtosis being zero. Becketti (2013) argues that samples from a symmetrical distribution have an expected skewness of 0 and an expected excess kurtosis of 0 (which is the same as a kurtosis of 3) and thus the caution points to the definition of JB.

Similarly, Becketti (2013) explains that the Breusch–Godfrey (B-G) test is a test for autocorrelation in the errors in a regression model and the test based on the residuals from the model investigated in a regression analysis where a test statistic is generated with a stated null hypothesis of no serial correlation of any order up to level p.

Other important tests for autocorrelation with similar evaluation are the Durbin–Watson test and the Ljung–Box test. However, Becketti (2013) is quick to point out that the Durbin–Watson statistic (or Durbin's h statistic), is valid for nonstochastic regressors and for testing the possibility of a first-order autoregressive model, such as the $AR(1)$ for the regression errors (Becketti, 2013).

Becketti (2013) suggests another prominent general test, called the Ramsey Regression Equation Specification Error Test (RESET) that is suitable for the linear regression model specification. Becketti (2013) encourages the use of the RESET approach because it possesses the ability to evaluate whether non-linear combinations of the fitted values are able to assist in explaining the response variable. The intuition behind the test is that, if non-linear combinations of the explanatory variables have any power in explaining the response variable, the model is misspecified in the sense that the data generating process might be better approximated by a polynomial or another non-linear functional form (Becketti, 2013).

4.6 Overall evaluation of the model performance

The forecasting ability of the model was used to determine the statistical soundness of the analytical approaches used for this study. The forecasting ability of models were evaluated, using the assessment of the value of forecast error. The forecast error value is obtained as the deviations of the forecast value from the actual value (Hamilton (1994). Lütkepohl (2005) advises that a model that produces a low error value is considered as a sign of good forecasting ability and the results are qualified for using for forecasting and policy purposes (Lütkepohl, 2005). Different forecast statistics, which were used to evaluate how well our model captures the real, actual values, were based on Lütkepohl (2005) and Gebrehiwet *et al* (2010), and outlined the following seven statistical techniques, namely Root Mean Squared Error (RMSE), Mean Average Error (MAE), Mean Average Percentage Error (MAPE), Theil Inequality Coefficient (U), Bias, Variance and Covariance proportions. For brevity and preference, this study only describes four of these techniques.

The RMSE is the standard deviations of the forecast errors (Lütkepohl and Krätzig, 2004) and has the following mathematical equation:

$$RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(\hat{y}_t - y_t)^2} \tag{4.23}$$

The MAE is computed as the average value of the absolute value of the error terms occurring in each period, and is given in Equation (4.24) as:

$$MAE = \frac{1}{T}\sum_{t=1}^{T}|\hat{y}_t - y_t| \tag{4.24}$$

MAPE is calculated as the error in terms of percentage of the actual value and follows Equation (4.25):

$$MAPE = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{\hat{y}_t - y_t}{y_t}\right| \tag{4.25}$$

To some extent, the Theil Inequality Coefficient (U) is equally used to detect the ability to forecast. Equation (4.26) presents the formation of U where the top number in the formula is the accounts for the root mean squared errors. The Theil Inequality Coefficient lies between 0 and 1, with 0 indicating a perfect fit (Lütkepohl 2005). For purposes of clarity, the RMSE and MAE are derived from variation of scale of a dependent variable, while the MAPE and Theil Inequality Coefficient do not depend on variation of scale within the predicted variable.

$$U = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(\hat{y}_t - y_t)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(\hat{y}_t)^2 \sqrt{\frac{1}{T}\sum_{t=1}^{T}(y_t)^2}}} \tag{4.26}$$

Bias proportion indicates how far is the mean of the forecast from the mean of the actual series. Likewise, variance proportion indicates how far is the variance of the forecast from the variance of the actual series (Lütkepohl, 2005). Statistically, covariance proportion measures the remaining unsystematic forecasting errors. The idea is that it is important to note that the bias, variance and covariance proportions add up to one and are given as proportions out of 1. If the forecasts are said to be good, the bias and variance proportions should be small, which is the case in the estimated behavioural equation (Lütkepohl, 2005).

4.7 Chapter Summary

This chapter applied the economic theory presented in earlier chapters to specify an econometric model of all equations necessary to develop the model the dualistic beef industry. In addition, it presented the annual, behavioural simultaneous equations in terms of the live beef cattle number supplied for slaughter, cattle demand, cattle stock, beef cattle exports and beef for both the formal and informal market segments. The analysis accounts for several policy regulations that have impacts on the industry.

All data needed for developing the model, with their sources and constructions are also outlined. Most of the endogenous variables are obtained from Meat Board of Namibia and NSA and the exogenous variables are obtained from the Ministry of Agriculture, Water and land Reform, the Ministry of Trade, Small Enterprise and Industry Development, Meatco and the Bank of Namibia.

The methodology of estimation is based on the ARDL specification which nested several models. Therefore, this approach allows to test various competing models in estimating each equation. The diagnostic tests for and purpose of test were presented such as checking for normality (using the Jacque-Bera approach), serial correlation (using the Breusch-Godfrey and the Ljung–Box test), homoscedasticity (using the ARCH LM and White approach), misspecification (using Ramsey RESET test) and parameter stability (using Recursive Estimates). The chapter presented model validation which is based on the statistical method which included the use of Root Mean Square Error, Mean Absolute Error, Mean Absolute Percentage, the Theil Inequality coefficients and the graphical techniques (comparing the actual and estimated values of the model). The econometric estimation results of all the specified models are presented in the next chapter.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Introduction

This chapter presents the results of each model specified earlier. In the following section, the estimation results of all individual equations are presented. This is followed by diagnostic tests of the residuals of the equations. These tests examine violations of the underlying apriori assumptions of the techniques evoked in the estimation. Where required, on any violations of assumption, corrections are invoked to improve the model performance and adequacy.

5.2 Results of Individual Equations

The supply of beef estimation begins with the cow herd numbers in the production cycle of the cows, the calf crop being the source of beef, and the average slaughter weight. The calving rate determines the number of calves born. The number of calves at maturity (weaners and oxen) and their mass determines the amount of beef supplied in both the formal (commercial) and informal (communal) sub-sectors. This beef supply block is described by the following equations: cattle herd number, off-take rate and average slaughter weight, and beef production; thus, the number of slaughter stock multiplied by the slaughter weight yields the beef supply estimations for both the formal and informal sub-sectors. The supply equations and their formulations were discussed in the previous section. The next section presents the estimated results based on endogenous equations outlined earlier in chapter 4.

5.2.1 Cattle herd number estimation

Cattle herd numbers has two results based on the estimated equations, covering the commercial formal, commercial informal, and communal informal areas in the two sub-sectors. From the cattle herd numbers, we can then derive the off-take rate to yield the numbers of slaughter stock available in both sub-sectors. The available slaughter stock multiplied by the average slaughter weight yields the amount of beef produced in both the sub-sectors. Both cattle herd number equations are formulated to estimate the functional relationship that exists between cattle herd numbers, beef carcass producer prices, input costs, and rainfall. The result of the cattle herd numbers equation for the formal commercial area is given as follows:

$$CHENF = 1585.9659 + 0.0029CHENF_{t-1} + 0.0500BPPF + 0.1325BPPF_{t-1} - 0.0225AICF + 0.0154AICF_{t-1} + 0.2707ARFF - 0.1686ARFF_{t-1} - 0.0739ARFF_{t-2} \quad (5.1)$$

where:

CHENF Cattle herd number in the formal commercial area (1000)

BPPF Average beef carcass producer price in the formal market (100 cents/kg);

AICF Average input costs (production costs on labour) in the formal area (N$1000)

ARFF Average annual rainfall in the formal commercial areas, measured in 100 mm, average, with lagged variable.

From Table 5.1, we can deduce that the regression results give an adjusted R^2 of 0.7582. This means that only about 76% of the dependent variable (cattle herd numbers in the formal area) can be explained by the variation in the behavioural patterns of the explanatory variable. The model shows a strong explanatory power, with coefficients retaining the expected signs. As expected, producer price pr kilogramme is positive and statistically significant at 10% level. Implying that, an increase in producer price per kg, it is expected that slaughter cattle supplied will increase by 0.05 in the current period, and by 0.13 in lagged period. However, an increase in average cost of production index, production is expected to decrease by 0.023, holding other factors constant. The result of the autoregressive distributed lag for the cattle herd number equation in the formal sector is given in Table 5.1.

Table 5.1: ARDL model results for cattle herd number in the formal commercial area

Variable	Coefficients	Std. Error
Constant	1585.9659	180.9491
CHENF(-1)	0.0029	0.0008*
BPPF	0.0500	0.0743
BPPF(-1)	0.1325	0.0371*
AICF	-0.0225	0.0064*
AICF(-1)	0.0154	0.0052*
ARFF	0.2707	0.0595*
ARFF(-1)	0.1686	0.0731
ARFF(-2)	-0.0739	0.0147*
Adjusted R^2	0.7582	
F-Statistics	22.9578 (0.0000)	

*Note: *denotes significant values at 0.05 level, and ** denotes significance at the 0.10 level.*

Table 5.2 and Figure 5.1 presents the diagnostic outcome on the residual for Equation (5.1). Based on the outcome in Table 5.2, it is inferred that the foundations of OLS are not violated and therefore the coefficients obtained can be used for forecasting.

Table 5.2: Model misspecification tests for cattle herd number in the formal area

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		1.6372	0.4410
Serial Correlation	Breusch-Godfrey	N * R-squared	1.6655	0.4348
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	4.8042	0.3080
	ARCH LM(-1)	N * R-squared	0.1375	0.7107
	ARCH LM(-2)	N * R-squared	0.6110	0.7367
	Harvey	N * R-squared	6.5944	0.1589
Misspecification	Ramsey RESET LR(-1)	1	0.8327	0.3709
	Ramsey RESET LR(-2)	2	1.6874	0.2081

Figure 5.1 shows how the graph of fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line meanders around the zero mean and be used for forecasting. In support of that statement, Figure 5.1 shows how the graph of fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line meanders around the zero mean. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting.

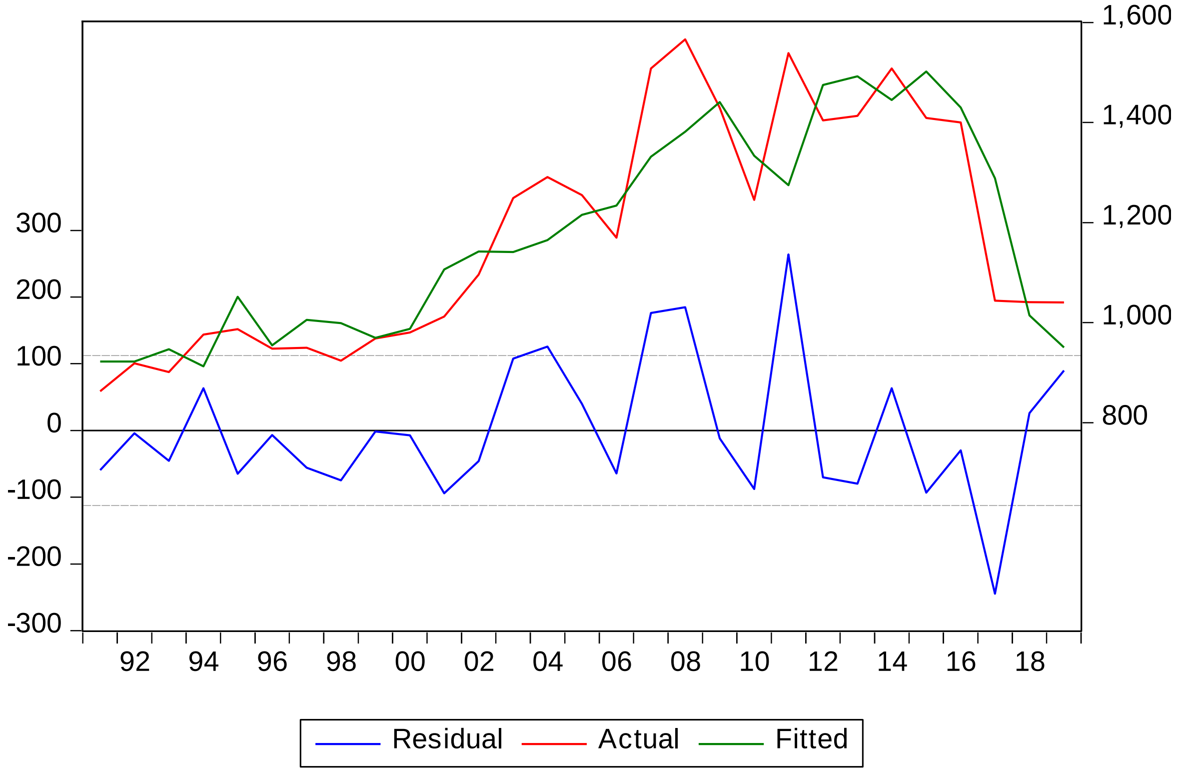

Figure 5.1: Residual, actual and fitted graph of cattle herd numbers in the formal area

Similarly, the estimation of the cattle herd number in the informal communal areas depicts the functional relationship that exists between, cattle herd numbers, the average beef carcass producer price, average input costs and average rainfall. Results for cattle herd number equation for the informal communal area is given as follows:

$$CHENI = 1044.7776 + 0.8366CHENI_{t-1} + 0.7772BPPI + 0.0053AICI - 0.1601AICI_{t-1} + 0.1976AICI_{t-2} - 0.0038ARFI + 0.1485ARFI_{t-1} - 0.1493ARFI_{t-2} \quad (5.2)$$

where:

CHENI Cattle herd number in the informal communal area (1000)

BPPI Average beef carcass producer price in the informal market (100 cents/kg);

AICI Average input costs (production costs on labour) in the informal area (N$1000)

ARFI Average annual rainfall in the informal communal areas measured in 100 mm, with lagged variables.

The results of the autoregressive distributed lag for cattle herd number equation in the informal sector are presented in Table 5.3. Sims (2014) states that the null hypothesis that says all slopes are equal to zero is rejected. The adjusted R-squared measures the goodness of fit of the regression line, or how best the model fits the data (Sims, 2014). The adjusted R^2 measures the portion of the movement of dependent variable that can be explained by the regression (Baltagi, 2008). Thus, the larger the adjusted R^2, the better the model fits the data. Sims (2014) suggests that, if the adjusted R^2 is close to 1, then the regression explains most of the movement in the dependent variable. The regression outcomes give an R^2 of 0.8457. This means that 85% of the cattle herd in the formal area can be explained by the changes in the behavioural patterns of the explanatory variables.

Table 5.3: ARDL model results for cattle herd number in the informal area

Variable	Coefficients	Std. Error
Constant	1044.7776	9.0234
CHNI(-1)	0.5365	0.1350*
BPPI	0.7773	0.3536*
BPPI(-1)	0.0054	0.0018*
AICI	-0.1601	0.3044
AICI(-1)	0.1976	0.5320
ARFI	-0.0038	0.7596
ARFI(-1)	0.1485	0.9872
ARFI(-2)	-0.1494	0.0701*
Adjusted R^2	0.8457	
F-Statistics	21.5099 (0.0000)	

*Note: *denote significant values at 0.05 level.*

Table 5.4 and Figure 5.2 the diagnostic outcome of the residual of Equation (5.2), and the diagnostic outcome shows that the foundations of OLS are not violated and thus the coefficients obtained from the estimated model can be used for forecasting purposes.

Figure 5.2 shows how the graph of fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line meanders around the zero mean and be used for forecasting. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting.

Table 5.4: Model misspecification tests for cattle herd number in the informal area

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		0.7985	0.6708
Serial Correlation	Breusch-Godfrey	N * R-squared	0.0011	0.9732
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	8.9059	0.2595
	ARCH LM(-1)	N * R-squared	0.7190	0.3965
	ARCH LM(-2)	N * R-squared	0.8852	0.6424
	Harvey	N * R-squared	7.7490	0.7262
Misspecification	Ramsey RESET LR(-1)	1	0.2674	0.6114
	Ramsey RESET LR(-2)	2	5.1740	0.0176

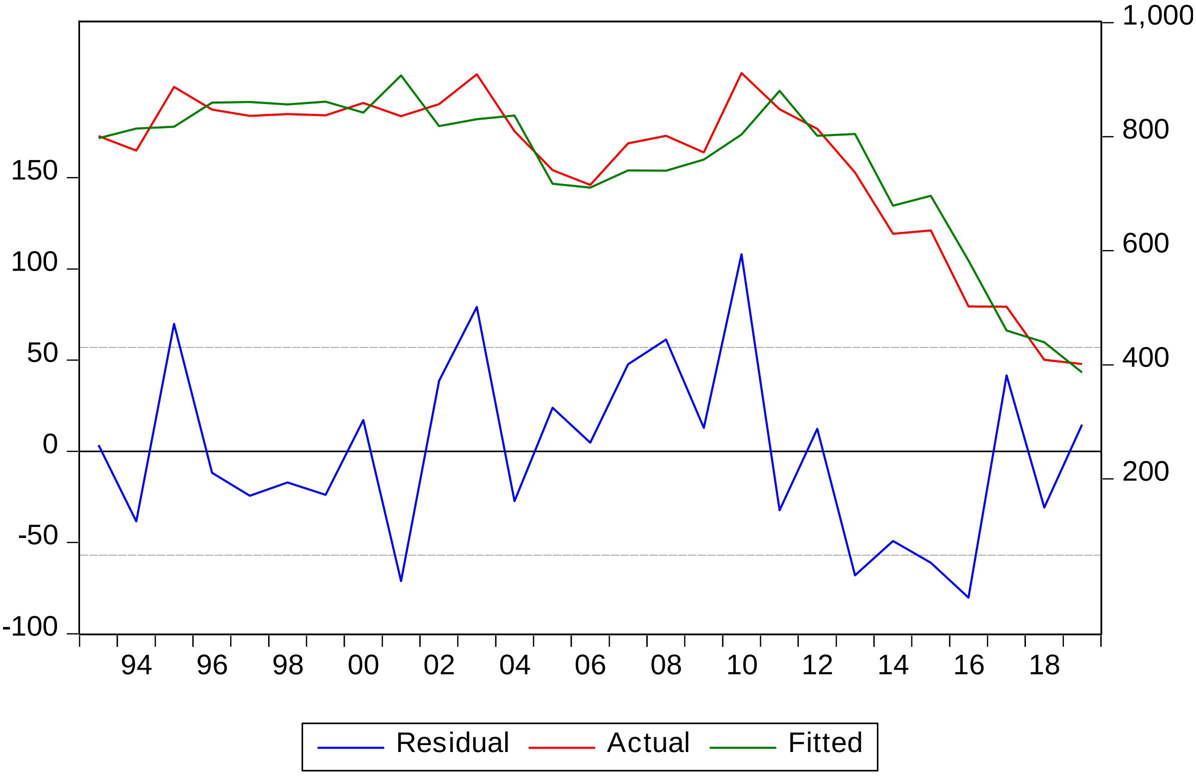

Figure 5.2: Residual, actual and fitted graph of cattle herd numbers in the informal area

5.2.2 The off-take rate estimation

The off-take rate equation consists of two equations, one for the commercial sector and one for communal sector. Determining these two equations leads to estimating the beef supply block for Namibia. For the commercial (formal) sector, Equation (5.3) is used and Equation (5.4) below deals with the off-take rate in the informal (communal) sector.

$$OTRF = OTRF_{t-1} + BCPF + CCF + RFF + \mathcal{E} \qquad (5.3)$$

where:

OTRF	Off-take rate in the formal market (commercial) area (100 %); with lag explanatory variable
BCPF	Average cattle price in the formal market (100 cents/kg);
CCF	Calf crop in the formal area (1000 head); with a lagged variable.
ARFF	Average Rainfall in the commercial area (100 mm), average, with lagged variable.

The model results set out in Table 5.6 show the standard errors, which indicate the significant determinants. The dependent variable is the off-take-rate in the formal area. The independent variables include the lagged off-take rate in the formal area (-1), current cattle prices in the formal area, cattle producer price, lagged one and two years (-1 and -2), the current calf crop in the formal area, calf crop in the formal area, lagged 1 to 3 years, rainfall in the commercial area, and lagged rainfall (-1). Table 5.6 provides the summarised results, and we can deduce that only the cattle prices lagged two years and the calf crop lagged 3 years were significant at 0.05 level, while the rest of the variables were not significant.

The explanation is that the number of the off-take-rates not being significant is largely a result of the fact that cattle reproduction is determined by biological processes, such as the long period it takes from the time a calf is born until it can be marketed. Similar results were also obtained by Ogundeji, Jooste and Oyewumi (2011) in South Africa, who found that the possible reason why the cattle producer price was not significant was attributable to the inability of cattle producers to increase throughput because of the biological processes that characterise animal production.

As shown in Table 5.6, the F-statistics value for testing the overall hypothesis is 2.12. Sims (2014) states that the null hypothesis that says all slopes are equal to zero is rejected. The adjusted R-squared measures the goodness of fit of the regression line, or how best the model fits the data (Sims, 2014). The adjusted R^2 measures the portion of the movement of dependent variable that can be explained by the regression (Baltagi, 2008). Thus, the larger the adjusted R^2, the better the model fits the data. Sims (2014) suggests that, if the adjusted R^2 is close to 1, then the regression explains most of the movement in the dependent variable. The regression outcomes with trend give an R^2 of 0.59, and without trend, the results gave an adjusted R^2 of 0.59. This means that 59% of the off-take-rate in the formal area can be explained by the changes in the behavioural patterns of the explanatory variables.

Table 5.5: ARDL model results for the off-take rate in commercial area

Variable	Coefficients	Std. Error
Constant	0.1957	0.4753
OTRF(-1)	0.0438	0.2172
BCPF	0.0258	0.0164
BCPF(-1)	0.0100	0.0210
BCPF(-2)	-0.0497	0.0163*
CCF	0.0004	0.0007
CCF(-1)	-0.0005	0.0010
CCF(-2)	-0.0007	0.0009
CCF(-3)	0.0014	0.0007*
ARFF	0.0003	0.0004
ARFF(-1)	0.0007	0.0005
Adjusted R^2	0.5868	
F-Statistics	2.1218	

Note: * denote significant values at 0.05 level

Table 5.6 provides the diagnostic outcome of the residual of Equation (5.3) and the diagnostic outcome of the model shows that the foundations of OLS are upheld and coefficients obtained can be used for forecasting purposes.

Table 5.6: Misspecification tests for the off-rate in the commercial area

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		0.8270	0.6613
Serial Correlation	Breusch-Godfrey	N*R-squared	0.5699	0.7520
Homoscedasticity	ARCH LM(-1)	N*R-squared	0.0513	0.8208
	ARCH LM(-2)	N*R-squared	4.0302	0.1333
	Harvey	N*R-squared	11.2932	0.3351
Misspecification	Ramsey RESET LR(-1)	1	2.2721	0.1317
	Ramsey RESET LR(-2)	2	2.8099	0.2454

Figure 5.3 shows how the graph of fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line meanders around the zero mean and be used for forecasting. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting.

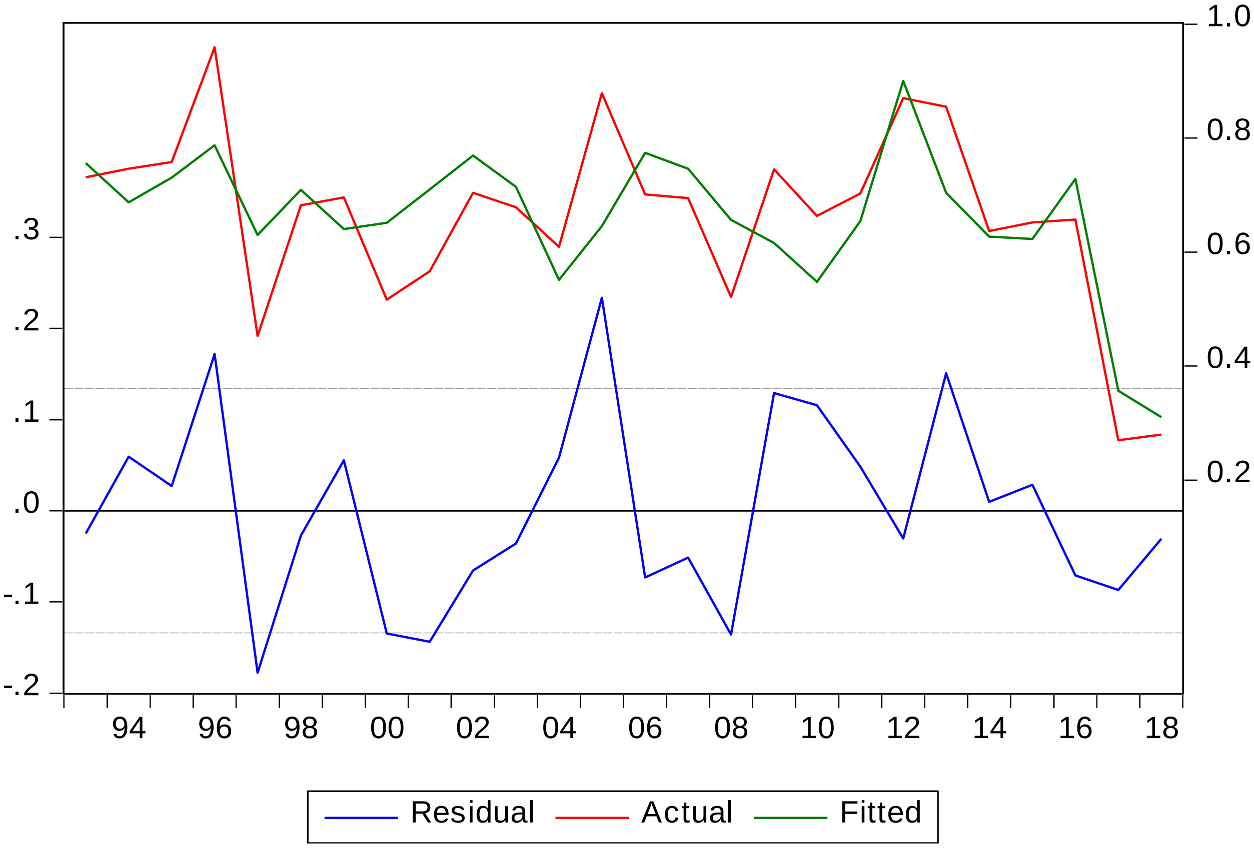

Figure 5.3: Residual, actual and fitted graph of off-take rate in the formal area

Similarly, as in the formal sub-sector, the off-take rate equation for the informal sub-sector is given as follows:

$$OTRI = -0.0306 + 0.7509OTRI_{t-1} - 0.0002CCI + 0.0003CCI_{t-1} - 0.0018BCPI - 0.0062BCPI_{t-1} - 0.0033BCPI_{t-2} + 0.0071BCPI_{t-3} - 0.0008ARFI \quad (5.4)$$

where:

OTRI	Off-take rate in the informal market (communal) area (100%), with lag explanatory variable
CPI	Average cattle price in the informal market (100 cents/kg)
CCI	Calf crop in the informal area (1000 head), with a lagged variable
ARFI	Rainfall in the northern communal areas (NCAs), measured in 100 mm, average, with lagged variable.

The model results set out in Table 5.8 shows the coefficients and standard errors, of the estimated model. The dependent variable is the off-take-rate in the informal area. The independent variables include the lagged off-take rate in the informal area (-1), current cattle prices in the informal area, cattle producer price in informal area, lagged one and two years (-1 and -2), the current calf crop in the informal area, calf crop in the informal area lagged 1 to 3 years, rainfall in the communal area, and lagged rainfall (-1). Table 5.8 provides the summarised results, and we can deduce that off-take rate, lagged 1 year, the current cattle prices, and the cattle prices, lagged 1 year and 3 years, and rainfall in the informal area were significant at 0.05 level, while the rest of the variables were not significant.

Table 5.7 shows that the F-statistics value for testing the overall hypothesis is 17.98 and that the null hypothesis, which says all slopes are equal to zero, is rejected. The results of the autoregressive distributed lag for the off-take rate in the informal sector are presented in Table 5.7.

Table 5.7: ARDL model results for the off-take rate in the communal area sector

Variable	Coefficients	Std. Error
Constant	-0.0306	0.6117
OTRI(-1)	0.7509	0.1479*
CCI	-0.0002	0.0007*
CCI(-1)	0.0003	0.0001*
CPI	-0.0018	0.0003
CPI(-1)	-0.0062	0.0031*
CPI(-2)	-0.0033	0.0032
CPI(-3)	0.0071	0.0031*
ARFI	-0.0008	0.0003*
Adjusted R^2	0.8445	
F-Statistics	17.9756	

Note: * denotes significant values at 0.05 level

Table 5.8 displays the diagnostic outcome of the residual of Equation (5.4), and the diagnostic outcome of the model conforms to the assumptions of OLS and obtained coefficients can be used for forecasting purpose. For brevity the explanation of the model diagnostics were presented in section 4.6 of this chapter.

Table 5.8: Model misspecification tests for the off-take rate in informal areas

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		10.4157	0.0054
Serial Correlation	Breusch-Godfrey	N * R-squared	2.7484	0.2530
Homoscedasticity	ARCH LM(-1)	N * R-squared	1.6303	0.2017
	ARCH LM(-2)	N * R-squared	2.9053	0.2339
	Harvey	N * R-squared	6.2961	0.6141
Misspecification	Ramsey RESET LR(-1)	1	0.1358	0.8936
	Ramsey RESET LR (-2)	2	0.0637	0.9686

Figure 5.4: Residual, actual and fitted graph of the off-take rate in the informal area

5.2.3 Slaughter weight estimation

The slaughter weight estimation uses two equations, covering the formal sub-sector and the informal sub-sector. Both slaughter weight equations are formulated to estimate the functional relationships that exists between average slaughter weight, average beef producer price, average input costs, and average rainfall. The slaughter weight equation for the formal commercial area is given as follows:

$$ASWF = 181.6841 + 0.4276ASWF_{t-1} \mp 2.0776BPPF - 0.0323AICF - 0.0467AICF_{t-1} - 0.0892ARFF - 0.1805ARFF_{t-1} \qquad (5.5)$$

where:

ASWF Average slaughter weight in the formal or commercial area (100 kg), on its own lagged variable.

BPPF Average beef producer price in the formal market (100 cents/kg)

AICF Average input costs (production costs on labour) in the formal area (N$1000), with lagged variable.

ARFF Rainfall in the formal areas measured in 100 mm, average, with lagged variable.

From Table 5.9, we can deduce that the regression results give an adjusted R^2 of 0.22. This means that 22% of the dependent variable (average slaughter weight in the formal area) can be explained by the changes in the behavioural patterns of the explanatory variables. The explanatory efficiency of this model is weak, therefore the results obtained from this model can only be used with caution for forecasting purposes. The result of the autoregressive distributed lag for slaughter weight equation in the formal sector are given in Table 5.9.

Table 5.9: ARDL model results for slaughter weight equivalent in the formal area

Variable	Coefficients	Std. Error
Constant	181.6841	55.8976
ASWF(-1)	0.4276	0.1914
BPPF	2.0776	2.2892
AICF	-0.0323	0.0247*
AICF(-1)	-0.0467	0.0256*
ARFF	-0.0892	0.0899**
ARFF(-1)	-0.1805	0.0907**
Adjusted R^2	0.2248	
F-Statistics	2.2083	

Note: *denotes significant values, at 0.05 level, and ** denotes significance at 0.10 level.

Table 5.10 presents the diagnostic outcome of the residual of Equation (5.5), and the diagnostic outcome shows that the classical assumptions of OLS are not violated, however caution should be taken when using the obtained coefficients for forecasting. Caution should be taken by relaxing the assumptions for normality and skewedness in the diagnostics of the residuals obtained from the model.

Table 5.10: Model misspecification tests for slaughter weight carcass equivalent in the formal area

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		1.5969	0.4500
Serial Correlation	Breusch-Godfrey	N * R-squared	5.0397	0.0805
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	9.3835	0.1531
	ARCH LM(-1)	N * R-squared	0.4771	0.4897
	ARCH LM(-2)	N * R-squared	0.3759	0.8286
	Harvey	N * R-squared	5.7745	0.4489
Misspecification	Ramsey RESET LR(-1)	1	0.0261	0.8718
	Ramsey RESET LR(-2)	2	0.2426	0.8858

The slaughter weight equation for the informal area is given as follows:

$$ASWI = 101.1348 + 0.4574ASWI_{t-1} + 0.0094BPPI - 0.0040AICI - 0.0068ARFI \quad (5.6)$$

where:

ASWI — Average slaughter weight in the informal area (100 kg), on its own lagged variable.

BPPI — Average beef producer price in the informal market (100 cents/kg)

AICI — Average input costs (production costs on labour) in the informal area (N$1000)

ARFI — Average annual rainfall in the northern communal areas, measured in 100 mm.

From Table 5.11, we can deduce that the regression results give an adjusted R^2 of 0.1033. This means that 10% of the dependent variable (average slaughter weight in the informal area) can be explained by the changes in the behavioural patterns of the explanatory variables. The estimated results of equation 5.6 are similar to the outcome of equation 5.5 in the sense that both models produce weaker r-squared values. Similarly, caution should be taken by relaxing the assumptions for normality and skewedness in the diagnostics of the residuals obtained from the equation 5.6 model results. The result of the autoregressive distributed lag for slaughter weight equation in the informal sector is given in Table 5.11. The F-statistics value for testing the overall hypothesis is 1.778. The null hypothesis that says all slopes are equal to zero is rejected.

Table 5.11: ARDL model results for slaughter carcass weight equivalent in the informal area

Variable	Coefficients	Std. Error
Constant	101.1348	41.4348
ASWI(-1)	0.4574	0.2258
BPPI	0.0094	0.1800
ICI	-0.0040	0.0038
ARFI	-0.0068	0.0035
Adjusted R^2	0.1033	
F-Statistics	1.778	

Note that none of the factors are significant for Equation (5.31).

Table 5.12 displays the diagnostic outcome of the residual of Equation (5.6), and the diagnostic outcomes of the model conform to the classical assumptions of OLS and the obtained coefficients can be used for forecasting.

Table 5.12: Model misspecification tests for slaughter carcass weight equivalent in the informal area

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		2.4129	0.2992
Serial Correlation	Breusch-Godfrey LM Test (-1)	N * R-squared	0.2005	0.6543
	Breusch-Godfrey LM Test (-2)	N * R-squared	3.1422	0.2078
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	4.3146	0.3651
	ARCH LM(-1)	N * R-squared	1.1396	0.2857
	ARCH LM(-2)	N * R-squared	2.4794	0.2895
	Harvey	N * R-squared	4.6273	0.3277
Misspecification	Ramsey RESET LR(-1)	1	1.6453	0.1141

Figure 5.5 shows how the graph of fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line meanders around the zero mean and be used for forecasting. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting.

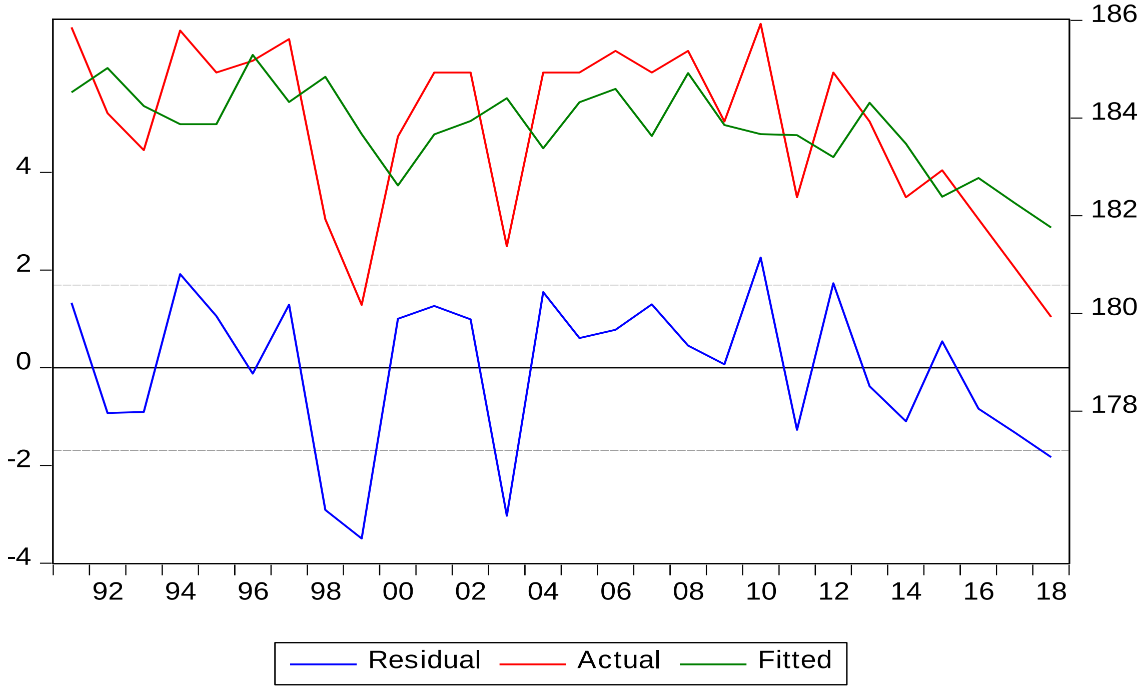

Figure 5.5: Residual, actual and fitted graph of slaughter weight in the informal area

5.2.4 Weaner and beef disappearance estimation

The next section discusses the estimation of live weaner and beef demand.

5.2.4.1 Weaner supply estimation

The weaner supply equation considers the beef supply, the average beef carcass price, and the average rainfall. Again, the procedure involves the estimation of two separate equations for the sub-sectors, i.e., the sub-sector in the formal area and the sub-sector in the informal areas. The equation for beef supply in the formal sub-sector is given as follows:

$$WEXPRSA = WEXPRSA_{t-1} + WPR + WPR_{t-1} + WPR_{t-2} + WPR_{t-3} + BCPN + BCPN_{t-1} + BCPN_{t-2} + BCPN_{t-3} + CHN + CHN_{t-1} + \varepsilon \quad (5.7)$$

where:

WEXPRSA	Weaner marketed from the formal area (number), with lagged variable.
WPR	Ratio of the Average weaner auction price in Namibia (N$ per kg) to the South African weaner auction price, with lagged variables
BCPN	Average beef carcass price for slaughter stock in Namibia (N$ per kg), with lagged variables
CHEN	Cattle herd numbers in Namibia, in thousands, with a lagged variable.

Table 5.13 presents the results of Equation (5.7). As can be noted in Table 5.13 the ARDL results for the weaner export from the formal area is a dependent variable determined by the covariance of lagged variable, ratio of the average auction weaner price in Namibia and the average weaner auction price in South Africa, average beef carcass price in the areas of Namibia and its own lag and the cattle herd numbers in Namibia and its own lag. It is noted from Table 5.13 that the number of weaners exported in the previous period or year is statistically significant, at the 0.05 level. The ratio of the auction price of weaner, where it is noted that covariance of the lagged (2 and 3 years) weaner price ratio are positive and statistically significant at the 0.05 percent level. A ratio value equal to a unit and above implies that increase in the weaner auction price ratio will increase the number of weaners marketed in the South African market. Similarly, if all price conditions for weaners are unfavourable, resulting in a ratio below a unit, more weaners will be marketed in the domestic market. Therefore, the weaner price ratio of the domestic weaner auction price to the South Africa weaner price, and how the ratio relates to the beef carcass price in Namibia, serves to dictate the modus operandi of the cattle producers and marketers in Namibia. In addition, domestic beef carcass price, in a one-year lagged period, as well as in periods lagged two and three years, have positive and statistically significant (0.2099, 0.1758, and 0.2397, respectively) impacts on weaner exports for Namibia. This means that farmers can export more weaners if the previous reasons for price expectation were satisfactory.

The numbers of cattle available in the current and previous years are positive and statistically significant at the 0.005 level. If export conditions are favourable, cattle producers are expected to market more weaners to South Africa. The adjusted R-squared is 87 percent, meaning that 87 percent of the variation in weaner exports to South Africa is explained by weaner price and its lagged value, the beef carcass price ratio, number of weaners exported and the cattle herd in Namibia. The F-statistics value for testing the overall hypothesis is 6.5 percent, with a p-value of 0.0000. The joint null hypothesis that says all slopes are equal to zero is rejected because the F probability value is less than the 0.05 level.

Table 5.13: ARDL model results for the weaner export to South Africa from the formal area

Variable	Coefficients	Std. Error
Constant	204.5129	14.4099
WEXPRSA(-1)	-0.3715	0.2274*
WPR	0.3707	0.7903
WAPN(-1)	1.3125	1.1839
WAPN(-2)	0.2939	1.1585*
WAPN(-3)	0.8807	0.0782*
BCPN	0.1913	0.0705
BCPN(-1)	0.2099	0.0125*
BCPN(-2)	0.1758	0.0122*
BCPN(-3)	0.2397	0.0935*
CHN	0.01849	0.0093*
CHN(-1)	0.1998	0.0861*
Adjusted R^2	0.87685	
F-Statistics	6.4837	

Note: * denotes significant values, at the 0.05 level

Table 5.14 and Figure 5.6 present the diagnostic outcomes of the residual of Equation (5.7), and the diagnostic outcomes show that all of the classical assumptions of OLS are upheld and model can be used for forecasting purpose. Figure 5.6 shows how the graph of the fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line meanders around the zero mean.

Table 5.14: Model misspecification tests for weaner exports to South Africa from the formal area

Purpose of test	Test	d. f	Test statistics	Probability
Normality	Jarque-Bera		1.0959	0.5781
Serial Correlation	Breusch-Godfrey	N*R-squared	0.0011	0.9737
Homoscedasticity	ARCH LM(-1)	N*R-squared	1.4846	0.2230
	ARCH LM (-2)	N*R-squared	2.5919	0.2736
	Harvey	N*R-squared	15.8214	0.1995
Misspecification	Ramsey RESET LR (-1)	1	3.6090	0.0575
	Ramsey RESET LR (-2)	2	3.6569	0.1607

Figure 5.6 shows how the graph of fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line fluctuates around the zero mean. The model results and coefficients are statistically sound, therefore, can be used for forecasting. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting purpose.

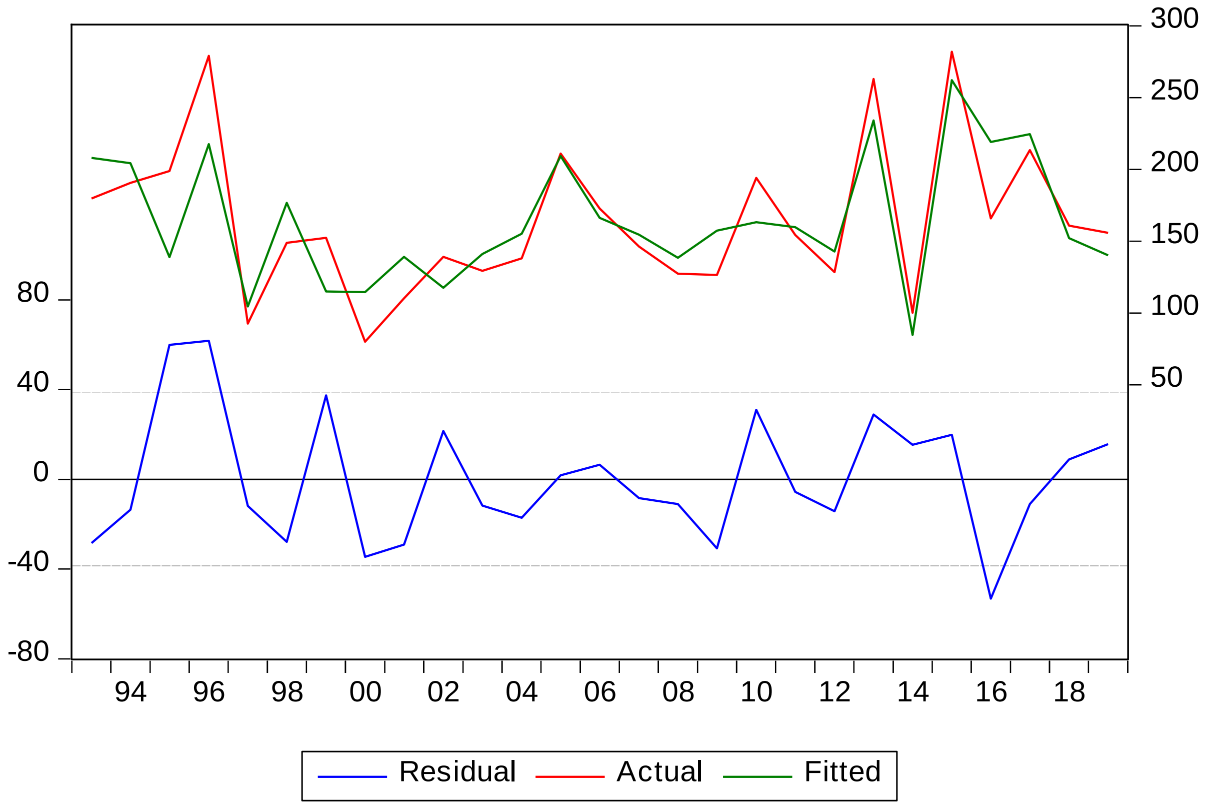

Figure 5.6: Residuals, actual and fitted graph for weaner exports to South Africa from the formal area

The beef export estimation takes into account the average EU beef carcass price, expressed in Namibian dollar, and beef trade restrictions. Namibia exports chilled boneless beef to the EU. The procedure involves the estimation a single equation for the sub-sector, i.e. the commercial area. The beef export equation is given as follows:

$$EUEXP = 6.9660 + 0.0.6431EUEXP_{t-1} + 0.0993BPRAT - 1.3907TRES \qquad (5.8)$$

where:

EUEXP	Beef exports to the European Union from the formal area (1000 kg) and lagged one year
BPRAT	Beef carcass price ratio of European Union (100 c/kg and the domestic carcass beef price)
TRES	Trade restrictions on the export of beef to the EU markets; a SHIFT variable.

Table 5.15 presents the results derived through Equation (5.8). The ARDL results for the beef exports from formal area are dependent on its lagged variable, the ratio of the beef carcass price

in the EU to the domestic beef carcass price, and the trade restrictions based on quality and quantity of beef supplied to the EU markets. It can be deduced from Table 5.15 that the volume of beef exported in the previous period or year is statistically significant, at the 0.05 level. Similarly, the ratio of the EU carcass price to the domestic carcass price is positive and statistically significant at the 0.05 level. This implies that the price offered by EU markets is superior to the domestic beef carcass price, and thus enables Namibia to export more beef to the EU markets. If the domestic carcass price is trending below the EU carcass price, the EU beef markets remain important for Namibian beef. On the contrary, trade restrictions have negative (-1.3907) and significant impacts on the exports of beef by Namibia.

The adjusted R-squared is 75 percent and it means that 75 percent of the variation in beef exports to the EU markets is explained by the variation in quantity of beef exported in the previous period, beef price ratio in the domestic market, and the trade policy status. The F-statistics value for testing the overall hypothesis is 10.33 percent; thus, the joint null hypothesis which states that all slopes are equal to zero is rejected at the 0.05 level. Based on variables presented in Table 5.15, the export of beef estimation can be written as:

Table 5.15: ARDL model results for beef exports to European Union markets from the formal area

Variable	Coefficients	Std. Error
Constant	6.9660	6.2465
EUEXP(-1)	0.6431	0.1398*
BPRAT	0.0993	0.0078*
TRES	-1.3907	0.4006*
Adjusted R^2	0.75064	
F-Statistics	10.33231	

Notes: *denotes significant values at the 0.05 level

Table 5.16 and Figure 5.7 present the diagnostic outcomes of the residual of Equation (5.8), and the diagnostic outcomes show that all of the classical assumptions of OLS are upheld and therefore, coefficients can be used for forecasting purposes.

Table 5.16: Model misspecification tests for Beef export to European Union

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		4.1279	0.1269
Serial Correlation	Breusch-Godfrey LM Test (-1)	N * R-squared	0.0287	0.8654
	Breusch-Godfrey LM Test (-2)	N * R-squared	1.8019	0.4062
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	5.4222	0.6086
	ARCH LM(-1)	N * R-squared	0.0865	0.7685
	ARCH LM(-2)	N * R-squared	0.1067	0.9480
	Harvey	N * R-squared	25.6629	0.0006
Misspecification	Ramsey RESET LR(-1)	1	2.3688	0.1238
	Ramsey RESET LR(-2)	2	2.3723	0.3054

Figure 5.7 shows how the graph of fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line fluctuates around the zero mean. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting.

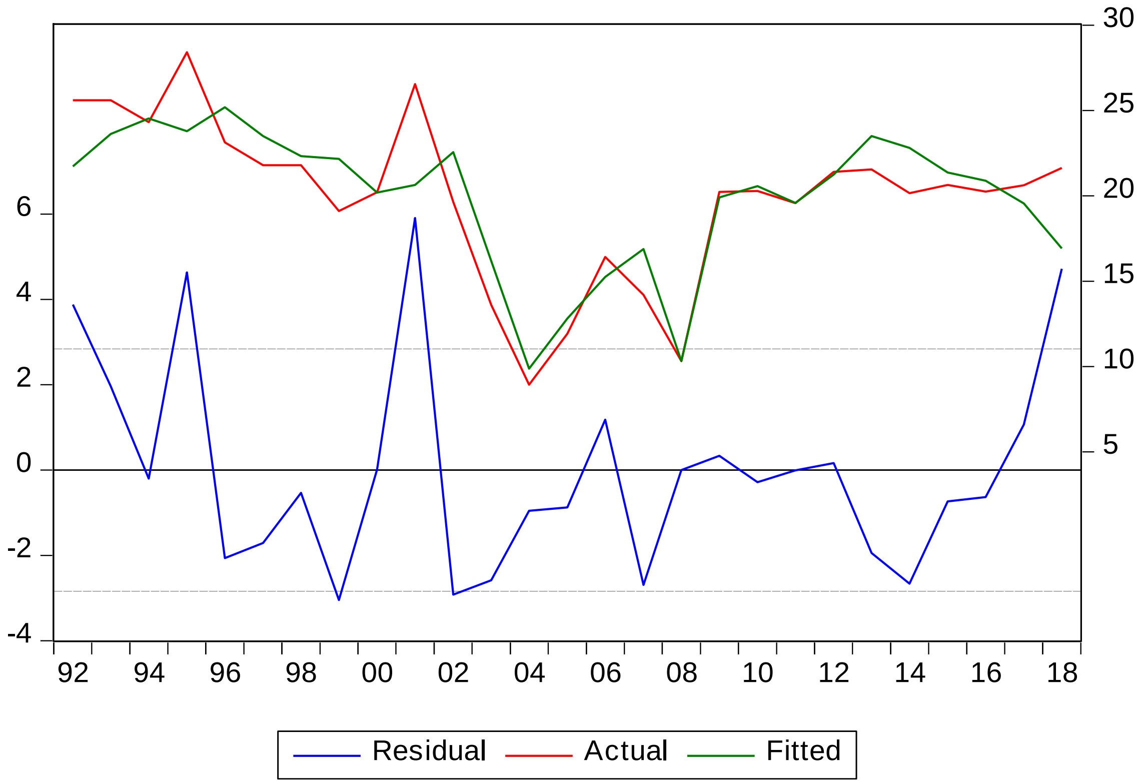

Figure 5.7: Residuals, Actual and fitted graph of beef export to the European Union

5.2.4.2 Beef disappearance estimation

The beef disappearance estimation considers the average beef demand in the formal area, south of the veterinary cordon fence, the average price of chicken, the average household income for urban households, based on NSA estimations, and the average retail price of beef. Note that the procedure involves the estimation a single equation for the sub-sector, i.e., the commercial area. The beef demand equation is given as follows:

$$BDF = RBEP + RCKP + RBP + RGDPPC + TREND + \varepsilon \qquad (5.9)$$

where:

BDF	Beef domestic demand in the formal areas, expressed in 1000 kg or tonnes per capita
RBEP	Average retail beef price (in real terms), expressed in 100 cents per kg, with lagged variable
RCKP	Real chicken retail price (in real terms), expressed as average price in 100 cents per kg

RGDPPC	Real GDP per capita, a proxy of average income per household and expressed in 1000 Namibian dollars per household, based on NSA income surveys.
TREND	Quality variations, tastes and preferences, over time.

Table 5.17 presents the results derived through Equation (5.9). As it can be noted, in Table 5.17 the ARDL results for the beef demand in the formal commercial area is dependent variable augmented real retail price of beef, retail price of chicken, real GDP per capita and trend variables. It can be seen from Table 5.17 that the own price of beef is negative and significant at the 0.05 level, and that the chicken price and real GDP per capita are positive and significant, at 10 percent. These findings are consistent with the expectations of the law of demand, and depict the inverse relationship between the quantity demanded for a product and its own price. From the real GDP per capita, it can be deduced that beef is a normal commodity because the coefficient is positive. The model performance indicates that the adjusted R-squared is 64 percent. The F-statistics value for testing the overall hypothesis is 7.74 percent; thus, the joint null hypothesis that says all slopes are equal to zero is rejected at the 0.05 level because the probability value is less than 0.05.

Table 5.17: ARDL model results for beef disappearance from the formal area

Variable	**Coefficients**		**Std. Error**
Constant	15.3078		7.02901
RBP	-1.1450		0.2309*
CHKP	0.0112		0.2998**
RGDPPC	0.3089		1.6490**
Trend	0.0024		1.7274
Adjusted R^2		0.6447	
F-Statistics		7.7410	

Note: * and ** denote significant values, at 0.05 and 0.10 levels, respectively

Table 5.18 and Figure 5.8 present the diagnostic outcomes of the residual of Equation (5.9), and the diagnostic outcomes show that all of the classical assumptions of OLS are upheld and are statistically sound and can be used for forecasting purposes.

Table 5.18: Model misspecification tests for beef demand in the formal area

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		0.9014	0.6372
Serial Correlation	Breusch-Godfrey LM Test (-1)	N * R-squared	0.6491	0.4204
	Breusch-Godfrey LM Test (-2)	N * R-squared	2.4758	0.2900
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	9.1166	0.6929
	ARCH LM(-1)	N * R-squared	0.4539	0.5005
	ARCH LM(-2)	N * R-squared	0.7378	0.6915
	Harvey	N * R-squared	10.0452	0.6120
Misspecification	Ramsey RESET LR(-1)	1	15.6387	0.0001
	Ramsey RESET LR(-2)	2	16.0463	0.0003

In support of that statement, Figure 5.8 shows how the graph of fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line meanders around the zero mean. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting.

Figure 5.8: Residuals, actual and fitted graph for beef demand in the formal area

The informal beef disappearance estimation takes into account the average beef demand in the communal areas, north and south of the veterinary cordon fence, the average retail price of beef, the average price of chicken, the real GDP per capita (average household income for rural household based on NSA estimation) and the trend variable. Note that the procedure involves the estimation a single equation for the communal sub-sector. The beef demand equation is given as follows:

$$BDI = RBP + RCKP + RGDPPC + Trend + \varepsilon \qquad (5.10)$$

where:

BDI	Beef domestic demand in the informal areas, expressed in 1000 kg per capita
RBEP	Average real retail beef price, expressed in 100 cents per kg, with lagged variable
RCKP	Average real chicken retail price, expressed in 100 cents per kg, with a lagged variable

RGDPPC	A proxy of the average household income, expressed in 1000 Namibian dollar per household, based on NSA income survey, with lagged variables
TREND	Quality variations, tastes and preferences, over time.

Table 5.19 below presents the results derived through Equation (5.10). As can be seen from Table 5.19, the ARDL results for the beef demand in the informal area is dependent variable augmented by its own retail beef price, real price of chicken, real GDP per capita (proxied by the income of household and own lagged variables, own retail beef price, and its lagged variables). It is noted from Table 5.19 that the real retail price of beef and the real chicken price are significant, at the 0.05 level. These findings are consistent with the expectations of the law of demand, meaning the coefficients depict the inverse relationship between the quantity demanded and the price of the competitive commodity for substitutes. The model performance indicates that the adjusted R-squared is 59 percent. The F-statistics value for testing the overall hypothesis is at the 0.05 level; thus, the joint null hypothesis that says all slopes are equal to zero is rejected, at the 0.05 level.

Table 5.19: ARDL model results for beef demand from the informal area

Variable	**Coefficients**		**Std. Error**
Constant	10.1511		2.6467
RBP	-0.5934		0.02085*
RCKP	0.0044		0.0014*
RGDPPC	0.0560		0.8267
TREND	0.0063		0.3879
Adjusted R^2		0.5948	
F-Statistics		5.0777	

Note: *denotes significant values at the 0.05 level

Table 5.20 and Figure 5.9 present the diagnostic outcomes of the residual of Equation (5.10), and the diagnostic outcomes show that all the classical assumptions of OLS are upheld and coefficients displays the expected signs. In support of results presented in Table 5.20, Figure 5.9 shows how the graph of the fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line meanders around the zero mean.

Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting.

Table 5.20: Model misspecification tests for beef demand in the informal area

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		1.9698	0.3734
Serial Correlation	Breusch-Godfrey LM Test (-1)	N * R-squared	0.3060	0.5801
	Breusch-Godfrey LM Test (-2)	N * R-squared	2.3246	0.3128
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	7.9720	0.5370
	ARCH LM(-1)	N * R-squared	0.5089	0.4756
	ARCH LM(-2)	N * R-squared	1.2087	0.5464
	Harvey	N * R-squared	9.8455	0.3631
Misspecification	Ramsey RESET LR(-1)	1	3.1807	0.0745
	Ramsey RESET LR(-2)	2	12.1467	0.0023

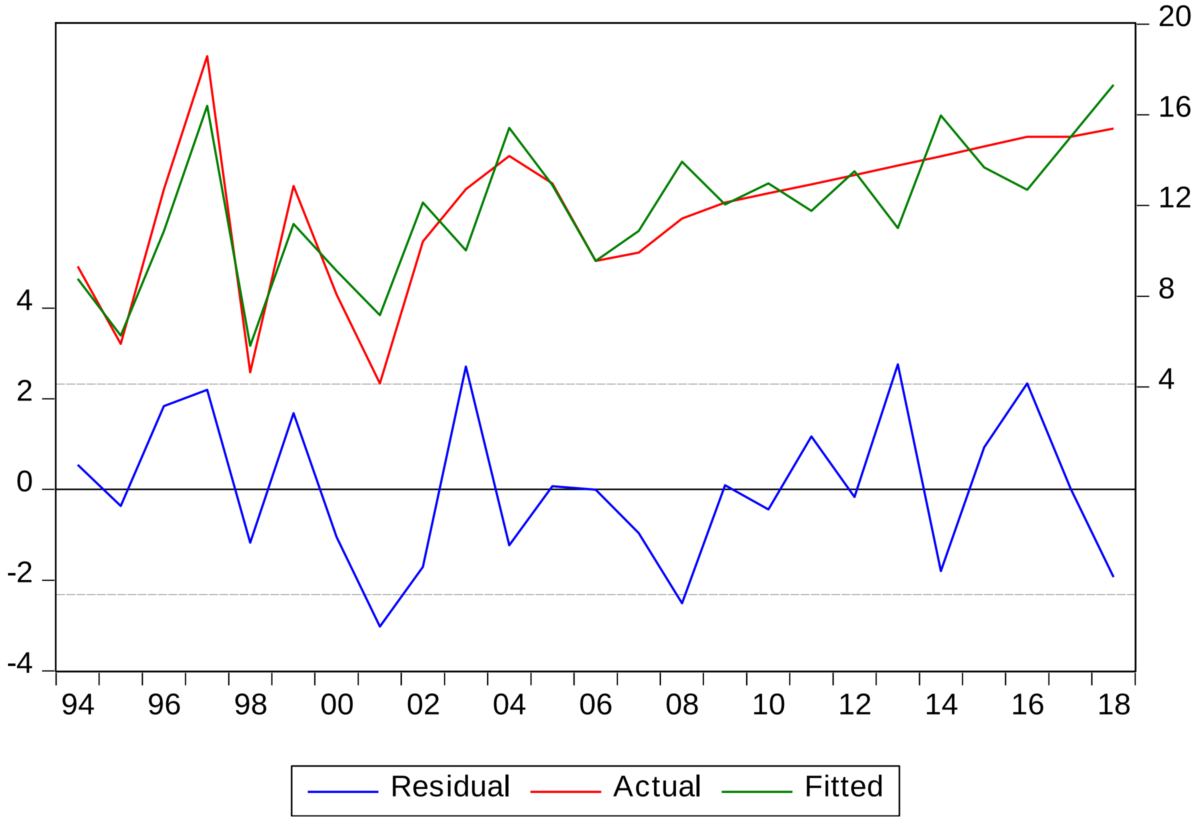

Figure 5.9: Residuals, actual and fitted graph for beef demand in the informal area

5.3 Price block equation

The block of the price linkage shows the pricing processes in the domestic market, the formal market price, and the informal market price. Chapter 3 above has explored the relationship between the domestic prices, the formal and informal beef carcass prices, compared with the South African prices, and the EU export prices. However, this sub-section illustrates the linkages of the informal price to the formal beef carcass price.

5.3.1 Formal market price linkage

The domestic average carcass price of beef is estimated as a function of the domestic carcass price of beef in Namibia, lagged one period, the average export price paid by EU markets and its own lagged variable, the tariff policy (quota restriction and quality – chilled boneless beef), and the volume of beef exported and its own lagged variable. This allows for flexibility in evaluating the impact of EU pricing and trade requirements for Namibian beef, compared with a separate, average weaner auction price paid by the South African market. However, the intention was to estimate the domestic price as a function of the South African import price, minus transport, insurance and freight costs. However, the South African weaner price depicts the price that a farmer receives per head of weaner marketed on the hoof.

$$BCPF = BCPF_{t-1} + EUCP + EUCP_{t-1} + TARF + TARF_{t-1} + BCEX + BCEX_{t-1} + +BCEX_{t-2} + \varepsilon \quad (5.11)$$

where:

BCPF	The average beef carcass producer price, expressed in 100 cents per kg, with lagged variable
EUCP	European Union carcass price export, expressed in domestic currency in 100 cents per kg, with a lagged variable
TARF	Average tariff payable for every exportable kilogramme of beef, expressed in 100cents per kg, with lagged variable
BCEX	Beef carcasses exported from the exporting abattoirs or agencies in Namibia, expressed in 1000 kg, with lagged variables.

Table 5.21 presents the results derived through Equation (5.11). As can be seen from Table 5.21, the ARDL results for the current average price for beef in the domestic formal commercial

area is a dependent variable determined by its own past lagged variable, average EU carcass price and its own lagged variable, tariff and its own lagged variable and beef carcass quantity exported from Namibia. Table 5.21 shows that the lagged average beef domestic price is positive and significant, at the 0.05 level. The average export price and its lagged variables are equally significant, at the 0.05 level. Similarly, the EU carcass price and the lagged variable are positive and significant, both at the 0.05 level. These findings are consistent with the expectation that the domestic price of beef for the expected commodity is linked to the export price. The coefficient for the tariff is negative and significant, at the 0.05 level. This implies that, as tariffs increase, exports decrease, as does the domestic producer price received by exporters. The model performance indicates that the adjusted R-squared is 71 percent, implying that 71 percent of the variation in beef carcass price is explained by the total variation in the exogenous variables. The F-statistics value for testing the overall hypothesis is 11 percent; thus, the joint null hypothesis that states that all slopes are jointly equal to zero is rejected, at the 0.05 level.

Table 5.21: ARDL model results for price linkage

Variable	**Coefficients**		**Std. Error**
Constant	0.9459		0.9492
BCPN(-1)	0.7947		0.1316*
EUCP	0.0749		0.0121*
EUCP(-1)	0.0726		0.0119*
TARF	-0.0329		0.0766
TARF(-1)	-0.0201		0.0044*
BCEX	0.0444		0.0564
BCEX(-1)	-0.0848		0.0907
BCEX(-2)	0.0440		0.0043*
Adjusted R^2		0.7123	
F-Statistics		11.3176	

*Note: * denotes significant values at the 0.05 level*.

Table 5.22 and Figure 5.10 present the diagnostic outcomes of the residual of Equation (5.12), and the diagnostic outcomes show that all of the classical assumptions of OLS are upheld and statistically sound for forecasting purposes.

Table 5.22: Model misspecification tests for the price linkage equation

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		0.6439	0.8803
Serial Correlation	Breusch-Godfrey LM Test (-1)	N * R-squared	0.0179	0.8936
	Breusch-Godfrey LM Test (-2)	N * R-squared	8.0263	0.0181
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	9.7675	0.4611
	ARCH LM(-1)	N * R-squared	1.7566	0.1851
	ARCH LM(-2)	N * R-squared	1.6429	0.4398
	Harvey	N * R-squared	6.8307	0.7413
Misspecification	Ramsey RESET LR(-1)	1	0.0426	0.8839
	Ramsey RESET LR(-2)	2	0.5774	0.7492

Figure 5.10 shows how the graph of the fitted values estimated from the equation tracks the actual values of the model, while, as expected, the residual line meanders around the zero mean. It is expected that the mean of the residuals should sum to zero. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressors in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting.

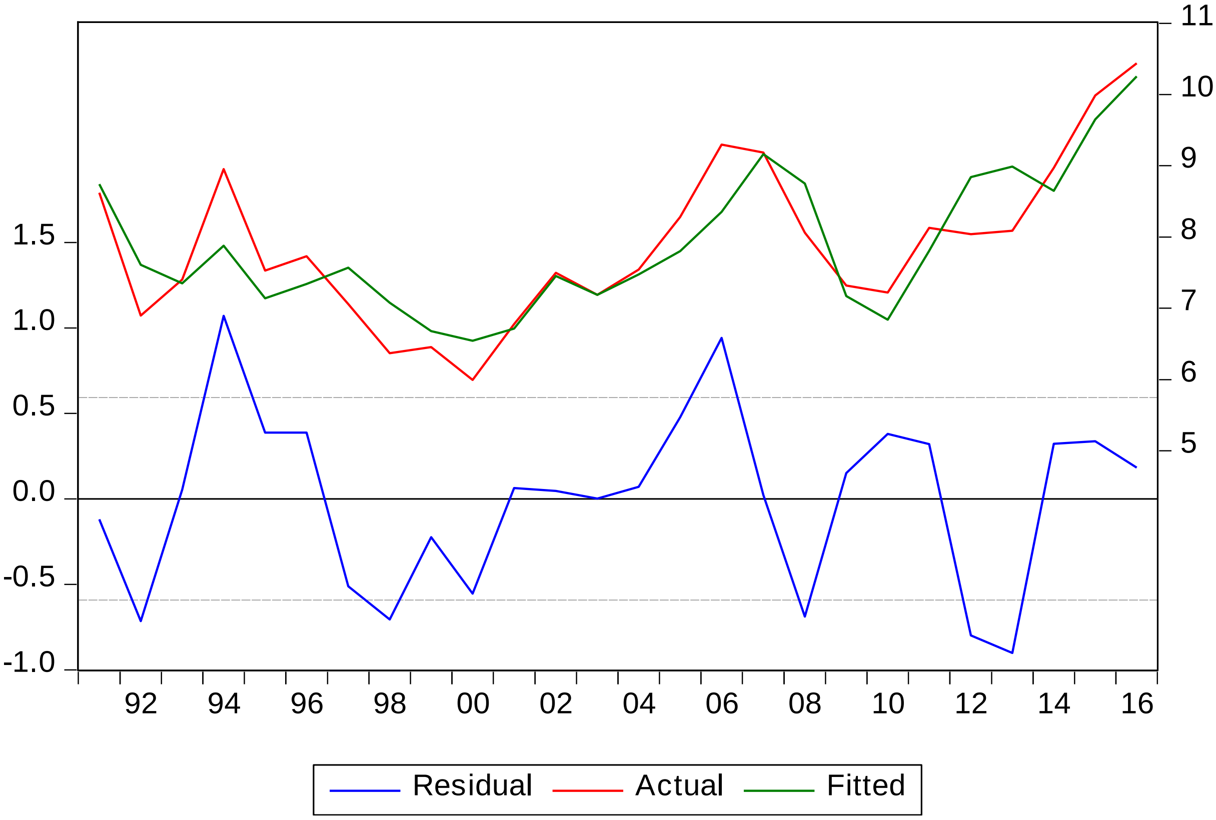

Figure 5.10: Residuals, actual and fitted graph for the price linkage equation

5.3.2 Informal market price linkage

The informal beef carcass price of beef is estimated as a function of the average carcass price of beef paid in the formal market, and its own lagged variable. The motivation for this estimation was to gain more desirable results, which depict the accuracy of the price transmission from the formal market to informal market. This dictates the relationship that prevails between the two prices in the domestic market. The equation is expressed as follows:

$$BCPI = 10.799 + 0.0755BCPI_{t-1} + 0.0636BCPF + \varepsilon \qquad (5.13)$$

where:

BCPI Average beef carcass price per kg in the informal area, expressed in 100 cents per kg, with a lagged variable

BCPF Average beef carcass price per kg in the formal area, expressed in 100 cents per kg

ε random error, with a mean of 0.

Table 5.23 presents the results derived through Equation (5.13). As can be noted in Table 5.23 the ARDL results for the average beef domestic price in the informal communal area is a dependent variable determined by its own past value, and average carcass producer price per kilogramme in the formal market. Table 5.23 shows that lagged average beef domestic price is positive and significant, at the 0.05 level. Similarly, the formal average beef carcass producer price is significant, at the 0.05 level.

The model performance indicates that the adjusted R-squared is 85 percent. This is statistically sound because 85 percent of the variation in the average beef price in the informal areas is explained by the total variation in the determinants. The F-statistics value for testing the overall hypothesis is 82, implying that the joint null hypothesis which states that all slopes are equal to zero is rejected at the 0.05 level, with a probability of 0.000.

Table 5.23: ARDL model results for price linkage in the informal areas

Variable	**Coefficients**	**Std. Error**
Constant	1.0799	0.5527*
BPPI(-1)	0.7553	0.1292*
BPPF	0.0636	0.0391*
Adjusted R^2	0.8523	
F-Statistics	81.8088 (0.0000)	

Note: *denotes significant values at the 0.05 level

Table 5.24 and Figure 5.11 present the diagnostic outcomes of the residual of Equation (5.14), and the diagnostic outcomes show that all of the classical assumptions of OLS are upheld.

Table 5.24: Model misspecification tests for the informal price linkage

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		1.7487	0.4171
Serial Correlation	Breusch-Godfrey LM Test (-1)	N * R-squared	0.0001	0.9910
	Breusch-Godfrey LM Test (-2)	N * R-squared	0.0029	0.9985
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	4.0732	0.1305
	ARCH LM(-1)	N * R-squared	0.1155	0.7339
	ARCH LM(-2)	N * R-squared	0.6827	0.7108
	Harvey	N * R-squared	0.0947	0.9538
Misspecification	Ramsey RESET LR(-1)	1	5.4645	0.0194
	Ramsey RESET LR(-2)	2	5.6016	0.0608

Figure 5.11 shows how the graph of the fitted values estimated from the informal price equation tracks the actual values of the model. As expected from post-estimation diagnostics, the residual line meanders around the zero mean. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied and the endogenous equation can be used for forecasting.

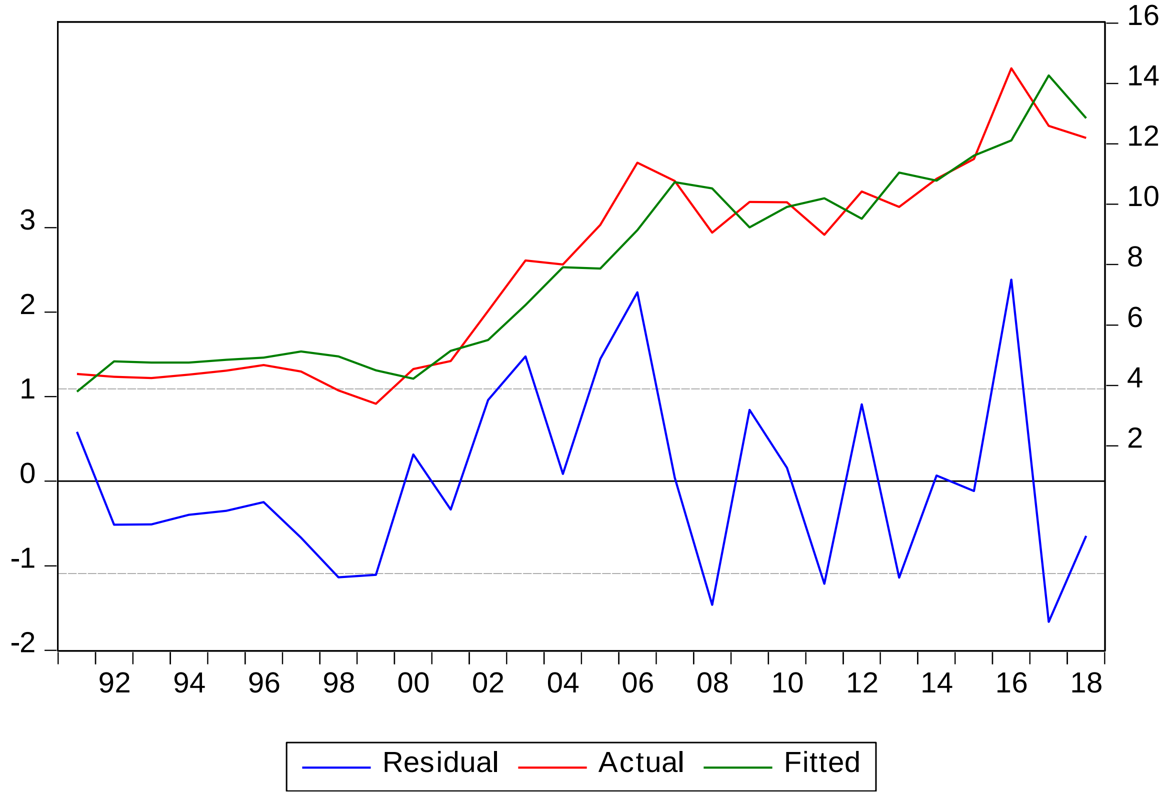

Figure 5.11: Residuals, actual and fitted graph for the informal price linkage

5.3.3 Weaner price estimation

The weaner price estimation for the domestic market depicts the functional relationship that exists between the previous year's weaner auction, the domestic beef carcass price and its own lag, the current and lagged number of weaners supplied and marketed at auction in the domestic market or exported, and the South African auction price.

$$WPNAM = 2.7794 + 0.1522WPNAM_{t-1} + 0.0004BCPN - 0.0096BCPN_{t-1} - 0.0138WMARK + 0.9932WMARK_{t-1} - 0.4924WMARK_{t-2} + 0.0853WMARK_{t-3} - 0.1136WPRSA - 0.1824WPRSA_{t-1} + 0.3284WPRSA_{t-2} + \varepsilon \quad (5.15)$$

where:

WPNAM The average auction weaner price in the domestic market, expressed in 100 cents per kg, and has lagged variable

BCPN The average beef carcass price in the domestic market, expressed in 100 cents per kg, with own lag

WMARK The number of weaners marketed, with own lag, expressed in 1000 head;

WPRSA The average feedlot auction price for weaners in South Africa, expressed in 100 cents per kg, with own lags;

ε random error, with a mean of 0.

The weaner estimation derived from equation 5.15 results are presented in Table 5.25. Table 5.25 presents the ARDL results, the average auction price for weaners determined by its own lagged variable, and its average carcass producer price and its own lagged variable, and the number of weaners marketed and its own lags (1 to 3). Table 5.25 shows that lagged average auction price is positive and significant, at the 0.05 level. Similarly, the current average beef carcass producer price is significant, at the 0.05 level, while the lagged variable is negative and significant, at 10%. The numbers of weaners marketed, lagged 3 periods, is positive and significant, at 10%. This means that a 3-year period of weaner marketing would have a positive impact on the auction price. Similarly, the South African feedlot auction weaner price, lagged 2 periods, is positive and significant at 10%. The price transmission of the weaner auction price from the South African feedlots to Namibia is positive and significant.

Results presented in Table 5.25 indicates that a one-percent increase in the South African feedlot auction price would lead to a 3.28-percent increase in the average weaner price in Namibia. The model performance indicates that the adjusted R-squared is 96 percent. This is statistically sound model because about 96 percent of the variation in weaner exports is explained by the total variation in the determinants of weaner exports. The F-statistics value for testing the overall hypothesis is 66.6 percent. Accordingly, the joint null hypothesis that says all slopes are equal to zero is rejected, at the 0.05 level, with a probability of 0.000.

Table 5.25: ARDL model results for price linkage in the weaner price estimation

Variable	Coefficient	Std. Error
Constant	2.7794	1.5426*
WPNAM(-1)	0.1522	0.2704*
BCPN	0.0004	0.2381*
BCPN(-1)	-0.0096	0.2688**
WMARK	-0.0138	0.0057
WMARK(-1)	0.9932	0.0057
WMARK(-2)	-0.4924	0.0066
WMARK(-3)	0.0853	0.0071**
WPRSA	-0.1136	0.1287
WPRSA(-1)	-0.1824	0.1412
WPRSA(-2)	0.3284	0.1814**
Adjusted R-squared	0.9652	
F-stat	66.6201 (0.0000)	

Note: * and ** denote significant values at the 0.05 and the 0.10 levels, respectively

Table 5.26 and Figure 5.12 present the diagnostic outcomes of the residuals, based on description provided in Subsection 5.6.5 presented earlier.

Table 5.26: Model misspecification tests for the weaner price estimation

Purpose of test	Test	d. f	Test statistic	Probability
Normality	Jarque-Bera		1.4046	0.4954
Serial Correlation	Breusch-Godfrey LM Test (-1)	N * R-squared	2.5985	0.1070
	Breusch-Godfrey LM Test (-2)	N * R-squared		
Homoscedasticity	Breusch-Pagan-Godfrey	N * R-squared	11.4116	0.4094
	ARCH LM(-1)	N * R-squared	1.1208	0.2898
	ARCH LM(-2)	N * R-squared	1.7565	0.4155
	Harvey	N * R-squared	9.3072	0.5936
Misspecification	Ramsey RESET LR(-1)	1	3.5829	0.0792
	Ramsey RESET LR(-2)	2	2.2925	0.0169

Figure 5.12 shows how the graph of the fitted values of weaner price estimated from the equation tracks the actual values of the model. As expected from the post-estimation diagnostics that the residual line meanders around its mean of zero. Furthermore, the strict exogeneity condition, which requires that the regression error has a mean of zero conditional on current, future, and past values of the regressor in a distributed lag model, is satisfied.

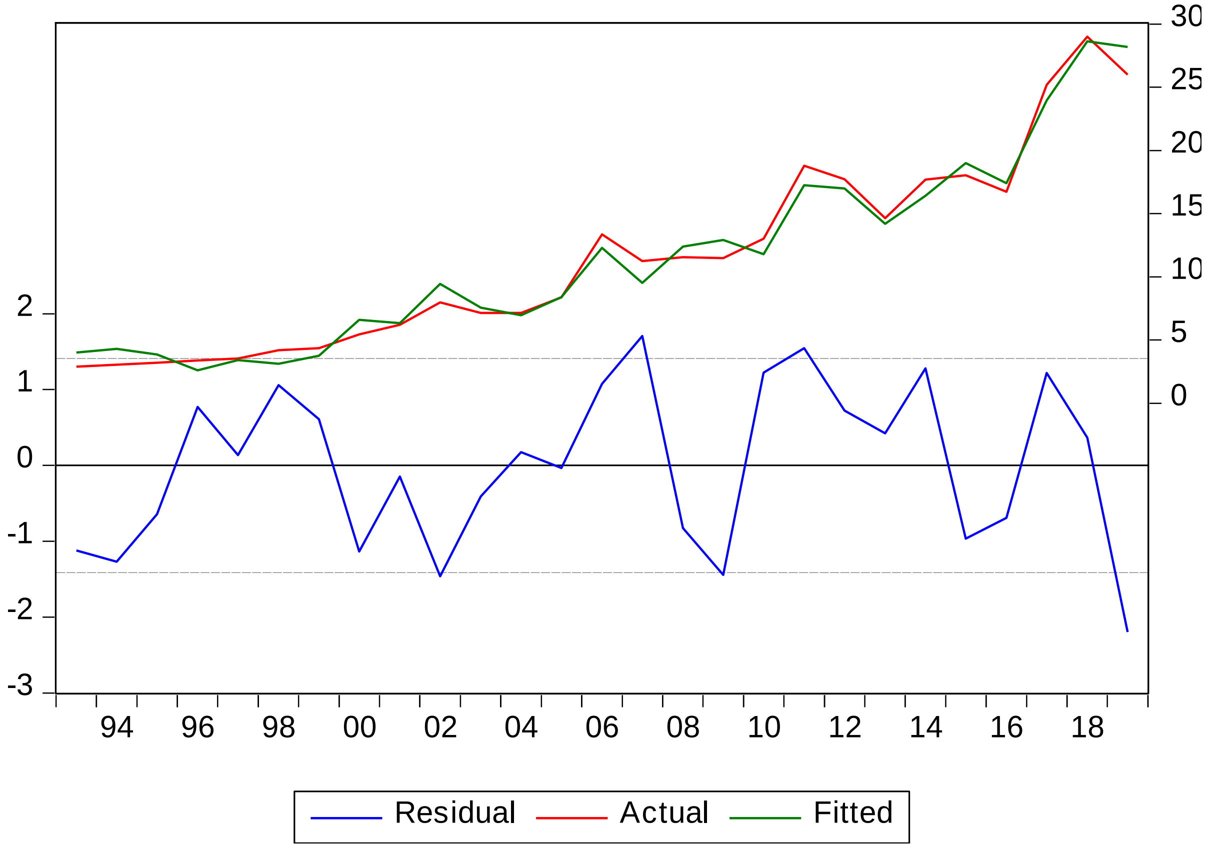

Figure 5.12: Residuals, actual and fitted graph for the weaner price estimation

5.4 Results of the overall model performance

This section presents the results of the overall performances of the individual model. The evaluation of the model performance is based on the forecasting ability of the model to determine the statistical soundness of the analytical approaches used for this study. Section 4.7 of this study outlined the following statistical techniques, namely Root Mean Squared Error (RMSE), Mean Average Error (MAE), Mean Average Percentage Error (MAPE), Theil Inequality Coefficient (U). If the forecasts are said to be good, the bias and variance proportions should be small, which is the case in the estimated behavioural equation (Lütkepohl, 2005). Table 5.27 presents the outcome of the four approaches.

Table 5.27: Static and dynamic simulation outcome

Variable name	Root Mean Square Error	Mean Absolute Error	Mean Absolute Percentage Error	Theil Inequality Coefficient
Off-rate in S-VCF	0.1019	0.0846	13.7415	0.0752
Off-rate in N-VCF	0.0118	0.0101	14.1290	0.0677
Slaughter weight in S-VCF	7.4988	5.1331	2.2583	0.0159
Slaughter weight in N-VCF	1.6214	1.3364	0.7289	0.0044
Cattle supply in S-VCF	40.7506	31.1712	9.3600	0.0599
Cattle supply in N-VCF	5.2727	4.4237	9.5141	0.0549
Beef supply in S-VCF	9.2427	7.5655	12.0987	0.0712
Beef supply in N-VCF	0.6718	0.5056	5.9946	0.0385
Weaner export to RSA	8.0421	6.6690	26.6655	0.1225
Beef export to EU	2.5259	1.9733	10.1994	0.0618
Beef demand the formal market	1.6038	1.2989	12.8262	0.0653
Beef demand in the informal market	0.6641	0.5158	6.0904	0.0390
Price linkage equation for the formal market	1.2271	0.9478	15.1038	0.0731
Price linkage equation for the informal market	1.5356	1.2255	19.0408	0.0913

From Table 5.27, it is evident that, of the 14 endogenous equations presented, only cattle supply in the formal area (S-VCF) has the mean absolute error value greater than 10 percent while majority of the equation have Root Mean Square Error and Mean Absolute Error greater than 10 percent, however, the equation performs well on the Thiel Inequality coefficient value, which is close to 0.05 and significant, meaning that the residuals of the endogenous equations in the model are drifting towards 0. All endogenous equations have MAPE percentage less than 50%. Therefore, the diagnostics for these equations it can be concluded that the model performs reasonably well and it is parsimoniously, thus it can effectively be used for forecasting policy scenario analysis.

5.5 Chapter Summary

This chapter presented the results emanating from the individual models specified earlier. As a necessity for econometric time series modelling, conducting diagnostic tests on residuals of the estimated model is paramount. Thus, tests for the verification of the parsimony and for the existence of any misspecifications in the model were conducted. In this analysis, a necessary and sufficient condition for identification is followed, where residuals are used to diagnose the problems of heteroscedasticity, autocorrelation, normality, and ARCH effects. In doing so, any violations of the assumption were corrected with appropriate techniques, such as data transformation and normalising the data.

Moreover, the presence of serial correlation in the model is addressed by using the Cochrane–Orcutt iterative procedure. Based on the results, most of the diagnostic tests conducted on the estimated equations display no violations of the basic assumptions. The adjusted R-squared, which measures the goodness-of-fit, lies below 90% but more than 40% for most of the models. This percentage indicates a satisfactory model result. Furthermore, the diagnostic tests indicate the absence of problems associated with the model framework development. Therefore, this study followed the verdict of Hamilton (1994)'s argument, that the strategy is to start with a very general model and then to progressively simplify it by applying certain data-based simplification tests.

It can be summarised here that this chapter has used different forecast statistical tests to validate the model. Thus, applying the Root Mean Squared Error, Mean Average Error, Mean Average Percentage Error, Theil Inequality Coefficient, Bias, Variance and Covariance proportions, indicate that the model estimates replicated the actual values. It is therefore safe to conclude that the model is robust enough to be used for scenario analysis and forecasting purposes. The coefficients estimated for the individual equations are then used for scenario and forecasting, as is presented in Chapter 6.

CHAPTER 6:
SIMULATION AND OUTLOOK

6.1 Introduction

In this chapter, the examines the robustness and ability of the integrated model to perform the simulation of the scenarios. I firstly develop baseline projections, and then compare alternative policy scenarios to the baseline projections. The simulation results in this chapter are based on the coefficient parameters obtained from equations estimated and explained in chapter 5 using the partial equilibrium framework. It should be mentioned here that getting model closure right is just as important as having good supply and demand elasticity estimates to obtain the realistic impact. These results are allowing the researcher to accept or reject the hypothesis and methodology followed in this dissertation.

The baseline projections are undertaken for the following endogenous variables in the model: (i) cattle number production; (ii) off-take rate; (iii) slaughter mass; (iv) beef production; (v) beef disappearance (domestic consumption and exports); (vi) price; and (vii) gross margin.

6.2 Macroeconomic Assumptions and Selected Exogenous Variables Outlook

Macroeconomic variables are exogenous to the forecasts in this chapter. The variables include population, exchange rate, Real GDP per capita, household income, beef disappearance, production cost index, and rainfall. The United Nations Department of Economic and Social Affairs, Population Division, has forecast the Namibian population to increase to 2.78 million in 2025, meanwhile the model projection indicate that Namibia is expected to have 2.78 million people in 2027 and this expected to increase by 80 000 people in 2028 and in 2030 the population in projected to be 2.78 million.

Household income in the urban areas is projected to increase from 29.31 thousand Namibian dollars per household in 2020 to 30.34 thousand Namibian dollars per household in 2030. On the other hand, in rural areas, the household income was forecast to increase from 7.33 thousand Namibian dollars per household in 2020 to 7.59 thousand Namibian dollars per household in 2030. The projection shows that the real GDP per capita is expected to post a slight decrease of 0.74 percent from 2022, decease by 0.74 in 2023 and 2024, with a slight increase of 1.26 in 2030.

The exchange rate is forecast to weaken, and this is depicted in rates for 2022 of 1639.00c/USD, steadily depreciating to 1786.02c/USD in 2024, a further depreciation is projected in 2027 and 2028 respectively. However, the projection shows a stabilised scenario for 2029 and 2030.

The projection of production cost is projected to increase by 5.87 percent and 13.95 percent over the overlook period in both the formal and informal beef sub-sector, respectively, which is attributable to the fact that production cost per head of cattle is becoming a major driver of beef cattle production in the extensive farming system in Namibia. This is because of the accelerated impact of the high-cost of feeding cattle during periods of prolonged poor availability of grazeable veld. The higher cost for feed, buying of breeding material and other farm inputs are expected to increase the farm production expenses in the outlook period. The expected increase will be compounded by other major factors that are outside Namibia's control, such as wars and disease outbreaks. Every outbreak of FMD has the potential to accelerate the cost of production in the NCAs, where the production cost is expected to increase by 13.95 percent in the outlook period.

Rainfall is a key driver for veld condition in Namibia. In the leasehold and freehold title areas where cattle production is reliant on the extensive grazing system, good rainfall results in a substantial increase in veld condition, thus allowing the veld to regenerate substantially and to subsequently increase the carrying capacity or stocking rate on the veld. The projection shows that the informal area is expected to receive more rainfall than the formal production zones. It is expected that an increase in rainfall would enable the veld to recover, regenerate and enhance the carrying capacity of the grazing lands in a long-run.

Table 6.1: Summary of selected macroeconomic assumptions and exogenous variables for the outlook period

Variables	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Millions											
Population	2.58	2.62	2.66	2.71	2.74	2.78	2.86	2.78	2.78	2.78	2.78
Urban pop.	0.90	0.92	0.93	0.95	0.96	0.97	1.00	0.97	0.97	0.97	0.97
Rural pop.	1.68	1.70	1.73	1.76	1.78	1.81	1.86	1.81	1.81	1.81	1.81
Namibian cents per foreign currency											
Exchange rate100 cents per USD	1469.00	1435.00	1625.00	1580.00	1639.00	1685.00	1734.00	1786.02	1839.60	1894.79	1951.63
Namibian dollars per household (in thousands)											
Real GDP (base year 2012)	36.63	33.89	33.15	32.41	31.67	32.93	33.55	34.19	34.84	35.50	36.17
Household Income in Formal areas	29.31	30.31	30.32	30.33	30.33	30.34	30.34	30.34	30.34	30.34	30.34
Household Income in informal areas	7.33	**7.58**	**7.33**	**7.21**	**7.33**	**7.59**	**7.59**	**7.59**	**7.59**	**7.59**	**7.59**
Kg per capita											
Beef Disappearance in the formal areas	19.72	19.78	19.74	19.60	19.71	19.71	19.71	19.71	19.71	19.71	19.71
Beef Disappearance in the informal areas	5.93	5.97	5.94	5.87	5.94	5.95	5.95	5.95	5.95	5.95	5.95
Average beef consumption in Namibia	12.83	12.87	12.84	12.73	12.83	12.83	12.83	12.83	12.83	12.83	12.83
Cost index per head											
Production cost indexes in the commercial sector	3111.52	3104.17	3141.36	3168.58	3187.42	3190.53	3215.16	3251.27	3301.42	3317.36	3325.87
Production cost indexes in the communal sector	581.48	585.64	687.03	686.71	688.79	688.85	689.85	689.85	780.85	780.85	782.85

Mm											
Rainfall in commercial areas	248.00	242.26	241.24	243.83	242.44	242.50	242.93	242.62	242.68	242.75	242.68
Rainfall in communal areas	303.79	308.64	318.02	322.31	329.02	323.32	323.32	323.32	323.32	323.32	323.32

6.3 Beef Cattle Production Outlook

6.3.1 Beef cattle number outlook

The two sub-sectors of the cattle industry contribute a combined national cattle stock of over 2.5 million head of cattle. Model projection indicates that cattle population is expected to increase after experiencing 3-year period of declining cattle numbers. It is evident from Figure 6.1 that prior to 2021 most of the cattle stock numbers were situated on state land, both on the northern communal and southern sub-sector of the production system, however, since 2021 and after the devastating drought period, cattle stock numbers in the formal commercial sub-sectors have surpassed the communal sub-sector. Figure 6.1 presented the projection and shows that in the outlook period there will be just as many cattle in the commercial area as in the communal area.

Many of the fluctuations in cattle numbers are impacted by the veterinary cordon fence to production shocks. It is important to understand the time dimensions pertaining to cattle production cycles in Namibia. There is a seasonality pattern to calving, which is usually a regularly repeating pattern that is completed every 12 months, following the seasonal highs and lows in rainfall patterns that tend to occur at nearly the same times each year. Cattle production trends are experienced in a long-term direction. Cattle production cycles follow patterns that repeat themselves regularly over a period of years (Dakwa. 2007). For example, destocking and restocking will trend alternatively during years affected by drought, and during good years, respectively. Dakwa (2007) points that the differences in cattle numbers are associated with adjustments in stocking rates under these production systems.

It is expected that cattle numbers are expected to show growth in the commercial sub-sector and this is largely driven by the cows expected to slowly recuperate their biological cycle after disturbances experienced from the lack of sufficient feed. Commercial farmers who are currently in financial distress caused by the severe drought periods and had cattle stock numbers reduced to 60% will use their extensive farming experience and good livestock husbandry practices to restock, as permitted by the availability of grazeable veld and improved veld recovery rates. The availability of grazeable veld and improved veld recovery rates are key drivers for cattle stock recovery in the projection period. Coupled to the good management practices, the increase in prices for carcass and live cattle are among the enabling factors that prompt the rebuilding of the cattle herd.

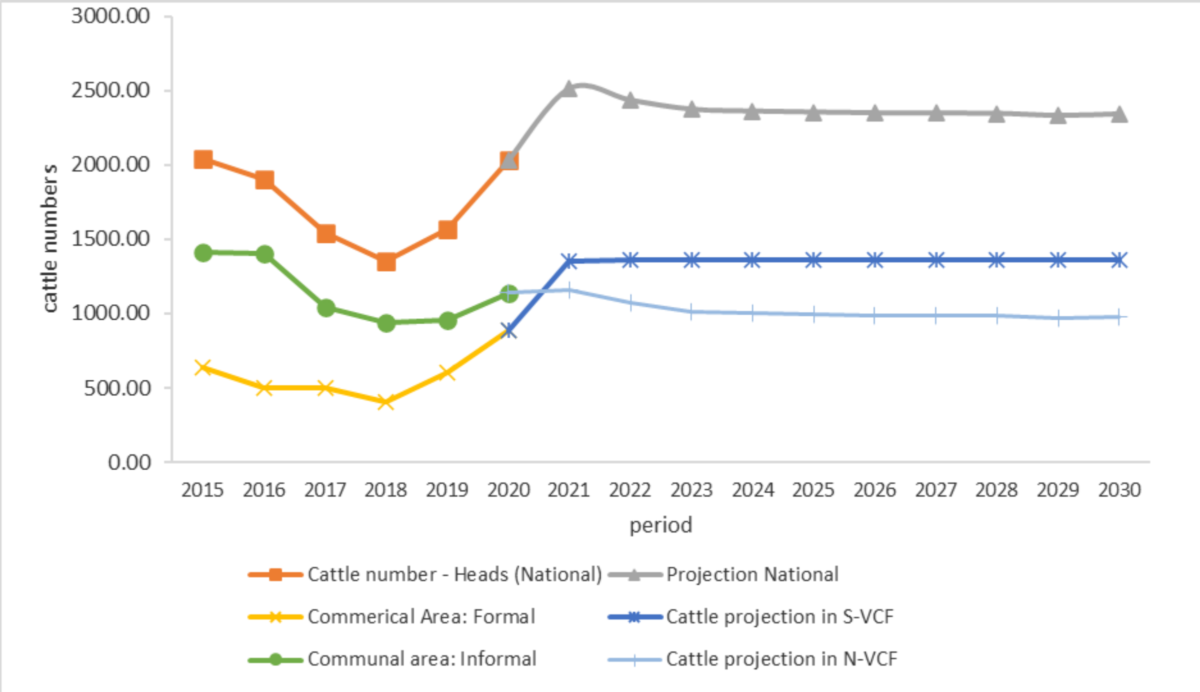

Figure 6.1: Cattle numbers in the commercial sector vs. the cattle stock in the communal sector

6.3.2 The outlook for the Cattle off-take rate

Figure 6.2 below indicates that the cattle slaughter off-take rates are traditionally low in the communal sub-sector. Accordingly, the commercial sub-sector has been a major contributor, and will remain a major contributor, to the national herd off-take from 2023 to 2030. The off-take rates are driven by the cattle herd size and by farming objectives. The off-take rate is the percentage of kilogramme of biomass removed from the total cattle stock of biomass on a farm.

The following example of a weaner production system is described for illustrative purposes:

- The weaner production system has 100 cows, with an average live weight of 350 kilogrammes (a typical cow in a communal area);
- This system generates an annual average 50 calves, which attain an average live weight of 120 kilogrammes;
- The farm operation experiences a mortality loss of 5 cattle, which each weighed an average live mass of 250 kilogrammes; and
- The farm has 3 bulls, with annual average live mass of 600 kilogrammes.

Consider that this farm will yield a biomass stock of 44 050 kilogrammes. If the farmer sells 45 weaners, with an average live mass of 200 kilogrammes, the farmer's off-take rate would be 20.4 percent. If the calf percentage increases to 70 percent, the farmer would be able to increase the off-take rate to 25 percent, or alternatively, to build up the cattle herd. If the rangeland conditions are favourable, herd management would improve, with fewer outbreaks of disease, cattle mortalities would be expected to reduce, and the farmer could then reach a higher off-take. It is equally expected that prior to experiencing poor veld conditions, the off-take rate would be higher and gradually decrease after the optimum stocking rate has been achieved.

It is evident from Figure 6.2 that the commercial sub-sector has been and continues to be a major producer of beef cattle slaughter stock in Namibia. This is mainly driven because of FMD free status, while cattle famers north of the VCF can only sell to their northern and eastern neighbours, where the marketing systems are still underdeveloped.

The projection shows that after low off-take rate in 2013 to 2020, an increase in off-take rates is expected 2022 to 2030. The increase is driven by steady recovery phase in the veld, a healthy cattle herd and prices. The off-take rate in the commercial sub-sector is projected to moderately increase in the outlook period, 2023 - 2030. The year-on-year projection indicates that the off-take rate for the commercial sub-sector would increase by more than 12 percent. However, the communal sub-sector will exhibit a moderate increasing trend, where the off-take rate is expected to increase in 2023 and expected to decline from 2024 to 2030. The off-take rates are equally based on the abilities of farmers to use strategies that improve cattle breeding stock and stabilise the current herd sizes. The projected increase in the off-take rate is expected to upsurge available slaughter stock for the beef industry in Namibia.

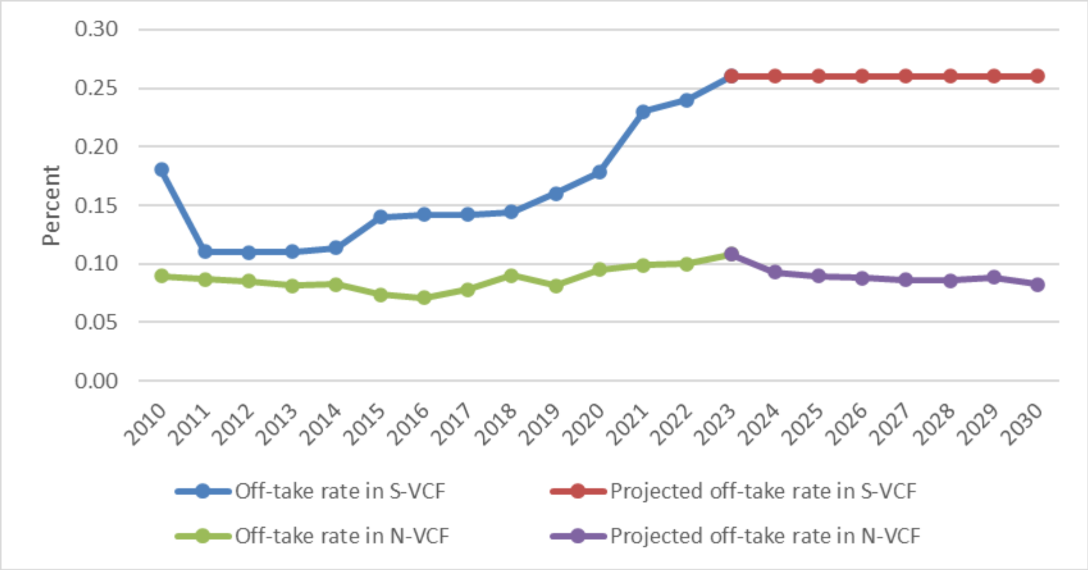

Figure 6.2: A comparison projection of the off-take rates between the formal and informal farming sub-sectors

6.3.3 The outlook for beef production

Figure 6.3 below indicates that the beef production from the commercial and communal sub-sectors is projected to increase from 2023 to 2030. Overall outlook for the country, beef production is expected to increase about 80 thousand metric tonnes from 2023 to 2030. The projection in the outlook period indicates that the production of beef is somewhat returning to the level prior to drought, and this is driven by improvement in the off-take rate and carcass prices.

The projection for the formal commercial sub-sector includes slaughter animals and the live exports mainly to RSA. While the communal beef production is mainly driven by the weaner system. Because of the limited markets north of the VCF, the projection indicates a moderate declining trend in beef production from 2023 to 2030.

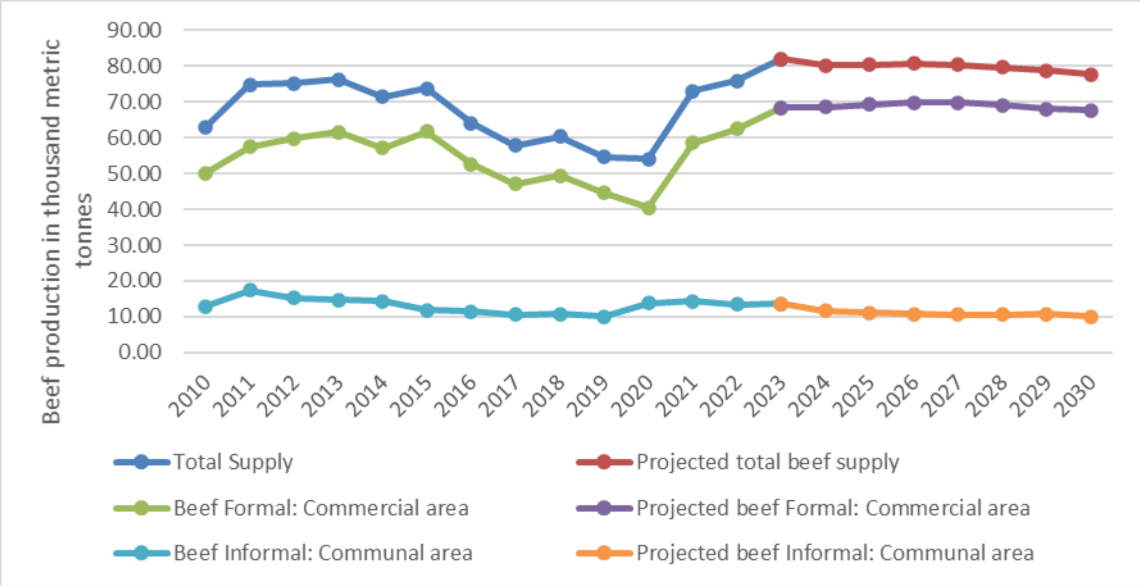

Figure 6.3: Beef production in the commercial sector vs. beef production in the informal sub-sector

6.3.4 The outlook for beef disappearance

The domestic utilisation of beef is projected to remain constant. The trend in average beef consumed per capita shows that 13 kilogrammes in 2023 – 2030 for Namibia. Beef consumption per capita is expected to stabilise around 13 kilogrammes in the outlook period in the informal areas. The consumption of beef in the informal sub-sector is projected to be less than 6 kilogramme per capita from 2023 to 2030 (presented in Figure 6.4).

Beef consumption is common in formal sub-sector and is driven by household income and access. A wedge exists between the access to beef in the formal areas and in the informal areas. In the formal areas, urban consumers are more likely to find beef readily available in the markets or shops than the informal or rural consumers would. In the rural areas, limitations to access the beef market are embedded in the veterinary regulation statutory laws and in the bottlenecks resulting from the lack of slaughterhouses and market infrastructure. Fewer beef cattle are slaughtered in the rural areas than in the commercial urban areas south of the VCF.

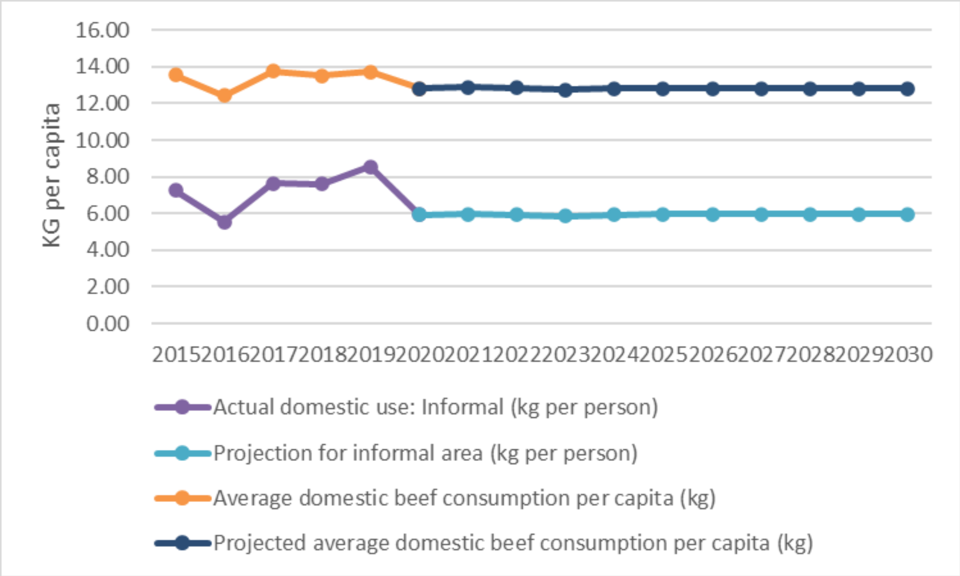

Figure 6.4: Projection of beef disappearance (demand) for Namibia

The availability of alternative red meat products to replace beef consumption remains strong in Namibia, although beef remains the most-preferred source of protein for many Namibians. The major driver for beef consumption in Namibia is household income for consumers in urban areas. However, future trends and the demand for prime Namibian beef by European markets implies that Namibian consumers' ability to afford prime beef could become more limited as prime cuts are destined for export markets.

Figure 6.5 indicates the destination of Namibian beef and it is evident from the figure that a cluster of EU countries and non-EU countries such as Norway, mainland China and Hong Kong, RSA and the rest of Africa (Angola, Ghana and Zimbabwe) are recognised markets for Namibia. The rest of Africa markets accounts for less 10 thousand metric tonnes of beef imports from Namibia. The model outlook indicates that Namibian beef exports are expected to increase by less than 20 thousand metric tonnes to 32 thousand metric tonnes from 2023 to 2030.

This beef export variation is expected because of impact on production, as discussed earlier. The Namibian export values are far below the export tonnages produced by major beef country exporters such as Australia, Brazil, Canada, the European Union (EU Agricultural Outlook, 2019), India, Mexico and the United States (FAPRI, 2016, 2017, 2018 and 2022; USDA, 2020).

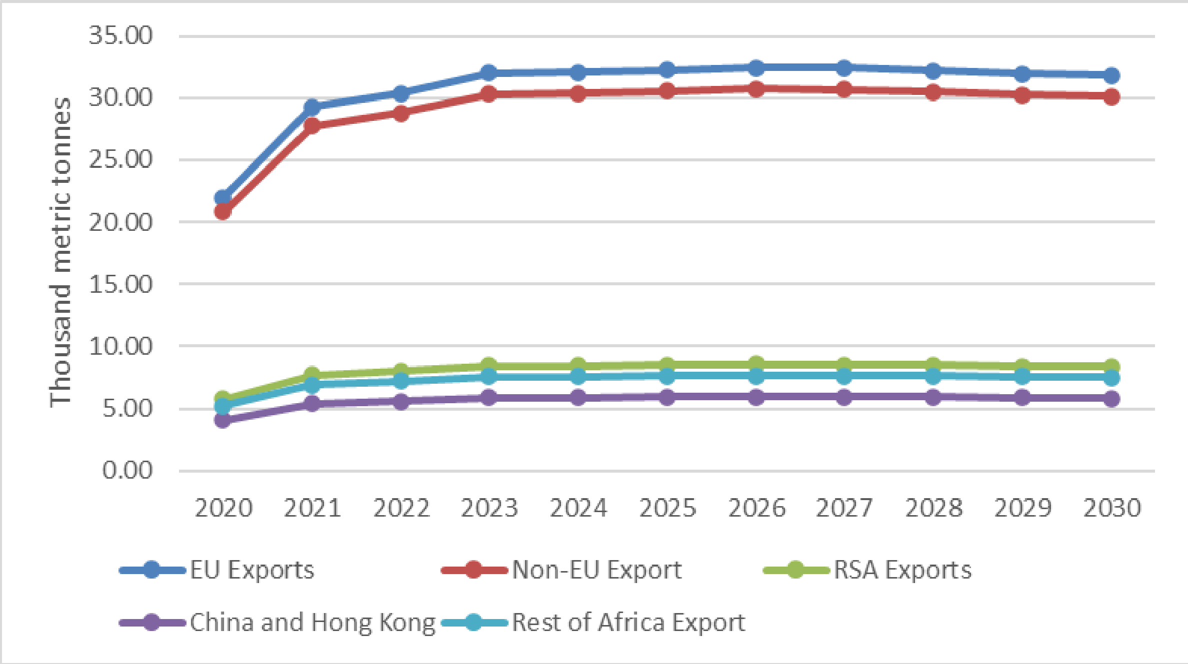

Figure 6.5: Projection of beef exports from Namibia to different export markets

6.3.5 The outlook for beef cattle price

Cattle producers generally select a production system depending on environmental factors, as well as the reliance on the price ratio between prices per kilogramme obtained for a seven-month weaner, live-weight, relative to the kilogramme carcass price of a 27-month-old slaughter animal. In contextualising beef pricing scenario, for example, in 1994, the producers received about 70 percent of the abattoir selling price, since then, the producers' share declined to less than 60 percent. This producer price share has declined by 0.7 percent annually over the past three decades. In January 2021, the weaner to slaughter price ratio reached a maximum of 92%. This is supported by the model projection which indicates that the average slaughter animal producer price is expected to increase from 2023 to 2025, representing an increase of about 7.08 percent. This is a result of farmers who are gradually re-building their cattle herd and increasing demand for beef in the domestic market and in importing countries that have currencies appreciating, relative to domestic currency. The projected increase in price plays a role in prompting farmers to increase their stocking rates, thereby boosting the supply of beef in the domestic market. Similarly, the beef price in the informal area exhibits a similar trend. The dynamics of price relationship between the formal and informal sub-sectors were adequately explored in Chapter 3. It is evident that informal beef prices are derived from the formal prices.

Figure 6.6 indicates that both sets of price trend upward from 2023 to 2030. Thus, the increase in producer carcass price signal improvement in gross margins at farm level. To date, the bulk of export growth has been attributed to exports of high-value cuts to the European Union and Norway, and more recently to new markets such as the USA and mainland China.

Figure 6.6 continues to show that the weaner auction price for Namibia is projected to increase from 2023 to 2030, with a year-on-year variation The South African weaner market will continue to remain important if the ratio between domestic beef carcass price and weaner price widens in the Namibian market. This means that, if the ratio driven by the efficiencies of the production systems and value chains, between domestic weaner price and carcass price, is below the 62-percent level, the ox production option will become lucrative, compared with the weaner production system.

Namibia's competitiveness in the export market will benefit further from the persistently weak exchange rate. However, the constant risk of outbreaks of disease and the non-compliance with biosecurity requirements by communal farmers north of the VCF will have negative implications for market access, which reduces the incentive to invest in large-scale, export-driven expansion.

The model projections indicate that the weaner and carcass price ratio will vary between 58 percent and 62 percent. The dynamics of the price ratio affect the farmers' decisions and have implications on the off-take rate and throughput at slaughter abattoirs, such as Meatco.

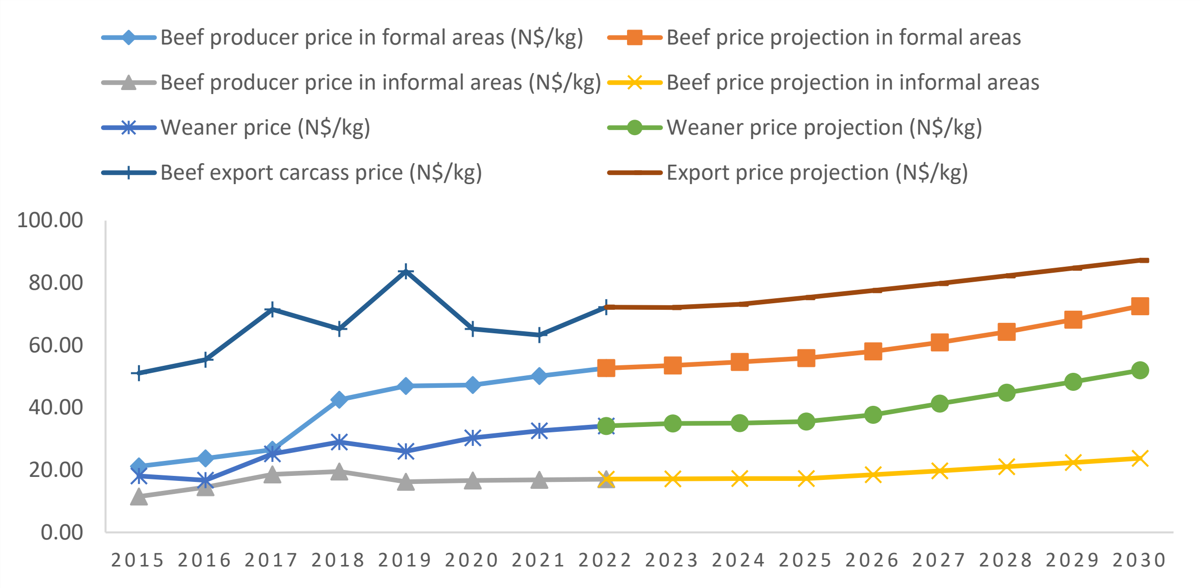

Figure 6.6: Projection of beef prices for different markets

It is evident that the domestic producer carcass price is below the trading partners because the prime cuts are exported to the trading partners such as Chinese, EU, non-EU, RSA and rest of Africa beef producer price under the period of projection, while the lower valued cuts are sold in the domestic market. Therefore, this practice results in the situation that domestic Namibian prices are lower than the EU and other trading prices. This price gap presented in Figure 6.7 has implications for ox production in Namibia. The fact that the ratio of the domestic carcass price to the EU price is below 40 percent, farmers view this as a disparity between what they obtain from the domestic export abattoirs and what these abattoirs earn from the export markets. Over time, the ox production system in Namibia became less profitable compared to weaner system when the ratio reached 92%. Farmers switch between the systems for profitability reasons. The switch to a weaner system has implications for export abattoirs, whose slaughter capacity would then be scaled down. To correct this status quo, going forward, slaughter abattoirs should introduce price support to local producers or pay higher carcass prices to producers. To realise the gross margin per hectare of beef cattle stocking rate that could accrue from utilising the export market, domestic export abattoirs should thus pay a beef carcass price of above the 60 percent price margin of the export price comparable to Figure 6.7 producer carcass price for the Chinese, EU, non-EU, RSA and rest of Africa beef producer price.

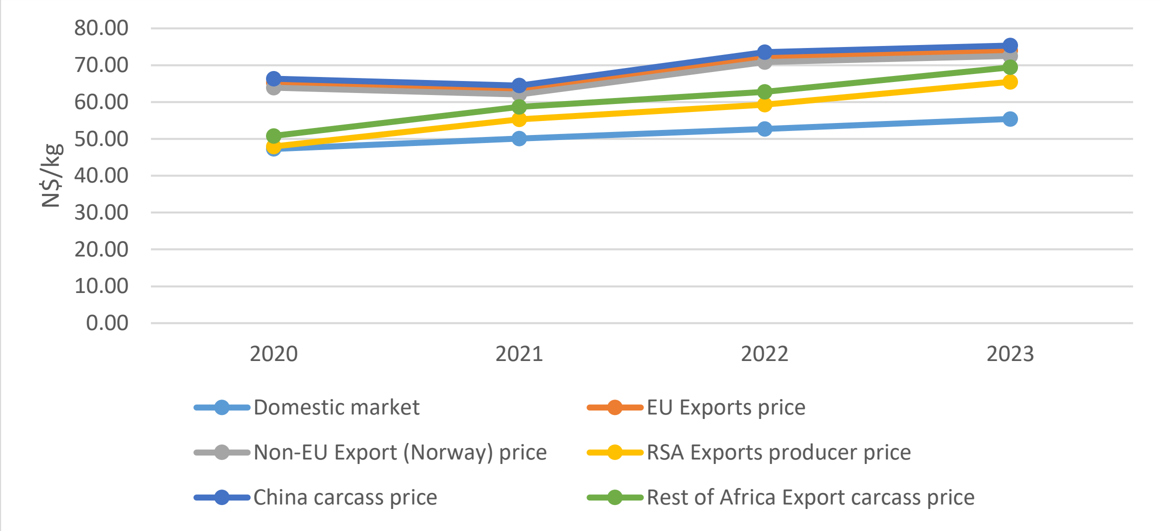

Figure 6.7: Average beef producer price of selected beef export markets (2020 - 2023)

Source: Meat Board, 2022.

6.3.6 Beef cattle production gross margin outlook

To thoroughly show the gross margin per hectare of the beef cattle industry, it is important to review the different production systems, as previously indicated. Namibian farmers opt for a cow-to-ox production system, or a cow-to-weaner production system, or opt to speculate between being a weaner producer or an ox producer. Therefore, these systems are dependent on price movements and the relative price ratios available for the product; thus, ox, weaner, and export price. Profit is calculated as the difference between revenue and costs, where revenue is the selling price multiplied by quantity sold (Sartorius von Bach and Kalundu, 2020). There are four alternative marketing channels that can be presented. Firstly, gross margins are derived from selling beef carcasses in local markets, formal and informal, using the domestic carcass prices receivable and domestic costs incurred annually. Secondly gross margin is derived from selling beef carcasses in export abattoirs, using the EU beef price per kilogramme. Thirdly, profits are derived from marketing weaners in the domestic market auction for prices expressed per kilogramme, again considering the costs incurred. Fourthly, gross margins are derived from exporting live weaners to the South African market, at beef prices expressed per kilogram, considering the costs incurred (Sartorius von Bach and Kalundu, 2020). It is evident that, of the three markets for beef carcasses, the Chinese, EU, non-EU markets (Norway and UK) export markets are expected to remain lucrative, compared to the domestic markets (both formal and informal). The Chinese, EU, non-EU markets (Norway and

UK), South African and Rest of Africa markets are projected to remain profitable for Namibian beef exports in the period under projection. This is true because the Chinese, EU and non-EU markets (Norway and UK) beef prices are higher than the prices prevailing in the domestic market (see Figure 6.7).

Under the projection period, the gross margin value of beef carcasses marketed in the informal market will increase by an average of 34.5 percent from 2023 to 2025. In comparison to the formal market, the informal market's gross margin percentages are low because beef cattle farmers in the informal markets are not motivated by cattle sales but are rather motivated by the prestige of keeping large herd sizes, while they still perceive cattle as providing a store of value and a capital good, even though the quality of cattle is degrading because of poor herd management. These beliefs are embedded in culture and traditions among farmers in the informal markets. Furthermore, although the drought offset indicates that most farmers in the communal sub-sector have lost many cattle due to drought, they nevertheless would opt to rebuild their cattle herd sizes to required numbers before they would offer cattle for sale at the slaughter abattoirs. Therefore, the gross margin for the communal sub-sector is not directly influenced by the carcass producer price, but by the personal decisions made by the farmers and the quality of cattle marketed. For example, most rural farmers in the NCAs are willing to market old cattle, falling under C grade, although C-graded cattle will not earn premium prices for the farmers (MBN, 2017; NAU, 2016 and NAU, 2018) as compared with the communal farmers south of the VCF.

It was explained in chapter 2 of this study that the nature of the production system used is highly dependent on the land tenure system available to the farmers and an individual farmer's willingness to market. Therefore, these dynamics constitute the reason why informal beef carcass prices are lagging the formal markets in terms of profitability. To offset these differences, advocacy and interventions have been presented by the government and by non-governmental organisations who focus on educating small-scale beef cattle farmers through outreach programmes that focus on best animal husbandry practices. These efforts include mentorship programmes that aim to realign the rationale of livestock farming objectives among small-scale rural cattle producers to turn cattle farming in rural areas into long-term, profitable and environmentally friendly operations.

The formal beef carcass market is profitable, although its profitability depends on the price ratio between the weaner auction prices and the beef carcass prices. However, over the years, the profitability of the formal beef carcass supply market has decreased. The decrease in recent years is primarily attributable to the fact that farmers prefer to market weaners at auction than to rear the weaners on the farm for the additional months (compounded by the distress on the veld conditions) required to sell them as slaughter oxen to the abattoirs. This means that farmers opt to switch from the cow-to-ox production system to the more profitable cow-to-calf to weaner system production system. The weaner system plays an important role in the long-term decision-making processes of the producers (NAU, 2019 and Sartorius von Bach, 2020).

Therefore, this status quo enables an inference to be made that the domestic weaner markets respond to price changes very weakly, or unresponsively, compared with the volumes of export to South African feedlots. This inference is supported by the large numbers of weaners exported to South African feedlots on a year-on-year basis. Thus, it is argued here that the South African feedlot market for weaners is profitable in the long run for the Namibian beef industry. For example, Sartorius von Bach (2020) points out that comparing the domestic weaner market with the ox market, the weaner market was about 49 percent more profitable per hectare in 1990, and it has increased to about 90 percent in recent years. Thus, the weaner production system or market is more profitable than ox production.

There are allegations among beef producers that Meatco, as an export abattoir, receives higher prices for their sales of high-quality beef carcass, prime cuts (A2 and A3 carcasses). This pricing disparity has had impacts on the domestic beef markets and production system (Dakwa, 2007). Although it is argued that about 50% of the price received by Meatco is for cost recovery, the disparity is still a concern for most producers. Since Meatco became a state-owned enterprise (SOE), the new board members have shifted their focus from the interests of freehold (commercial farmers) to representing the interests of communal farmers. However, the change in management could not cushion the financial management, operations and administration of the SOE. Many producers have thus moved away from supplying slaughter stock to the SOE. Over the years, this has resulted in the slaughter stock made available for slaughter at the Meatco abattoir dwindling to below 60 000 cattle thresholds to break-even. Although the price gap has narrowed over the years, many producers argue that the carcass prices they obtain from marketing their slaughter stock at the export abattoirs is about 60 percent lower than the prices that the export abattoirs receive for the same category of carcasses from alternative producers, as presented earlier in Figure 6.7. In recent years, the pricing disparities, delayed payments to producers and conflicting objectives are some of the drivers of beef producers to abate Meatco.

Figure 6.8 illustrates that gross margin projection in the commercial sub-sector is expected to increase from 2023 to 2030. It is evident from Figure 6.8 that the trend is higher than the levels experienced in years of drought 2015 to 2019. The gross margin projection of the formal commercial sub-sector is greater than the gross margin expectation for the communal sub-sector. This is expected and confirms to the price disparities that prevails in the two distinct sub-sectors of the Namibian beef sector, presented in chapter 3 of this study.

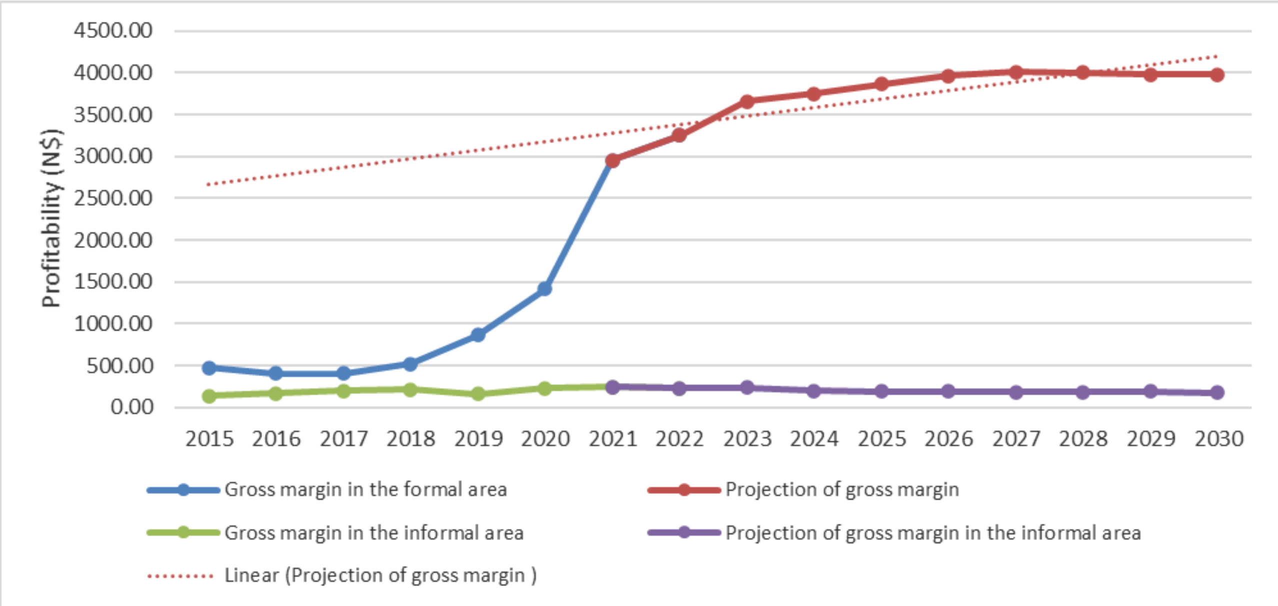

Figure 6.8: A projection of the gross margin per hectare value for beef carcass and weaner production for Namibia

The gross margin derived from exporting weaners to the South African market, and this trend is relatively higher than the option of using the domestic market. To some extent, marketing in the domestic beef market can be somewhat lucrative when poor auction beef prices are experienced in South Africa, when the prices are slightly lower in South Africa because of the influx of weaners from Botswana and Namibia into South Africa. The gross margins are cumulatively projected to be highest when prime prices are offered in the export markets (for boneless, chilled cuts and beef carcasses), in the South African weaner market, and in the domestic formal market, while the informal market will remain profitable from 2023 to 2030.

However, if the beef cattle stock of the informal communal areas is successfully included into the formal area beef stock, combined with strict observance of biosecurity measures to reduce the risk associated with transfer of animal diseases, then an accelerated growth scenario is predicted for the beef industry. The growth will equally depend on the business principle and environment of the slaughter abattoirs in Namibia.

The above scenario also incorporates expanded market access for exports, enabled by the FAN Meat regulations, traceability system, and improved productivity for developing producers to supply 150 000 additional weaners by 2025-2030, relative to the baseline. This scenario is explored further in section 6.4.

However, in the case that biosecurity is not guaranteed, resulting in an FMD outbreak occurring in the disease-free area, then, exports of beef will be restricted, this will cause local prices to drop to almost a half. This drop in price is attributed to the fact that, at current prices, only 13% of beef is locally consumed. This implies that Namibian markets cannot absorb all the beef produced by domestic producers if there are beef export restrictions. Surplus beef in the domestic markets will lead to lower beef prices in the domestic market.

Therefore, Namibia, with its FMD-free status within the S-VCF, is currently the only country with export status to the rest of the world. Losing that export status would require significant investment to be made to be allowed back into the international beef market arena.

6.4 Simulation of shocks in the model

To test the hypothesis of the study, three shocks were introduced into the model. The first of these shocks introduces an increase in the off-take rate (productivity gain) that increases the numbers of slaughter cattle from the informal sub-sector into the formal sub-sector. The cattle stock can be sourced from the current informal communal sub-sector, which has low off-take rates of about 10 percent (as compared to about 26 percent rate in the formal commercial sub-sector in an ideal production season) and has poor infrastructure for marketing. The 10 percent is comprised of slaughter and weaner stock destined for South Africa and the rest of Africa. However, this 10 percent could be increased by 10 percentage point, to yield a 20 percent off-take by the informal sub-sector producers. The 20 percent off-take rate is plausible for the communal sub-sector because the cattle stock level in these areas can enhance the productivity gain under strict guidelines and complying with slaughter abattoir regulations.

It should be noted here that under the current stocking rate, the commercial freehold production system has a very compelling off-take rate and cannot be overstretched from the current 26 percent. In other words, if the inclusion of the informal communal area beef cattle stock into the formal area beef stock is successfully implemented, supported by combined strict biosecurity measures to reduce the risk associated with the transfer animal disease, particularly FMD.

The resulting increase in the off-take rate could be viewed as an accelerated growth scenario (productivity gain) for the beef industry. The scenario also incorporates expanded market access for exports not only to South Africa and rest of Africa. If this is enabled by the traceability system and improved productivity for developing producers in the northern communal areas who would supply 150 000 additional weaners, relative to the baseline. In other words, a productivity gain could arise because of a policy regulation shock that prescribes the removal of the veterinary cordon fence. The argument here is that this scenario assumes that all existing markets are maintained.

The removal of the veterinary cordon fence would be accompanied by strict regulatory measures that guard against the further proliferation of FMD and other animal diseases. Thus, this would allow greater numbers of slaughter cattle stock from the informal communal area to be moved, marketed, and slaughtered in the formal commercial area south of veterinary cordon fence, where there are well-developed marketing and slaughter facilities. The concept behind this shock is a widely argued topic in Namibia.

Furthermore, the removal of the veterinary cordon fence can be modelled as a trade policy retaliatory shock emanating from the EU, which would impose further restrictions on Namibia’s exports to the EU because of the opening of the veterinary cordon fence. However, under this shock, Namibia could still export beef to other non-EU markets, particularly Chinese and regional African markets under the projected AfCFTA, at significantly better carcass prices than the prevailing domestic carcass price.

6.4.1 Productivity gain of a 20% shock

A 20-percent increase is introduced in the model into the off-take rate in the informal sub-sector in 2023, such that the magnitude of the impact can be observed for 2024, 2025 and through to 2030. The shock of a 20%-increase is plausible because, currently, the off-take rate in the formal commercial sub-sector is at about 26%, and so the additional 20% cattle herd entering the commercial sub-sector from the informal communal areas. The off-take rate stands at about 10% from a cattle population of 1.7 million (MAWLR, 2020; Sartorius von Bach, 2020). Going forward, it is assumed that all cattle production drivers (calving rate, tenure systems, mortality rate, cattle disease outbreaks and stocking densities) are improved. It has always been the argument that there is potential to increase the off-take rate from the informal communal sub-sector, given the existence of the high stocking density in the informal sub-sector (both north and south of VCF). This means that there are sufficient stock numbers in the communal sub-sector that could increase in order to improve the current slaughter stock in the formal commercial sub-sector.

Another assumption is that the nature of the autoregressive distributed approach adopted in this model allows for this policy shock to be introduced in 2023 and to then evaluate the impact of that shock for 2024 and 2025, and then the full effect of the policy for 2025, as opposed to introducing the policy gradually. During the time period, it is assumed that the policy regulation as enacted would allow the slaughter of cattle at designated export abattoirs and minimum movement of cattle from north of the veterinary cordon fence, the farmers north of the fence would be able to market 20 percent of their slaughter cattle to lucrative markets elsewhere in Namibia, and African markets (Angola, Ghana and Zimbabwe) under the African Continental Free Trade Agreement. Stated differently, the current 26 percent off-take rate emanating from the commercial sub-sector would receive an additional 20 percent off-take rate, with cattle herd from the informal communal sub-sector to the north of cordon fence into the commercial sub-sector. Thus, it is projected that cattle slaughter numbers would increase at slaughter abattoirs.

The productivity gain would imply that slaughter stock and weaners flow from the informal sub-sector into the formal sub-sector, assuming that biosecurity issues and regulations are adhered to by informal cattle producers under the guidelines of DVS and export abattoirs. The productivity gain introduced in the informal sub-sector would enhance available slaughter stock, weaners production, beef production, beef carcass pricing and own-farm supply in the formal sub-sector to increase.

The model is formulated in a manner that when a shock is introduced in one year, the model will simulate the concurrent shock in subsequent years. Table 6.2 presents the result of a once-off shock of 20-percent introduced in 2023. A once-off shock of 20-percent off-take rate would cause increases in slaughter numbers in the commercial sub-sector of 14.48 percent in 2023, and about 0.05 percent in 2024. No impacts are expected from 2025 to 2030. Meanwhile in the informal sub-sector, slaughter stock is expected to increase by 0.04 percent in 2023, about 0.12 percent increase in 2024 and no increase in 2025. The shock further shows that slaughter stock is expected to increase by 0.19 percent in 2026, thereafter, 0.01 percent increase is expected in 2029 to 2030.

During the same period, the weaners stock is projected to increase by 4.01 percent in 2023, 0.38 percent in 2024, about 1.36 percent in 2025. Furthermore, weaner production is expected to increase by 0.76 percent in 2026 and further increases are expected from 2027 to 2030. In the outlook period, it is noticeable that the percent of weaners marketed, is lower than the slaughter stock because more cows and heifers than normal are sold for slaughter, this is expected to depress the carcass prices. As increased beef supplies finally reach the market, cattle prices fall to unprofitable levels. Under the same time period, beef production is projected to increase in the outlook period by 9.63 percent in 2023, 0.07 percent in 2024 and about 0.05 percent in 2025. Most of the beef production increase will be contributed by the flow of cattle from the informal sub-sector into the formal sub-sector. Where the projection indicates that beef production from the formal sub-sector is expected to increase by 15.29 percent in 2023 and by less than 0.12 percent in 2024 to 2030. Similar positive outlook is expected for the informal sub-sector. This is driven by the 20 percent flow of slaughter cattle into the formal market. The projection continues to show that beef production is expected to be positive from 2026 to 2030.

Evident from Table 6.2 is that after introducing the productivity gain, the average carcass price is projected to decrease by 0.62 percent in 2023 and about 0.49 percent in 2024. Thereafter, carcass price is expected to decrease by less than 0.23 percent in 2025 to 2030 in the commercial sub-sector. Since the carcass price in the informal market is derived from the formal market, the carcass price in the communal sub-sectors is expected to follow similar dynamics in the outlook period. A decrease of about 0.12 percent in 2023 is expected, thereafter the average carcass price is expected to decrease in 2024 to 2030.

Table 6.2 reports the impact of the productivity gain on the weaner price to decrease by 0.93 percent in 2023, further decrease by 1.03 percent in 2024 and 0.26 percent in 2025. Further decreases are expected in the 2026 to 2030 outlook period. The decrease is expected because the ratio between the weaner price and carcass price is expected to be lower than 62 percent, therefore, it is expected that beef producers will switch from weaner production to an ox production system because of the favourable price per kilogramme for carcass.

The overall impact of the productivity gain is beef production will increase from 2023 through to 2030. However, the increase in beef production has no impact observed on the on farm-supply stock from 2023 to 2030 and depresses the prices in both markets.

Table 6.2: A once-off shock of 20% increase in the off-take rate in the formal commercial sub-sector.

Variables		2023	2024	2025	2026	2027	2028	2029	2030
Slaughter stock	Formal: Commercial area	14.88%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Informal: Communal area	0.04%	0.12%	0.00%	0.19%	0.22%	0.05%	0.01%	0.01%
Weaner production	Weaner marketed	4.01%	0.38%	1.36%	0.76%	1.04%	0.93%	1.20%	0.94%
Beef Production	Rest of Namibia	9.63%	0.07%	0.05%	0.11%	0.08%	0.09%	0.08%	0.07%
	Formal: Commercial area	15.29%	0.09%	0.07%	0.14%	0.15%	0.14%	0.13%	0.12%
	Informal: Communal area	0.04%	0.12%	0.00%	0.19%	0.22%	0.05%	0.01%	-0.01%
	On-farm supply	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Price block	Weaner price	-0.93%	-1.03%	-0.26%	-0.20%	-0.01%	-0.09%	-0.08%	-0.10%
	Domestic beef linkage price: Commercial	-0.62%	-0.49%	-0.22%	-0.18%	-0.15%	-0.13%	-0.11%	-0.10%
	Beef carcass producer price: Communal	-0.12%	-0.09%	-0.04%	-0.04%	-0.03%	-0.03%	-0.03%	-0.02%

6.4.2 EU trade restriction of zero percent imports of Namibian beef

The assumption in this scenario is that the shock on the beef trade of an import restriction by the EU implies that Namibia would have zero exports of beef carcasses to the EU in the 2023 to 2025 period. However, it should be noted that, under this assumption, Namibia would still have access to other African importing markets, such as South Africa and the regional African markets through the popularised AfCFTA, and to international markets such as China, and Hong Kong, (Meatco, 2020). This means that a closure of the European Union market implies that Namibia would be in position to divert EU destined beef carcasses into these alternative markets.

The results of a single shock of export introduced in 2023 on the recursively linked model are presented in Table 6.3. It is evident from the table that an EU ban will result in production of beef to decrease in 2023, but rebounds to positive production is expected in 2024 to 2025. A positive rebound is possible because Namibia is expected to produce beef to supply other markets. Similar projection in the outlook period expected for the informal sub-sector indicates an increase in 2023 to 2030.

The hypothesised EU trade policy restriction shock would result in a projected 33.95 percent decrease in Namibian beef exports in 2023. However, it is expected that beef exports will rebound to positive levels in 2024 to 2025 because Namibia will divert the high value cuts to other markets. For Namibia to reduce the excess beef in the domestic market, exports would likely need to diversify, with high-value cuts still being destined for mainland China, Hong Kong and South Africa, with the remaining parts of the carcass being both sold in the domestic markets, and exported to the rest of Africa through AfCFTA, where the demand structure is like the Namibian domestic market. These markets have prices higher than the domestic producer price.

As expected, a scenario of zero exports to the EU implies that there would be excess beef in the domestic market, and this would result in the domestic average prices of beef carcasses in the formal and informal sub-sectors to decrease under the projection period, 2023 to 2030. Similarly, the weaner prices are projected to decrease in 2023 to 2030. The price decreases are expected because of the increase in the number of slaughter cattle and weaners available in the domestic market. The beef prices are displaying the same reaction because of their relationships and linkages modelled and explained in chapter 4 and 5, where the informal carcass price is derived from the formal carcass price, marketing cost and commission.

The implications of the decreases in beef production and exports, which are attributable to the EU trade policy restriction and compliance requirements, would result in decreases in the domestic producer price in 2023 to 2030 in the formal sub-sector and informal sub-sectors, which will have implications for the gross margin in both the sub-sectors. Producers will incur a reduction in the profitability from cattle farming and will be forced to switch to alternatives such as the booming biomass production. The EU shock would result in a positive short-term increase in weaner production in 2023 to 2030. The positive levels are expected because farmers will continue to market weaners to South African feedlots where prices are more favourable than in the domestic markets.

Table 6.3: The impact of EU zero export restriction on the Namibian beef sub-sector

Variables		2023	2024	2025	2026	2027	2028	2029	2030
Slaughter numbers	Formal commercial area	0.17%	0.05%	0.01%	0.02%	0.04%	0.05%	0.01%	0.01%
	Informal communal area	0.15%	0.41%	0.28%	1.09%	0.78%	0.14%	0.01%	0.00%
Weaner production	Weaner marketed	0.09%	0.08%	0.02%	0.09%	0.08%	0.02%	0.01%	0.00%
Off-take rate	Formal commercial area	2.15%	7.02%	11.90%	0.91%	3.11%	0.61%	0.06%	0.28%
	Informal communal area	0.46%	0.96%	0.56%	2.29%	1.47%	0.64%	0.18%	0.09%
Beef Production	Rest of Namibia	0.85%	0.64%	0.14%	0.10%	0.01%	0.06%	0.06%	0.06%
	Formal commercial area	1.37%	0.95%	0.26%	0.01%	0.09%	0.11%	0.10%	0.09%
	Informal communal area	0.15%	0.41%	0.27%	1.09%	0.78%	0.14%	0.01%	0.00%
Beef demand	Domestic use in the Formal sub-sector	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Domestic use: Informal sub-sector	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Exports sub-sector	-33.95%	0.55%	0.15%	0.01%	0.06%	0.06%	0.06%	0.05%
	On-farm supply/statistical discrepancy	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Price block	Weaner price	-3.49%	-5.02%	-1.50%	-0.32%	-0.12%	-0.08%	-0.06%	-0.04%
	Domestic Beef Linkage price: Formal sub-sector	-2.37%	-2.62%	-0.27%	-0.20%	-0.15%	-0.11%	-0.09%	-0.07%
	Beef carcass producer price: Informal sub-sector	-0.47%	-0.49%	-0.02%	-0.04%	-0.03%	-0.03%	-0.02%	-0.02%

It evident from Table 6.2 and 6.3 that the model is expected to simulate the once-off impact shocks concurrently. However, the simulation has so far produced mixed results. For example, it is expected that for a small exporting country under free trade, the domestic carcass price should remain unchanged if the supply shock is imposed. It is also expected that demand remain unchanged. This implies that getting model closure right is just as important as having good supply and demand elasticity estimates to obtain the realistic expected impacts. Therefore, it is important to mention here that the application of apriori information about the beef industry presented in chapter 4 and 5 should allow the impact shocks to be evaluated by each of the designated equations. However, the autoregressive distributed lag adopted in the modelling framework has produced results with the opposite effects of the policy impacts. Meaning that this model to be used for policy formulation purposes, considerable refinement of the model developed is required before it can be used for generating robust and realistic impacts.

From figure 6.9 it is evident that the EU export market remains the dominant and lucrative market for Namibia chilled boneless boxed beef. However, the non-EU markets such as UK, Norway and USA equally offer competitive prices, where Namibia can earn above 2 billion dollars in export earnings in 2023. An export ban imposed by the EU will provide opportunities for Namibia to divert EU destined box boneless beef to non-EU markets. Alternatively, Namibia could export beef to fewer restricting markets such as African markets under the diverse continental agreement (AfCFTA) but prices are significantly lower and mainland China and Hong Kong markets.

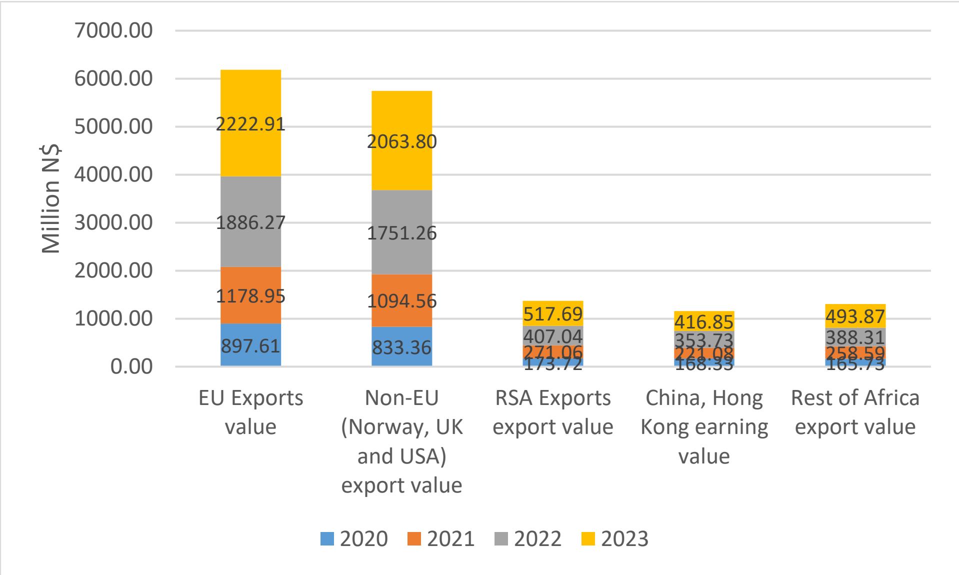

Figure 6.9: Beef gross margins from different export markets.

6.5 Chapter Summary

The analysis reported in this study demonstrates the use of partial equilibrium modelling. The analysis makes use of various datasets to develop a model used, inter alia, to simulate shocks and forecast cattle supply, demand, weaner production options and performance indicators for cattle, such as off-take rates and gross margin for the beef cattle industry in Namibia. Although the model as currently developed has its shortcomings, however, it is observed that the impacts of the simulation presents a mismatch in the outcome variables on slaughter numbers, beef production, prices, on-farm supply and beef export levels. In addition, the model simulates small impact because the autoregressive lag structure adopted on the 33 years of observation measuring the separate impact of the variables. Alternative formulation could be explored.

The experience in developing an important tool for analysis requires a better, clear and comprehensive dataset, such as a dataset that encompasses all the relevant exogenous variables that are needed for predicting and developing the production and utilisation outlook for weaners in Namibia. It is especially necessary to trace the product from the farmgate to the market, whether it is the communal weaner from south of the VCF to RSA directly, to a freehold producer to fatten it and sell it as long weaner on the auction or as slaughter animal locally in either the formal or informal market.

In this study, particularly for the simulation section, sixteen equations were developed and estimated. One identity was formulated for closing the model. Of the several equations, the weaner production equation performed well, and the results forecasted for the period 2020 – 2030 were satisfactory. The weaners marketed and the weaners exported equations produced satisfactory forecasts for the period 2020 – 2030. On the contrary, the equations estimated for per capita consumption and domestic price did not seem to yield the desired and expected results for the period 2020 – 2030. The estimated values were significantly lower than expected, which may be attributed to the loss in lagged parameters evoked in the ARDL specification and the inadequacy of data to fit the ARDL model.

Hypothetical shocks were introduced into the model to capture the impacts of policy regulation on the beef cattle sector. These include a 20% shock on productivity gain in the formal commercial sub-sector, the off-take increase, and a zero EU trade restriction on beef exports from Namibia. Under the scenarios, the impacts are expected on the slaughter stock, weaner production, beef production and average beef carcass pricing. The projected increases in the slaughter stock numbers from 2022 onwards have impacts on the carcass prices and weaner price in the outlook period. Where prices are expected to decrease and it is expected that if the adaptive price expectation of the producer is met, from decision making point of view, most cattle producers are expected to switch from weaner production to an ox production system because of the favourable price per kilogramme for carcass.

CHAPTER 7:
SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Summary

The primary objective of this study was to develop an integrated model that captures the supply and demand dynamics of the beef cattle industry in Namibia, especially given the existence of duality in the Namibian beef cattle production sectors. This study devised an integrated modelling framework that captures the effects of economic policies and other exogenous factors on the dualistic beef cattle sector. The premise of the argument is that the model fully measures and quantifies the simultaneous impacts of economic policies and exogenous factors on the sector (informal and formal sub-sectors). The partial equilibrium model was developed through the application of an autoregressive distributed lag (ARDL) framework to capture the dynamics of supply and demand for beef cattle in the dualistic formal and informal beef cattle markets in the commercial and communal sectors of Namibia. The partial equilibrium framework was based on the works of Ferris (2005) and therefore, this approach was taken to overcome the inefficiencies of the ordinary least squares approaches used by Sartorius von Bach *et al.* (1998), and Sartorius von Bach and Van Zyl (1990), and in the cost–benefit approach used by Chiribonga *et al.* (2007).

This study was complicated by challenges encountered in simulating the supply and demand responses for the informal market. The challenges arose when determining the drivers of non-economic factors influencing major responses in supply and demand decisions. It was ascertained that relevant data are usually unavailable, and where available, are limited and not sufficiently representative to formulate robust and conclusive findings that would guide policy decision making. On the supply side, the off-take rates are higher in the formal production areas and considerably lower in the informal production areas. However, if the beef producers in the informal communal area could be integrated into the formal production area and provided that strict biosecurity measures are followed to reduce the risks associated with animal disease transmission, then an accelerated growth scenario is predicted for the beef industry. The scenario also incorporates achieving expanded market access for exports, as enabled by compliance with the Animal Health Act (1 of 2011), with the FAN Meat regulations, and with an enhanced DVS monitoring and traceability system. The improved productivity provided for the developing producers' communal beef sub-sector could add another 20 percent off-take rate from the communal informal area north of the veterinary cordon fence, annually. However, average slaughter weights are higher in the formal areas than in the communal areas. Beef production is thus more pronounced in the formal production areas than in the informal production areas. This disparity gives the analysis bias, which is thus not wholly representative. However, the findings form the basis for further investigation.

This study pursued three objectives: (1) to evaluate the impact of price adjustment mechanisms and relationships in the beef cattle industry in Namibia; (2) to evaluate the impact of current trade policies and regulations introduced by the government on the beef demand and supply dynamics in the beef cattle industry in Namibia; and (3) to quantify the impact of the beef trade policies on the long-term gross margins of the beef cattle industry in the commercial and communal sub-sectors in Namibia. It was hypothesised in this study that, with a correct model specification and formulation, the integrated partial equilibrium model would provide the ability to generate various baseline projections, including the supply and demand variations, off-take rate, pricing and gross margin per hectare of the complex dualistic cattle sector. The integrated model can account for comprehensive analysis of the effects of supply shifts on cattle production and their impacts on both demand variation and long-term gross margin. Thus, an integrated model can serve as a tool to enable researchers to provide better guidance for proper policy formulation. The proper policy formulation strategies adopted from the usage of this model can stimulate the growth of the beef industry in Namibia.

The partial equilibrium model developed in this study simulates supply and demand responses under alternative policies. The study invokes different econometric tools to show how a long-term, integrated empirical model for the formal and informal beef cattle markets could be designed to provide better guidance for policy formulation. The model results validate the acceptance of the following hypotheses:

i. to evaluate the impacts of price adjustment mechanisms and relationships in the beef cattle industry in Namibia;

ii. to project a baseline of main aggregate variables for the beef cattle sector that includes the slaughter stock, off-take rate and beef cattle disappearance in the commercial and communal areas;

iii. to quantify the impact of the productivity gain on beef production, exports, pricing and long-term gross margin of the beef cattle industry in the formal and informal beef sub-sectors in Namibia.

The findings described in Chapter 5 of this study probed the dynamics of price formation as a precondition to understanding international trade and commodity markets from the perspective of a small country that trades a relatively large volume of a commodity in the world market. Thus, this study bridges the gap that exists regarding price formation in a small country that is a surplus producer and net exporter of a commodity. The Namibian beef market has for years exported a commodity – beef – that has enjoyed access to European markets and the South African markets. Understanding the price formation for the beef sector in Namibia enables good forecasts for beef producers and consumers in Namibia because it provides light for price formation transparency. Until October 2019, Namibian beef producers obtained internationally compatible prices. However, since then, the gross margin of beef producers has declined, partly because of the increasingly inefficient value chains pursued by the export abattoirs. The inefficient value chain has resulted in a favourable weaner production system (Sartorius von Bach, 2020). For comparability, it is noted that, for the past year, the Australian cattle producer parity price has been double than that in Namibia. Namibia could explore alternative markets such as China, Hong Kong and African markets under the AfCFTA, where biosecurity requirements favour Namibia. These type markets could unleash the gross margin gain for the informal sub-sector in the long-run.

Chapter 6 of this study probed the beef supply response through using the scenario simulation from the partial equilibrium model to provide policymakers with information on export supply variations and export demand conditions that could guide the policy formulation process. With this understanding of the partial equilibrium model formulation and results, beef producers and stakeholders could be provided with transparent information on the supply of beef cattle and demands for beef, stock adjustment, on-farm supplies and pricing, and on how such price information, formed domestically and internationally, could be translated into estimating revenue at farm level. On the other hand, for consumers, it signifies the value for money, represented by the willingness-to-pay for an exportable commodity, and the ability to make trade-offs between alternative commodities when pricing information is made available.

The major contribution of Chapter 6 is the provision of the integrated model of the Namibian beef cattle sub-sectors. This model allows the acceptance of the hypothesis that states that the long-term, integrated empirical model developed for the commercial and communal beef markets provides better projections of the supply and demand variations in the domestic beef market. Conversely, farm expenses include cattle stock purchases, feed, labour, machinery running costs, veterinary costs, capital spending, and loans, all of which reflect expenditure on land, buildings and machinery.

The findings of this study indicate that, indeed, farmers in the commercial sector of Namibia do respond to variations in both economic and non-economic factors. The findings revealed that, as expected, farmers in the formal sub-sector respond positively to price incentives (beef producer price) and remain negatively influenced by reduced rainfall. The informal sub-sector beef producers are contesting the price disparity between the formal and informal beef sub-sector, such that the off-take rates are low in the informal sub-sector compared to the formal sub-sector. However, all in all, these factors are inelastic, meaning that commercial beef farmers in the formal sub-sector respond only slightly to variations in both economic and non-economic factors.

However, an EU ban will result in production of beef to decrease in 2023, but it is expected to rebound to positive values in 2024 to 2025. Furthermore, the hypothesised scenario shock would decrease beef production in the commercial sub-sector by 1.37 percent in 2023 and is expected to return to positive levels in 2024 to 2025. Thereafter, it is expected that beef production would decrease in the 2026 to 2030, outlook period. While the same shock communal sub-sector indicates a decrease of 0.15 percent in 2023 and is expected to rebound to positive levels in 2024 to 2025. The same shock has implications on weaner production, where production is expected to increase in 2023 to 2024 and then it is expected to decrease in 2025. The export quantities of beef carcass are expected to decrease in 2023 and 2024, then increase in 2025.

Furthermore, in accepting the hypotheses, the model projects that a 20-percent productivity gain would cause increases in slaughter numbers in the formal commercial sub-sector of 0.17 percent in 2023 and less than 0.05 percent in 2024. It is further expected that the slaughter stock numbers maintain positive levels in 2025 to 2030. Under the same scenario, the informal sub-sector, the slaughter stock numbers are expected to increase in 2023-2029. The increase in slaughter stock from the informal sub-sector is expected because 20 percent of the slaughter animals are entering the formal markets. The increase in slaughter stock numbers is expected to impact on the price in both markets, where prices are expected to decrease because of increased supply.

During the same shock and period, the weaner stock numbers are expected to increase by 0.09 percent in 2023 and expected to maintain positive levels from 2024 to 2030. For the same outlook period, beef production is projected to increase by 0.85 percent in 2023, 0.64 percent in 2024 and less than 0.15 percent from 2025 to 2030.

The projected increases in the slaughter stock numbers in the sector have impacts on the carcass prices and weaner price for the same period. The average carcass price is projected to decrease by 2.37 percent in 2023, decrease by 2.62 percent in 2024, and about 0.27 percent in 2025 in the commercial sub-sector. Further price decrease is expected from 2026-2030. This is expected because of the increase in slaughter stock in the formal sub-sector. Similar expectation is observed in the outlook period for the carcass price in the communal sub-sectors, where prices is expected to decrease by 0.47 percent in 2023, about 0.49 percent in 2024 and less than 0.05 percent from 2026 to 2030. The weaner production is projected to show similar behaviour in the outlook period. This means that, if the ratio between domestic weaner price and carcass price, is below the 62-percent level, it is expected that beef producers will switch from weaner production to an ox production system because of the favourable price per kilogramme for carcass.
The impacts of the decreases in beef production and exports attributable to the EU trade policy restriction would result in decreases for the beef cattle industry in Namibia in export values of 33.95 percent in 2023, but the export value will rebound to positive levels in 2024 to 2030. The rebound is expected because Namibia will export to non-EU countries, China, Hong Kong, South Africa and rest of African markets under the ratified African Continental Free Trade Agreement.

7.2 Conclusion

For Namibia, the growth of the beef cattle sub-sectors in the formal market and in the informal market exhibits a mismatch, and the differing net farming incomes for producers in these two sectors show major divergences. The supply and demand dynamics of beef cattle in the formal and informal sectors are influenced by economic, non-economic and sectoral drivers. Incorporating these drivers into the analysis of the performance of the entire beef cattle sector without making a clear distinction between the two sectors could lead to misleading conclusions. Moreover, the economic policies and exogenous factors that affect the supply (production) and demand (consumption) of beef cattle in the formal sector could also affect the informal cattle markets in the communal sub-sector. Therefore, it is essential to account for the impacts of these policies on both the formal and informal sectors.

It is a well-known fact in Namibia that the cattle production industry remains in place as the main agricultural sub-sector of Namibia. The communal sector north of the VCF is negatively impacted and impeded by the FMD-endemic classification placed on it, which affects production practices, without having appropriate marketing channels in place. The area south of the VCF presents a different picture for all types of production because of the compliance with strict export controls in the area, while there is an increasing need in the northern area for improved farming practices and stricter biosecurity measures on the supply chain. Communal farmers struggle to access the commercial markets because of their lack of compliance with biosecurity measures. Thus, the integrated model indicates that, by improving the quality of cattle in the NCAs, a positive multiplier effect on beef cattle production would be created, meaning that greater numbers of cattle stock would be available for slaughter. In addition, to address the biases and limitations of previous models that have estimated the supply and demand issues in the cattle industry in Namibia, the model in this study has incorporated details of the beef cattle supply, prices and demand in the informal areas, with the result that this model is now able to analyse the net effect of legislation that impacts on production and prices.

In conclusion, this study shows that a partial equilibrium model that integrates the supply and demand dynamics of the formal and informal beef cattle markets generate baseline projections for key aggregate variables in the beef cattle sector, though requires refinement to eliminate disturbances on the shocks. Moreover, the incorporation of other main aggregate variables such calving rate and mortality rate and dummy variables to account for land tenure systems, into the partial equilibrium model enables the model to produce several indicators that can be used to evaluate the long-term economic and financial position of the beef cattle sector. Endogenizing the informal beef sector in the partial equilibrium model also enables the model to comprehensively analyse the net impact of exogenous drivers that have effects on both the supply and demand sides of the formal and informal markets of the beef cattle industry. This indicates that the results derived from shock and policy scenario simulations can be used for informing policymaking decisions. Thus, through proper refinement, this study provides a powerful modelling tool that can be used by policymakers to comprehensively investigate the net effects of economic instruments and legislation applied to the beef cattle industry, and to answer several "what if" questions.

7.3 Recommendations for Further Study

It is identified in this study that dealing with insufficient and aggregated data conceals major differences in the impacts of policy instruments applied across the sub-sectors, in particular beef cattle. Thus, it is important to disaggregate the production data (ox and weaner production systems) on FAN Meat database and NamLITS and the reliable pricing data for the areas N-VCF and S-VCF, formal and informal beef cattle sub-sectors would be sufficient to capture the dynamics of the diverse implications of the performance of the beef cattle industry in Namibia.

The disaggregation of formal and informal production details, as well as of marketing and price discovery options, would give more accurate analyses of policy impacts at sub-sectoral level, and this would also make it possible to project the profitability trends of beef cattle production. The process of analysing price formation and the flows of beef cattle and beef products into Angola, the European Union, non-European Union and South Africa requires gaining a better understanding of the existence of the domestic dualism of the Namibian beef cattle sector, the veterinary cordon fence dividing cattle farming into N-VCF and S-VCF, and the formation of formal and informal beef cattle sector. The dualism of the beef cattle sector needs to be understood for proper policy formulation. In summary, this study is the first to unpack the price relationships and the price dynamism that exist in the dualistic beef cattle market of Namibia.

Future studies should consider incorporating details of the cyclical rainfall pattern to determine whether an early warning system would reduce volatility in production. Gaining more accurate, prior knowledge of rainfall cycles would be important for farmers so that they would be able to make informed decisions on how to cushion the gross margin per hectare volatility in the livestock industry, and to lessen the impact of negative rainfall patterns on cattle production and on the national economy.

Future studies could examine a possible collapse of the cattle sector during periods of border closure, for example to live cattle (weaner) exports to South Africa, which would enhance the analysis of the impacts of these control measures on the status quo of the Namibian beef cattle numbers.

The incorporation of several parameters to analyse the pricing system, in particular the producer price at the export abattoir, would be meaningful for understanding how to prompt farmers to provide more slaughter cattle. It is usually simply assumed that the export abattoir determines the producer price by reviewing the average carcass returns and subtracting their operational and management costs to calculate the producers' share of approximately 60%. Analysis of industry data reveals that the estimated current year (2022) export returns are at about N$125/kg. Thus, Namibian cattle producers would expect a price of around N$75/kg. This would indicate that such price would be regarded as sustainable for producers to opt to fatten weaners locally for value addition. This would result in increased export abattoir throughput, which in turn contributes to farmers' financial sustainability at farm level.

Transparency in the pricing system should support a policy framework that advocates the continuation of exporting Namibian prime beef cuts to foreign markets. Transparent policy on the producer pricing system would improve the producers' trust in the pricing system, and ultimately would attract increased investment in the cattle sector for future national returns.

The beef quota allocation that Meatco enjoys under the coordination problem fostered by the government should be addressed to allow other private equity firms, which can afford the high fixed costs required and to comply with health and other regulations, to enter the beef cattle sector. The current domestic abattoirs do not pay beef producers fairly because the domestic export abattoirs, particularly Meatco, have been using an inefficient value chain design. The operational costs in the current value chain are far higher than in those used by major beef producers in the rest of the world (for example in Australia).

It would be useful for future studies to examine the selling of beef carcasses, not to domestic export abattoirs, but to marketing agents (middlemen, wholesalers) who make substantial profits. Such future studies should consider the fact that the Namibian weaner production system is guided by South African buyers of Namibian weaners, who can pay high prices. These weaners exported to South Africa are taken to efficient feedlots and thereafter to efficient abattoirs in South Africa. However, South African beef is not exported to the same prime markets as Namibian beef is. Thus, Namibia provides inefficient and long value chains for its oxen producers, while South African weaner importers of Namibian weaners apply short and efficient value chains to mature weaners to oxen for local South African consumption.

It is thus reflected, that with a correct model specification and formulation, such as might be developed in future studies, the integrated partial equilibrium model is able to provide the ability to generate various baseline projections for beef supply and beef demand variations, off-take rate, pricing, and allow for using prices to estimate gross margin of the complex dualistic cattle sector. This answers the hypothesis statement number 1. In addition, hypothesis statements 2 and 3 are answered by the fact that the integrated model was able to account for comprehensive analysis of the effects of supply shifts on cattle production and their impacts on both demand variation and long-term profitability, as described in Chapter 6. An integrated model is successfully developed in this study, however, it is observed that the impacts of the simulation presents a mismatch in the outcome variables on slaughter numbers, beef production, prices, on-farm supply and beef export levels. In addition, the model simulates small impacts because the autoregressive lag structure adopted on the 33 years of observation measuring the separate impact of the variables. Alternative formulation could be explored.

Although the model developed in this study has its limitations, it has achieved a relatively fair estimation, and its baseline projection is comparable with the baseline projections for major international beef producers, such as Australia, Brazil, Canada, India, Mexico, New Zealand, Uruguay and the USA (FAPRI-MU, 2022). However, the most critical requirement for the analysis is to have a good, clear and comprehensive dataset that encompasses all the relevant exogenous variables that are needed for predicting and developing the production and utilisation outlook for weaners in Namibia. Therefore, further research which incorporates several variable input costs for each production system, land tenure system, trade flow, and trade policies, would make the recursive effect of supply variation to demand variation of the beef cattle sector more desirable. In addition, getting model closure right is just as important as having good supply and demand elasticity estimates, such as the formulation and parameters estimated and presented in chapter 5 of this study are precondition to obtain the realistic impact. However, the lag structure adopted in the modeling framework has produced results depicting opposite effects and of small magnitudes on cattle stock, beef and weaner production and on-farm supply. Therefore, an alternative framework and refinement is required to generate robust and realistic impacts for policy formulation purposes.

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