ECONOMIC LOSSES AND EX-POST RESPONSE TO FOOT AND MOUTH DISEASE OUTBREAK AMONG SMALLHOLDER BEEF PRODUCERS IN NORTH-EAST DISTRICT, BOTSWANA

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A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Master of Science Degree in Agricultural and Applied Economics of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in any university and institution of higher learning for any award.

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Recommendation

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DEDICATION

This thesis is dedicated to my late grandmother, China Masole.

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ABSTRACT

Botswana's agricultural backbone the beef subsector, is threatened by recurrent foot and mouth disease (FMD) outbreaks. The current study was generally carried out to contribute towards better livelihoods of smallholder beef producers through enhanced resilience of their production systems to FMD in North East district, Botswana. Specifically, the study intended to; determine smallholder producers' perceived risk factors of the 2011 FMD outbreak, determine economic losses, and further determine factors attributed to the losses and finally to determine the role of factors on choice of smallholder producers' ex-post response to FMD. A multistage sampling technique was used to select 271 producers and were interviewed using a semi-structured questionnaire. Descriptive and inferential statistics, quantile regression and a multivariate probit models were used for analysis. Household heads whose livestock was affected by FMD were aged 55 years on average while those not affected were 58 years old. Affected farm households were from Matsiloje and Matshelagabedi, owned less cattle (21) and less agricultural land (4.43 ha) while those who were not affected were from Tsamaya, had more cattle (31) and more land (4.57 ha). Major five risk factors of FMD in the district were nearness to the border, cordon fence damage, livestock theft, communal grazing and farming in Matsiloje. In terms of economic losses, household farms in Matsiloje incurred more losses (BW151, 492.50/USD14, 796.00) than Matshelagabedi (BWP88, 639.68/USD8, 659.07) and Tsamaya (BWP75, 460.78/USD7, 371.65). Men owned more cattle (30) than women (19) thus incurred more losses. On that note, the government spent BWP11, 532, 500.00 (USD1, 126, 492.86) as compensation to producers. The economic losses incurred were increased by years of schooling, farm experience, market distance as well as the distance to grazing and water areas. In terms of ex-post responses to FMD, a positive effect towards adoption was observed with household size, opportunity cost incurred, frequency of contact with extension officers, training on FMD, market distance, distance to grazing and water areas as well as proximity to other household farms. In light of these results, policies geared towards reducing FMD costs through efficient control measures such as quarantine before stamping out are recommended. More education on FMD and sensitization of ex-post responses to the disease is vital to increase adoption of the same. Thus active involvement of relevant stakeholders, especially agricultural extension providers and the role of collective action are key in eradicating FMD.

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LIST OF ABBREVIATIONS AND ACRONYMS

AERC	African Economic Research Consortium
BAITS	Botswana Animal Identification System
BIC	Botswana Insurance Company
BMC	Botswana Meat Commission
BVC	Beef Value Chain
BVI	Botswana Vaccine Institute
BWP	Botswana Currency
CBPP	Contagious Bovine Pleuropneumonia
DVO	District Veterinary Office
DVS	Department of Veterinary Services
EAC	East African Community
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FMD	Foot and Mouth Disease
FMDV	Foot and Mouth Disease Virus
FVO	Food and Veterinary Office
GDP	Gross Domestic Product
GoB	Government of Botswana
HBM	Health Belief Model
IEPA	Interim Economic Partnership Agreement
IIA	Independence of Irrelevant Alternatives
KMO	Kaiser Meyer Olkin
LITS	Livestock Identification and Traceability System
MNL	Multinomial Logit
MOA	Ministry of Agriculture
MVP	Multivariate Probit model
NED	North East District
OIE	World Organization for Animal Health
OR	Odds Ratio
OLS	Ordinary Least Squares
PCA	Principal Component Analysis
QR	Quantile Regression

RTAs	Regional Trade Agreements
RUM	Random Utility Model
SADC	Southern African Development Committee
SDGs	Sustainable Development Goals
SDVA	Sub District Veterinary Area
SDVO	Sub District Veterinary Office
SPSS	Statistical Package for Social Sciences
SUR	Seemingly Unrelated Regression
SWOT	Strengths, Weakness, Opportunities and Threats
TADs	Trans Boundary Animal Diseases
USD	American dollar
USDA	United States Department of Agriculture

CHAPTER ONE
INTRODUCTION

1.1 Background of the study

Agriculture is the backbone of most developing countries' economy and it contributes a high share to gross domestic product (GDP) (Nchuchuwe and Adejuwon, 2012; Tarawali, 2015). Unlike many of the developing countries, Botswana's economy consisting of a 2 million populace depends primarily on natural resources, most notably diamonds which are responsible for economic growth (USDA, 2015). Contribution of the agricultural sector to Botswana's GDP has declined drastically over time; from about 40% in 1966 to about 2% in 2014 (Botswana Investment and Business Guide, 2016). Further, the potential of agriculture is limited largely due to the Kalahari Desert effect and persistent droughts since most farmers depend on rain-fed farming. These harsh conditions however, fail to prevent the beef industry from flourishing.

The beef subsector continues to be Botswana's largest component of agriculture dating as far back as pre-independence era and supplies the lucrative European Union (EU) market and South Africa (Botswana Investment and Business Guide, 2016). Beef industry contributes about 80% to agricultural GDP share (Mogotsi *et al*., 2016) and has potential to supply China and the Middle East markets (Botswana Investment and Business Guide, 2016). According to USDA (2015), about 85% of agricultural output draws from livestock production, mainly beef. Further, in 2014, beef exports injected 160 million dollars to Botswana's economy, second to diamonds which brought 7 billion dollars.

Concomitant to the successes recorded in the beef industry, numerous crises have been associated with the beef subsector and these include but not limited to; inefficient management, drought, continuous market changes, macroeconomic challenges, competition from other beef exporters and critical livestock diseases particularly Foot and Mouth Disease (FMD) and Contagious Bovine Pleuropneumonia (CBPP) (van Engelen *et al*., 2013; Masole *et al*., 2015; Baluka, 2016; Mogotsi *et al*., 2016).

Amidst these challenges, FMD which is a trade issue has resulted in export bans. Foot and mouth disease is an acute, highly contagious disease which spreads rapidly in cloven-hoofed animals such as cattle, sheep, goats, pigs and buffaloes (van Engelen *et al*., 2013; Nampanya *et al*., 2015a, 2015b; Lyons *et al*., 2015) and is caused by Foot and Mouth Disease Virus (FMDV) (Chandranaik *et al*., 2015; Mogotsi *et al*., 2016). The disease is associated with colossal losses. Literature refers to FMD as an economic disease and a world trade issue, because of the magnitude of economic damage it can cause especially to beef exporting countries (Knight-Jones and Rushton, 2013; Sinkala *et al*., 2014; Chandranaik *et al*., 2015). Botswana government development expenditure on economic services to agriculture grows rapidly especially during the FMD outbreaks, which are recurrent in nature and the expenses cover majorly management of the disease.

The country incurs huge control costs from movement restrictions, culling and slaughter, vaccination, wildlife controls and restricted market access (Baluka, 2016; Knight-Jones *et al*., 2016; Tago *et al*., 2016). The trade bans, owing to the FMD endemic, reduce producers' and rural dwellers' proceeds who solely depend on beef farming as a livelihood activity. It is therefore the responsibility of producers and other relevant stakeholders to quickly exterminate the disease once detected. This ensures compliance with the World Organization for Animal Health (OIE) and the European Commission (EC) standards which give a directive that beef from FMD-infected countries or zones cannot be exported to non-infected zones, such as the EU (Knight-Jones, 2015; OIE, 2015; Knight-Jones *et al*., 2016).

A number of FMD incidences have been recorded in the past decade and a half in Botswana. The FMD outbreak in 2003/04 was quickly controlled by stakeholders including the Ministry of Agriculture (MOA) under the Department of Veterinary Services (DVS) (van Engelen *et al*., 2013). However, FMD outbreaks of 2007 and 2011 were not brought under containment easily and led to temporary loss of access to the EU market. Loss of international market meant loss of foreign exchange for the country and smallholders who depend on the revenue for survival.

Two major ways of FMD spread in Botswana have been documented. In Ngami land and Chobe district areas (Northern part), the disease is prevalent because of the presence of buffaloes and the region is a common tourist site (van Engelen *et al*., 2013; Thomson *et al.*, 2013a, 2013b; Eygelaar *et al*., 2015). These habitually cross veterinary cordon fences coming in contact with livestock. The movements exacerbate the spread of the disease, thus the northern part is labeled a red zone. North-East District (Southern part) which is in the FMD free, EU export zone experiences FMD hits as a result of spill-over effects from the nearest border, leading to trans-boundary outbreaks (Knight-Jones *et al*., 2016; Mogotsi *et al*., 2016). According to Legesse *et al*. (2013) and Baluka *et al*. (2014), these trans boundary diseases have no respect for boundaries and can be responsible for an epidemic in the borders of another country. Banda *et* *al.* (2014) noted that FMD outbreaks in SADC region occurred round about the same time and had the same serotypes of FMD.

North-East District (NED), which encompasses zone 6 and 3c veterinary zones, depends on agriculture as the dominant activity. Livestock keepers in the district have been susceptible to FMD over some time. In a span of a decade, the district recorded two outbreaks (in 2002 and 2011), the recent major one being in 2011. As a result of the 2011 outbreak, the government had to spend over USD 3 million as compensation to producers who lost their cattle to the disease, for restocking, and other logistics (OIE, 2015). Reimbursement is usually expensive for the government which on the other hand has also been deemed incommensurate to market prices by producers given that is done irrespective of the age, breed or condition of the animal with exception to dairy cattle. According to Mogotsi *et al*. (2016) 47, 578 cattle and 25, 232 small ruminants in the containment zone of zone 6 were all stamped out and did not make it to the EU because of the health standards.

1.2 Statement of the problem

Foot and mouth disease is an economically and socially distressing disease in Botswana's beef value chain, which has been on the rise since year 2000, with recent outbreaks recorded in 2011, in FMD free, export zones. This has resulted in the loss of the EU export market due to market restrictions on movement of FMD infected livestock. Therefore, producers are hindered from taking advantage of lucrative market opportunities and ultimately loss of livelihood by smallholder producers. Though recent outbreaks occurred in 2011, currently little has been documented on producers' perceived risk factors to FMD outbreak. Economic losses in North East district following the last outbreak are poorly understood as well as the factors determining them. Further, smallholder producers' ex-post response to FMD is not clear let alone the role of socio-economic and institutional characteristics on the choice of the ex-post responses. Therefore, the current study was geared towards filling these knowledge gaps.

1.3 Objectives

1.3.1 General objective

To contribute towards better livelihood of smallholder beef producers through enhanced resilience of their production systems to FMD in North East district, Botswana.

1.3.2 Specific objectives

1. To determine smallholder producers' perceived risk factors of foot and mouth disease outbreak in North East district, Botswana.
2. To determine economic losses due to foot and mouth disease during the last outbreak among smallholder producers in North East district, Botswana.
3. To determine factors that influence economic losses due to foot and mouth disease during the last outbreak in North East district, Botswana.
4. To determine the effect of socio-economic and institutional factors on choice of smallholder producers' ex-post response to foot and mouth disease in North East district, Botswana.

1.4 Research questions

1. What are the smallholder producers' perceived risk factors of foot and mouth disease outbreak in North East district, Botswana?
2. What are the economic losses due to foot and mouth disease during the last outbreak among smallholder producers in North East district, Botswana?
3. What factors influence economic losses due to foot and mouth disease during the last outbreak in North East district, Botswana?
4. What are the effects of socio-economic and institutional factors on choice of smallholder producers' ex-post response to foot and mouth disease in North East district, Botswana?

1.5 Justification of the study

Botswana derives about USD 200 million annually from exportation of beef to international markets (USDA, 2015) and this forms part of the 2% share of agricultural sector contribution to GDP. The beef subsector is an integral part of the country's economy at socio-economic level and beyond. Hence, control and eradication of FMD is a priority to the country. Furthermore, successful management of the disease will contribute to the realization of the country's long term vision 2036 pillar of the four pillars, being sustainable economic development, which took over the baton from the just concluded vision 2016. This is also in line with the Sustainable development goals (SDGs) delivered in 2015. Goal 1, 2 and 3 of zero hunger, ending poverty and good health and well-being, respectively are more relevant to the case of FMD.

These goals contain a clause that if they are to be achieved, then control and eradication of animal diseases be efficiently done since they threaten food security and critically disadvantage smallholder producers who have challenges in controlling diseases, making them vulnerable to poverty (Tarawali, 2015; Knight-Jones *et al*., 2016). To North-East district, beef farming is a major income generating activity especially to smallholder producers who form the majority. They are reported to be faced with higher transaction costs and risks, FMD included. Literature also shows that it is challenging to control FMD in smallholder systems and impact is usually higher for smallholders. Understanding these producers' perceived risk factors to FMD outbreak as well as quantifying their economic losses has policy implications and informs what adjustments are needed taking into consideration producers' ex-post responses to the disease.

1.6 Scope and limitation of the study

The study focused on risk factors, economic losses and ex-post responses to FMD outbreaks of beef producers in North East district. The focus was only on those areas which experienced the 2011 FMD outbreak limited to smallholder beef cattle producers. The study used cross-sectional data and envisioned constraint due to failure of producers in providing accurate information about their enterprises. However, thorough probing during data collection enhanced the accuracy of the data collection.

1.7 Operational definition of terms

Batswana: people from Botswana.

Ex-post – occurring after the FMD outbreak.

Household: a group of people who have been living together under the same roof for a period of time. These are answerable to a household head and share the same eating table.

Perceived risk: the judgement that households make about the characteristics of FMD.

Pula - Botswana currency denoted by (**P**) and an ISO code BWP. (1USD=BWP10.26)

Smallholder - beef cattle producers with a cattle herd of 150 or less per household. These normally have communal grazing areas and water points.

FMD free, export zone – a region/area where no FMD vaccinations are administered and beef is exported from.

CHAPTER TWO
LITERATURE REVIEW

2.1 Beef production in Botswana

Cattle keeping that dates as far back as colonial era has persisted to be integral to Batswana's livelihoods. Botswana has 2.5 million cattle and 1.5 million sheep and goats (European Commission-FVO, 2015). The country is ranked the largest exporter of beef in Africa and about 60 percent of Batswana are cattle keepers with the majority at smallholder level, rearing Tswana cattle breeds (van Engelen *et al*., 2013). These are kept mainly for subsistence purposes in the arid and semi-arid areas of Botswana. The importance of cattle to the country cannot be overemphasized with income from the same lifting many people from poverty (Mogotsi *et al*., 2016). European Union remains Botswana's principal lucrative export destination. Botswana Investment and Business Guide (2016) reports that the livestock subsector has potential to benefit more from the EU market with value addition and possesses great potential to supply Middle-East, China as well as African markets.

Keeping up with the EU market has been deemed costly for the country but EU still prefers the Botswana beef for several reasons. The market prohibits use of growth hormones and animal based-feed, the beef exported should be from FMD-free status zone without FMD vaccinations as by OIE, up-to-date vaccination records for each animal slaughtered and the existence of a traceability system which Botswana complies with (Marumo and Monkhei, 2009; Moreki *et al*., 2012; van Engelen *et al*., 2013). The Botswana Meat Commission (BMC), Botswana's export monopoly, which was established in 1965, is tasked with the responsibility to export beef, slaughters and sells the meat internationally. Second to the mining sector, the beef subsector therefore stands as one of the most celebrated import substitution and export base of Botswana and a significant vehicle in alleviating poverty.

The traditional beef sector is characterized by communal land grazing systems, with livestock owners employing herdsmen to care for their livestock. These are responsible for grazing and watering the animals from shallow wells, boreholes and designated government water pumps. Smallholder producers (herd size less than 150) who are the majority keep their cattle in a kraal (livestock enclosure) system without fencing and according to Mogotsi *et al*. (2016) about 80% of beef exports are from communal grazers. Medium-scale to large-scale producers have well fenced and sheltered ranches. Some well-off producers have feedlots for weaning or fattening cows for slaughter (van Engelen *et al*., 2013).

2.2 Risk in agriculture

A strengths, weaknesses, opportunities and threats (SWOT) analysis of the beef value chain (BVC) points out contagious diseases such as FMD as major threats to the BVC as they result in suspension of export markets (Legesse *et al*., 2013; Masole *et al*., 2015; van Engelen *et al*., 2013). Therefore, FMD is a national concern to the beef industry. Dealing with risk involves costly mitigation measures such as buying an insurance package (Khan *et al*., 2013). Livestock insurance poses an appropriate way to absorb risk in agriculture to be particular (Boyd *et al*., 2013). However, the insurance market especially in the agricultural sector is underdeveloped in Botswana among cattle keepers (van Engelen *et al*., 2013). Furthermore, a number of banks in Botswana have agricultural insurance schemes which are said to be not affordable to an average smallholder producer.

Botswana Insurance Company (BIC) for example, introduced some livestock insurance products which had a number of conditions and biased towards commercial producers (van Engelen *et al*., 2013). Despite the failure to benefit smallholder producers, insurance offers good cover on accidental death, transit-related losses, theft and death from some diseases. Concerning the condition of death resulting from some diseases, requires prevention measures like vaccination to be taken, which violates the exportation agreements with the European Union of FMD free zones selling to the EU. Beef exported to the EU from FMD free zones is supposed to be free from FMD vaccinations. Developing countries such as Kenya and Mongolia through government assistance have developed insurance schemes affordable to those who could not afford them before (van Engelen *et al*., 2013). The same have recommended that other countries do likewise.

2.3 Foot and mouth disease

The disease is a highly contagious viral disease affecting cloven-hoofed animals such as cattle, goats, pigs, sheep and buffalos (Chandranaik *et al*., 2015; Lyons *et al*., 2015; Nampanya *et al.*, 2015a; Knight-Jones *et al*., 2016). It is an economic disease with detrimental impacts, especially to exporting FMD-free countries' economies (Legesse *et al*., 2013). The disease is identified by large blisters in the mouth and around the hooves and is associated with colossal losses of cattle, reduced milk yields, loss of draught power, occasional abortions and disease control costs (Knight-Jones and Rushton, 2013; Govindaraj *et al*., 2015; Lyons *et al*., 2015; Baluka, 2016; Knight-Jones *et al.*, 2016). Treatment of the outbreak is delicate and strict in Botswana owing to the significance of the beef subsector to the economy.

2.4 Socio-economic impact of foot and mouth disease

The impacts of FMD outbreaks across the world have been quantified in monetary units and qualitatively. The outbreak has large direct and indirect socio-economic impacts distressing to a lot of FMD- free zone countries. Producers at most are the ones who bear most of the revenue losses largely due to import restrictions. Many studies have documented the impact of FMD but few have done so for the smallholder (Baluka *et al.*, 2014; Lyons *et al*., 2015; Nampanya *et al.*, 2015; Baluka, 2016; Knight-Jones *et al*., 2016).

In Australia, ABARES modeling in 2013 predicted revenue losses of between US$ 5.6 billion and US$6.2 billion over 10 years in the present value terms, whereas in the incidence of a large multi-state outbreak, the model estimated losses between US$49.3 billion and US$51.8 over a 10 years' period (Buetre *et al*., 2013). Social impacts occurred at all levels affecting anyone involved in the beef value chain. Such social impacts being mental health issues, reduced welfare and altered gender roles occur following the outbreak (Buetre *et al*., 2013).

An analysis of the impacts of FMD outbreaks in cattle and buffaloes in India by Govindaraj *et al.* (2015) showed high FMD incidence risk across herd sizes while high mortality risks were observed in small herds. Huge losses were due to distress sales in indigenous cattle estimated at US$ 208, whereas in crossbred cattle, mortality loss had the highest toll at a cost of US$515, second being distress sales at US$490, milk yield losses at US$327, with treatment costs at US$38 and other costs at US$ 30. Losses on the buffalo side, both local and upgraded buffaloes had an average total loss per affected animal at US$440 and US$513 consecutively.

In Laos Peoples Democratic Republic, smallholder producers affected by the disease were reported to have average losses ranging from 16 to 60 percent of household incomes which varied across regions (Nampanya *et al*., 2015b). On an earlier study, Nampanya *et al*. (2014) estimated financial losses of US$ 30 881 at village level and US$ 13 512 291 at national level based on the number of villages with FMD outbreaks reported in 2011.

The FMD outbreak has also affected Africa. The East African Community (EAC) is no exception to FMD outbreaks. In Uganda, for example, Baluka *et al*. (2014) documented that the farms affected by FMD calculated costs per animal was more extreme in smaller farms/ herds. Financial estimates made were US$123 for small farms against US$17 on large farms. Parts of the costs were attributed to insufficient funds for vaccination and selling at distress prices by the smallholder.

In Tanzania, about two-thirds of households experienced huge milk losses from their cattle and goats following the 2013 FMD outbreak. The households were also affected by loss of livestock traction resulting from lameness induced by the disease (Casey *et al*., 2014). In Kenya, a study on the impact of FMD on milk production on large scale dairy farm took lactating European-breed cattle under consideration. The study by Lyons *et al.* (2015) found that mean daily milk yields dropped from about 20 to 13 kg per cow.

In Southern Africa, FMD is characterized by trans-boundary transmissions hence similar viral strains which also have impact on the producer directly (Thomson *et al*., 2015; Knight-Jones *et al.*, 2016). The region is said to be characterized by endemic infected wildlife which makes FMD control difficult. Banda *et al.* (2014) reported that FMD outbreaks in Southern African Development Committee (SADC) region occur round about the same time and that the same serotypes of FMD have been observed. In Namibia, Cassidy *et al.* (2013) suggested a benefit cost analysis done in wildlife dominant area, promised great benefits to the smallholder provided FMD is managed, failure of which will exacerbate poverty levels of the same in the country.

2.5 Foot and mouth disease outbreaks and impact in Botswana

New outbreaks have frequented since 2002 until 2015 after about two decades of not experiencing such and some were reported in non-EU export zones, largely the northern part of the country (Mogotsi *et al*., 2016; OIE, 2015). Further, the observed FMD history outbreak shows that there were three major regions where outbreaks were plausible to happen and these were Ngamiland (Zone 2a, 2b, 2c, 2d, 2e, 2f), Chobe area (Zone 1), Boteti river area (Zone 4a) and Nata (Zone 3b) all located in the northern part of the country (Figure 1) (Mogotsi *et al*., 2016).

The Northern part of Botswana contracts FMD from African buffaloes (*Syncerus caffer*) since the region is wildlife rich. The wildlife population is significant; buffalo numbers in particular which have a direct role in transmission of FMD in the country (Eygelaar *et al*., 2015). Cattle in the region are vaccinated against the disease, automatically disqualifying the region from exporting to the EU (van Engelen *et al*., 2013; European Commission-FVO, 2015), hence labeled the red zone. However, the Southern part of the country, which includes the location of the current study (NED), declared an FMD-free zone without vaccination experiences FMD outbreaks resulting from spillover effects from Zimbabwe (Knight-Jones *et al*., 2016).

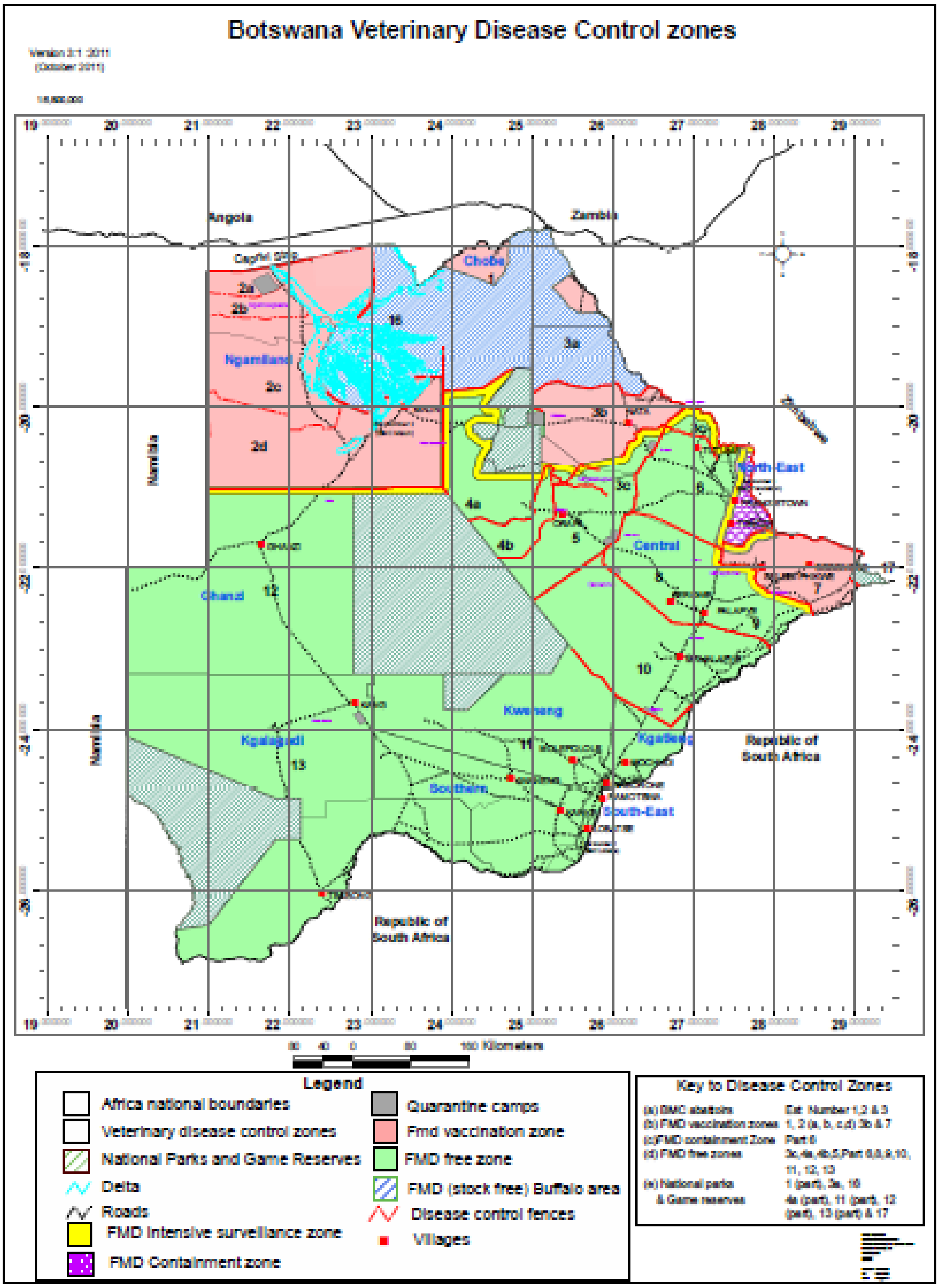

Figure 1: Veterinary disease zones

Source: Department of Veterinary Services, Botswana (2013)

A study by Mogotsi *et al.* (2016) found out that the major five factors leading to spread of FMD in some part of Central and North East districts were; lack of protection zones, livestock theft, owner apathy, wildlife-livestock interface and veterinary cordon fence damage. Furthermore, trans boundary transmissions are due to illegal movements of livestock across the border, short distances to the border and damaged fences as a result of wildlife. North East district experienced two counts of FMD outbreaks in 10 years, which is 2002 and 2011. Mogotsi *et al*. (2016) reported that the 2002 FMD outbreak resulted in stamping out of all 47, 578 cattle and 25, 232 small ruminants in zone 6 alone. The last outbreak has been reported to be the most drastic as it resulted in temporary closure of local abattoirs for inspection and the EU export market. The most affected producers were those east of the railway line closest to border.

The Government of Botswana (GoB) spent over US$ 3 million compensating producers who had lost their cattle to the disease, for restocking, and other logistics (OIE, 2015). Further, restocking of cattle to affected producers was delayed for two years and compensation payments were insignificant to producers, exacerbating the impact of the disease. Counseling was conducted after the 2011 outbreak to minimize trauma and depression amongst producers. This was necessary because some of the producers kept beef cattle for prestige, whereas for some, beef farming was the household's main income earner.

2.5.1 Economic losses

Economic losses associated with FMD documented across the world are reported to vary depending on factors such as the livestock production system (Knight-Jones and Rushton, 2013; Senturk *et al*., 2016). Production losses and vaccination costs have been estimated between 6.6 to 21 billion dollars for FMD endemic countries and 1.5 billion dollars for non-endemic countries. Documentation of economic losses due to FMD in Botswana has been poorly done especially at household level. Evidence collected is only limited to the number of animals lost due to the outbreak on grounds of morbidity and mortality. However lacking, is how much in monetary terms producers had to forgo following the export ban. This then calls for thorough investigation on the same.

2.6 Disease management

Major investments have been made to sustain the beef subsector into being an export subsector through and through. The government of Botswana, through the Department of Veterinary Services (DVS) has promised to ensure the goal is achieved through the management of diseases in order to comply with OIE standards. The GoB offers free veterinary services to producers that would be considered a private good elsewhere, albeit this being detrimental to the tax payer who could be the same producers. Botswana Vaccine Institute (BVI) was established in 1979 to produce *inter alia*, FMD vaccines for the local and international market (Banda *et al.*, 2014).

Concerning disease management through livestock identification, OIE requires producers to label their cattle for traceability and identification purposes which helps producers identify their lost stock or pick them out easily from a group in communal grazing (Marumo and Monkhei, 2009; Moreki *et al*., 2012). A new identification system for cattle named Botswana Animal Identification System (BAITS) was introduced in 2014, in place of the previous Livestock Identification and Traceability System (LITS). The new system supports identification with a double ear tag, with one tag having an electronic identifier, and takes over from the electronic bolus system (van Engelen *et al*., 2013). However, BAITS is done parallel to branding which relays an owner's identification brand and the disease control zone they are placed in.

Botswana has been divided into veterinary zones for disease control and protection. North-East District consists of Zone 3C and Zone 6 (a and b). In the same district, the last outbreak was most drastic in zone 6, with the exception of zone 3C. Following the 2011 FMD outbreak, zone 6 bordering Zimbabwe was reshaped in 2013 and further divided in 2014, to create zone 6 a and b. Zone 6b comprises cattle keepers along the border with a width allowance of approximately 10 km under intensive surveillance (OIE, 2015). Any cattle found within the 10km space are terminated immediately on spot to avoid contamination with other animals. The area is still considered as FMD-free zone. Zone 6b is now considered a protection zone which further protects zone 6a ultimately. Permanent staff patrol has been employed keeping in check the status of the border fence with respect to cattle movement.

The border also has a river of which its access has been inhibited to Botswana cattle and the government has resorted to providing water points to water the livestock. Locally, FMD- free zones as stipulated by OIE where vaccination is not done are protected from disease threats by restricted movements of live animals, as well as, livestock products. Strict conditions exist for any movement of beef and beef products which include movement conditions, residency conditions, and standards for meat treatment together with clinical and epidemiological check (European Commission-FVO, 2015). According to OIE requirements, veterinary authorities require proof of an international veterinary certificate verifying the product(s) being moved to be coming from FMD free country/zone with no vaccination for at least three months and also indicating that they were slaughtered in health approved abattoirs with thorough inspections (Knight-Jones, 2015).

Following an outbreak in FMD free zones with vaccination, usually vaccination is administered to prevent future outbreaks, but with FMD free zones without vaccination like zone 6 which exports to the EU, stamping out of all affected livestock is the solution. To maintain the OIE status following the 2011 FMD, GoB rolled out a compensation program to all affected producers in the form of restocking and payments. According to Mogotsi *et al*. (2016), Option 1 of the compensation policy for cattle involved 100% cash to producers with ten or less cattle; Option 2 entailed 70% cash and 30% restocking at P1700.00 (USD165.69) per animal which is irrespective of breed, age or condition of the animal. However dairy cattle prices were increased to P7500.00 (USD730.99) per animal, whilst for small stock, compensation was 100% restocking.

2.7 Trade policy reviews following FMD

Botswana has preferential market access to the European market with tradable quotas established under the Lomé Convention in (1976-2000) and sustained under the Cotonou Agreement signed in 2003, as well as, the Interim Economic Partnership Agreement (IEPA) since 2009 (van Engelen *et al*., 2013). The agreements entail requirements on Phytosanitary measures on health and animal standards on trade, complex traceability system, no use of growth promoters, meat be from FMD free zone without vaccination even if the animal is certified as disease free hence deboning is required especially by the EU (Grynberg, 2012).

The agreements come with duty and quota free access. The country also benefits from Regional Trade Agreements (RTAs) with South Africa in the SADC region with duty free and quota free access in the markets. FMD is a trade issue since exports experience trade bans according to health standards which means loss of foreign currency (Legesse *et al*., 2013; van Engelen *et al*., 2013; European Commission-FVO, 2015). Recently, the country has experienced reductions in beef exports due to recurrent FMD outbreaks (van Engelen *et al*., 2013).

2.8 Perceived risk factors to foot and mouth disease

For purposes of this study, perceived risk refers to the judgement that households make about the characteristics and severity of FMD risk. The disease risk prompts households to diversify their sources of income hence developing some coping measures. Several studies attest to the fact that FMD leaves the smallholder very vulnerable to poverty (Baluka *et al*., 2014; Knight-Jones *et al*., 2016). However, the same show that this is not the case for medium and large scale producers. Impacts on FMD across the world indicate that households severely affected by the disease experiencing high mortality losses were those with small herds (Baluka *et al.*, 2014; Baluka, 2016).

These households are generally characterized by limited resources which restrict them from managing the disease to avoid loss. These are, however, vital to the economy as a whole. In India, Govindaraj *et al.* (2015) concluded that FMD caused huge loss to producers and as a coping measure; they were forced to sell their cattle under distress condition, selling them at cheap prices. The same producers even suffered psychological stress. Impact of FMD among smallholder producers is not well documented let alone their perceived risk to the disease and ex-post response measures. Hence, to address the gap, the existing study on how beef producers in North East District of Botswana respond to FMD outbreaks given their perceived risk factors was carried out.

2.9 Theoretical and conceptual frameworks

2.9.1 Theoretical framework

The current study will be based on the concept of Health Belief Model (HBM) and utility maximization theory.

Health Belief Model

The HBM developed in the early 1950s by social psychologists Hochbaum, Rosenstock, Kegels and Leventhal (Orji *et al*., 2012) is rooted in human health but has over time gained popularity in animal health. The study adopts and modifies the HBM. The concept of the model is that behavior of health is resolved by personalized beliefs or rather household perception about disease risk as well as disease reduction measures to reduce incidences (Jemberu *et al*., 2015). Human Belief Model captures four perception statements that influence a certain health behavior. The statements are;

1. Perceived *susceptibility* about the likelihood of getting FMD,
2. Perceived *severity* (seriousness) of the condition,
3. Perceived *benefits* of an action to reduce threat (susceptibility and severity),
4. Perceived *barriers* posed by the costs of taking a disease reduction measure.

According to Jemberu *et al*., (2015) the perceived risk explains why a household would choose a particular health behavior or otherwise. Households with a belief that they are susceptible to FMD, that it would have severe after effects, believe a disease reduction measure would be beneficial overpowering the costs in decreasing its occurrence and threat, then they are most likely to apply the measure. The HBM was used to assess the smallholder producers' perceived risk factors as well as their implementation of ex-post response measures to FMD outbreaks.

Utility maximization theory

The theory of economic choice proposes that individuals are rational, and their choice of an option depends on maximum utility derived. According to Greene (2012) unordered choice models like multinomial models are motivated by a random utility model (RUM) which derives from utility theory. A consumer is faced with a situation or a set of alternatives which reveal something about their underlying preferences given by the choice they make. The utility concept states that an individual, who in this case, is a household, makes a choice that yields the highest utility. The household is assumed to be deriving a certain level of utility from each ex-post response strategy. Beef producers are expected to make a decision as to which coping measure best to adopt so to maximize their utility in terms of cushioning themselves against future FMD outbreaks. The utility is not directly observed (latent variable U_{ij}), it is only observed from the attributes of the ex-post responses they select. For the ith household faced with *J* choices, the utility of choices *j* is:

$$U_{ij} = z'_{ij}\theta + \varepsilon_{ij} \tag{1}$$

Where

U_{ij} = Utility, z'_{ij} = deterministic part which includes characteristics of households and attributes of choices, ε_{ij} = random component.

The assumption is that if a household makes choice *j* in particular, then U_{ij} is the maximum among the *J* utilities. The probability that choice *j* is made then is:

$$\Pr ob(U_{ij} > U_{ik}) \text{ for all other } k \neq j \tag{2}$$

2.9.2 Conceptual framework

The framework has been developed on the basis of producers' ex-post response to FMD outbreak and choosing the best measure given the producers' available resources to maximize utility; this also captures relationships amongst various relevant variables (Figure 2).

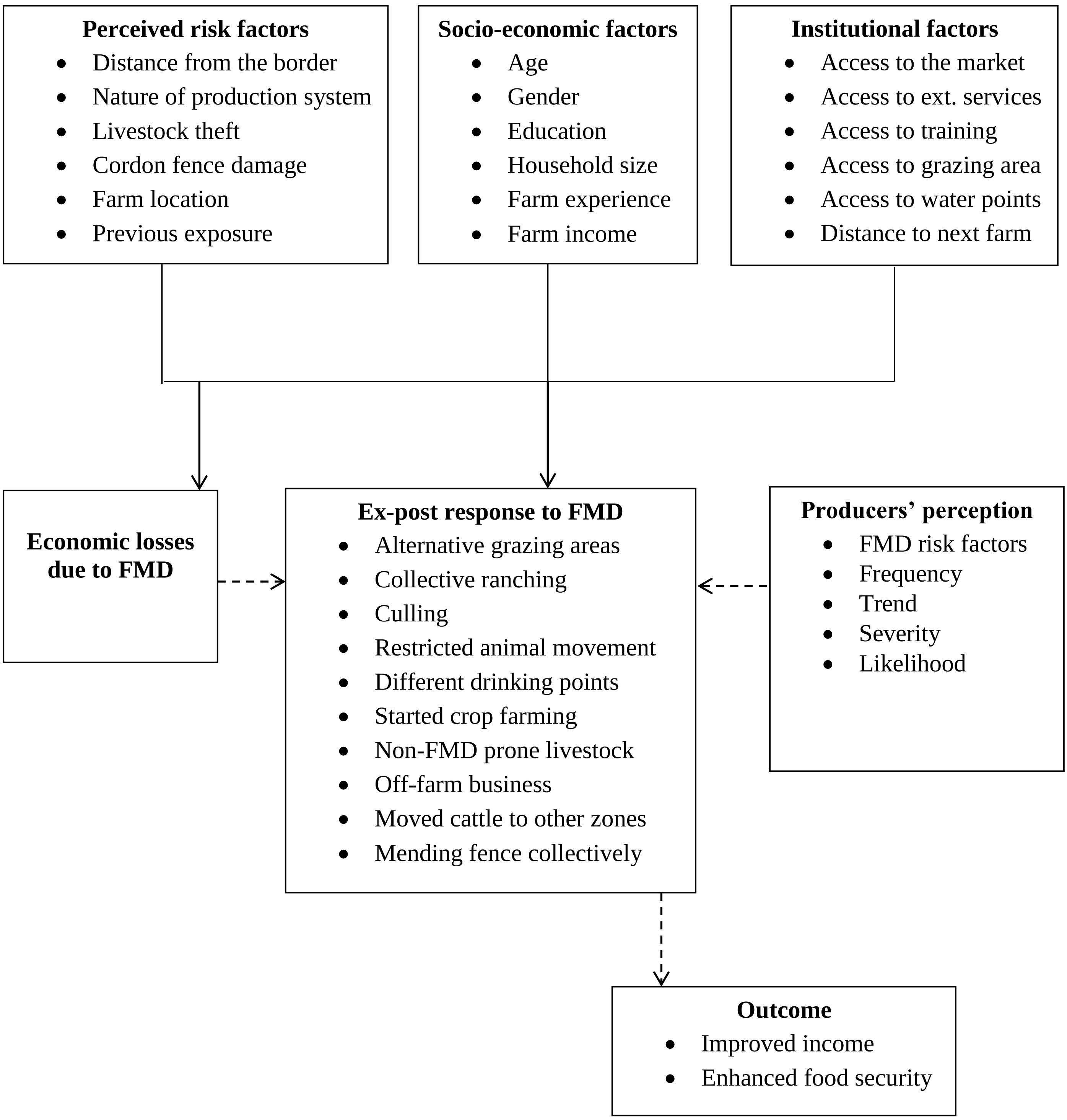

Figure 2: Conceptual framework

Captured in the framework is the perceived risk factors of FMD, prevailing socio-economic and institutional characteristics, the economic losses due to the disease as well as, the ex-post response to FMD by producers. In this study, the choice of an ex-post response to FMD is expected to lead to increased incomes derived from farming and improved food security. However, responses to FMD outbreaks require more labour, and capital and more efficiency in terms of management and increased costs of production, since the costs of production will be spread across the ex-post responses.

Vulnerability starts with exposure to risk or a shock that people face in pursuit of their livelihoods. The disease, FMD is covariant risk factor which threatens producers' livestock. How susceptible these producers are, is determined by the producers' perceived risk factors of FMD due to the outbreak. These factors together with the socio-economic and institutional factors result in some degree of economic loss which resulted in the forgone EU market opportunity. Possession of socio-economic and institutional factors which are producers' attributes, alongside the producers' perceived risk factors and the economic losses experienced, determine how they respond to FMD hits.

Following an outbreak, producers who are rational and have continued in beef farming regardless of the economic losses incurred are assumed to have adapted at least one of the following ex-post response measures that maximize their outcome. A household might choose response 1: alternative grazing areas, which follows past lessons learnt by producers who became victims of FMD grazing their cattle east of the railway line closer to the border, so substitute grazing areas west of the railway line exist. Communally grazing producers who are very prone to FMD might choose to enter into a collective action production system of ranching, such is ex-post response 2. Culling could be done to separate the adult cows from the young ones as they are believed to be more prone to FMD (Response 3).

Some producers might choose to restrict the grazing movements of cattle away the border while some may get private watering points as depicted by response 4 and 5, respectively. As for responses 6, 7 and 8 producers might venture into diversified income portfolios to enhanced income sources. Regarding response 9, some producers might decide to move some of their livestock to other green zones free from outbreaks. The final response involves producers in a group working collectively to mend damaged cordon fence. It is with great expectation that the responses shall cushion producers from future outbreaks, more resilient and realize improved incomes. This shall contribute to enhanced food security and overall improvement in welfare.

CHAPTER THREE

METHODOLOGY

3.1 Study area

The study was conducted in North East district, which is in the veterinary disease control zone of zone 6. The district is the second smallest of the 10 districts in Botswana and lies within coordinates 21°5′0″S, 27°30′0″ E. Specifically, three sub-district veterinary areas (SDVA) namely: Matsiloje, Matshelagabedi and Tsamaya in zone 6b were surveyed. The last FMD outbreak was confined to zone 6b boundaries (a protection zone of zone 6a) which is east of the railway line closest to the nearest border fence and did not cross over to zone 6a. North East district encompasses Francistown which is home to one of the three Botswana Meat Commission's (BMC) abattoir plants that export to the international market (van Engelen *et al*., 2013). The district borders Zimbabwe from the East and the Central district from the west (Figure 3).

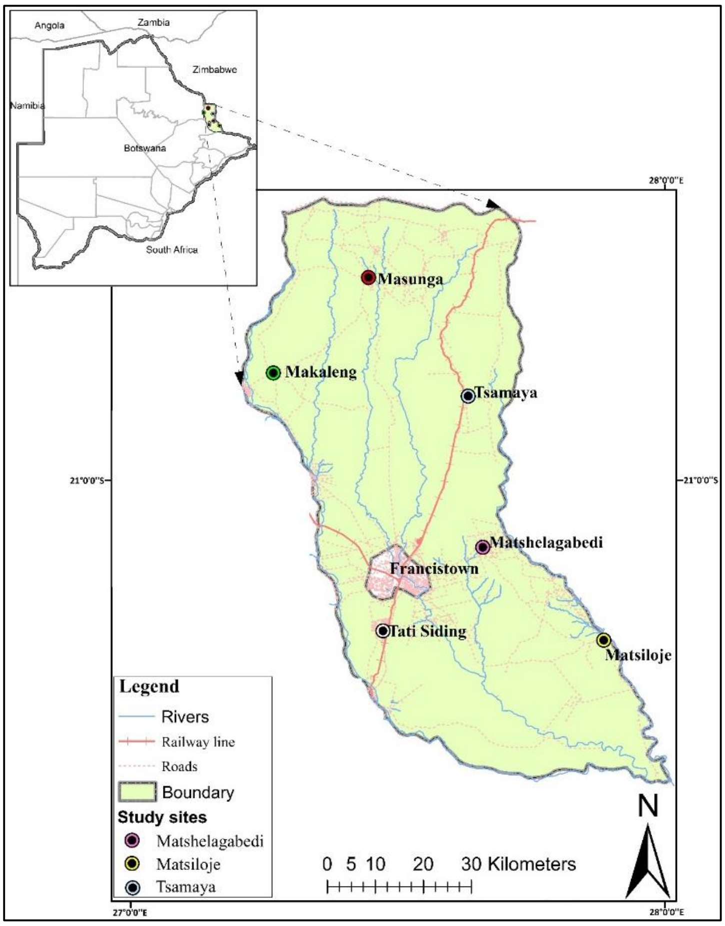

Figure 3: Map of North East district

Source: World Resource Center (2017)

The district is defined by a semi-arid climate with average annual rainfall of 470 mm and temperature ranging from 4°C to 35°C (Mogotsi *et al*., 2016). Vegetation is characterized by woody species of *Colophospermum mopane* dominating in numbers (Moreki *et al*., 2016), *Acacia nigrescens Acacia tortilis and Combretum apiculatum* (Mogotsi *et al*., 2016) and grass species such as *Aristida congesta, Eragrostis rigidior, Panicum maximum, Schmidtia pappophoroides* and *Urochloa mosambicensis (*Madzonga and Mogotsi, 2014; Dambe *et al*., 2015*)*. Ntshe, Ramokgwebana, Shashe and Tati rivers cover most of the district in length. Dwellers are associated with mixed farming since agriculture is a dominant activity usually for subsistence purposes. Livestock keepers are defined by community grazing (cattle and small stock) and arable farmers usually grow rain fed field crops (millet, sorghum, groundnuts and beans) (Moreki *et al*., 2016). Gathering of mopane worms (*Imbrasia belina*) is an economic activity generating income and providing a protein source to the district's inhabitants.

3.2 Sampling technique

Multistage sampling procedure was used to select the study respondents. North-East district has been purposively selected because it was the most affected FMD free-zone without vaccination, from trans-boundary transmissions of 2011. Within the district, Sub-District Veterinary Areas (SDVA) affected by the recent FMD outbreak of 2011 due east of the railway line were purposively selected (Table 1). The total population of beef producers in the three SDVAs was 837 according to the information from the Sub-district Veterinary Offices (SDVO). Thereafter four villages were randomly selected in each SDVA, amounting to 12 villages altogether. From then, starting at some random place at the top of the list, from a population source list obtained from the SDVOs, every 3rd producer name was selected until the desired sample size was reached. The sample derived for each SDVA was distributed proportionately by size to the villages.

3.3 Sample size determination

The study adopted Yamane's (1967) sample size formula where at 95% confidence interval, the sample size was found as;

$$n=\frac{N}{1+N(e)^2} \qquad (3)$$

Where

n is the desired sample size, N is the population size and ℓ is the acceptable error (0.05).

$$n = \frac{837}{1 + 837(0.05)^2} = 271 \text{ respondents}$$

Table 1: Producers' population and sample size

SDVA	Veterinary zone	Number of producers	Sample size
Matsiloje	6b	327	106
Matshelagabedi	6b	195	63
Tsamaya	6b	315	102
Total		**837**	**271**

Source: Department of Veterinary Services, Botswana (2017)

3.4 Data collection and analysis

Prior to a full scale study, a pretest on 14 households was done to check the validity of the questionnaire with the help of 4 enumerators who were trained preceding the preliminary test and after corrections were effected. The study used both primary (cross-sectional) and secondary data. Primary data was sourced through a semi-structured questionnaire which was administered to beef producers during the period of May and June 2017. Secondary data was collected from District Veterinary Office (DVO) reports and reviews from journals, reports, books and the internet. Data was then managed using STATA 14 and SPSS 22.

3.5 Analytical framework

Objective 1 (To determine smallholder producers' perceived risk factors of foot and mouth disease outbreak in North East district)

3.5.1 Perceived risk of producers to diseases has received considerable attention in the field of animal health particularly the disease of foot and mouth. Several literature (Ayebazibwe *et al*., 2010; Allepuz *et al.*, 2013; Elnekave, *et al*., 2015; Jemberu *et al*., 2015; Abdela, 2017) have documented perceived risk factors to animal diseases. To explore the animal health of cattle based on the perceptions of producers, FMD perception statements were ranked on a point rating scale or Likert scale.

Every household selected, ranked and scored major risk factors of FMD in their area. The relevant level of perception assigned to the variable was according to the household's judgment. The risk factors were on the basis of FMD being introduced in a farm when there is an outbreak. Owing to differences in the economic impacts of FMD among smallholders, these producers are expected to have different perceptions about the risk of the disease (Jemberu *et al*., 2015).

To analyze the perceptions, descriptive statistics for all variables was generated into numerical calculations like means, frequencies, percentages or graphs and tables (Greene, 2012). Further, the study employed inferential statistics to make inferences about the population based on the data sample. The t-test and F-tests were generated to make inferences on whether significant differences exist between the means of two or more groups.

Further, the study derived odds ratio and ranked the FMD risk factors. Odds ratio (OR) was used to determine factors attributed to the outbreak. It is a measure of association between exposure and outcome (Szumilas, 2010), in this case, FMD factors and the disease itself. Furthermore, OR explores the possibility that an FMD outbreak will occur given the exposure factors compared to the odds of the outbreak occurring in the absence of the exposure. To an extent, OR is used to determine where the exposure is a risk factor for FMD as well as comparing the magnitude of the different risk factors of FMD. The odds ratios were calculated using a two-by-two frequency table.

		Outcome status +	Outcome status -
Exposure status	+	a	b
	-	c	d

Where

a= Number of exposed cases, b= number of exposed non-cases, c=number of unexposed cases and d=number of unexposed non-cases. Therefore,

$$OR = \frac{a/c}{b/d} = \frac{ad}{bc}$$

The odds ratio are thus interpreted according to Szumilas (2010) and Australian Physiotherapy Association (2016) as;

OR<1 exposure associated with lower odds of outcome (FMD less likely to occur)
OR=1 exposure does not affect odds of outcome
OR>1 exposure associated with higher odds of outcome (FMD more likely to occur)

The confidence intervals (CI) at 95% will further be used to confirm precision of the OR, though it does not report the statistical significance of the measure. Large CI are associated with low precision level and the opposite is true. A CI that straddles an OR over 1 is used to explain an association between exposure and outcome. The most commonly used significant tests for odds ratio are Fisher's Exact Probability test, the Likelihood Ratio Chi-Square and the Pearson Chi-Square.

Further, in terms of ranking the risk factors, the Friedman test was used to evaluate the level of importance of risk factors attributed to the last outbreak, since it was ordinal in nature. The procedure is used to rank variables by level of importance. The data was measured on a 4-point scale from not important to very important. The null hypothesis for the Friedman non-parametric analysis of variance is that there exists no differences between the variables under investigation. The null is rejected when the *p*-value is less than the indicated significant level, implying that at least two of the variables are significantly different from each other. Chi-square (Friedman Q) shows how far mean ranks lie apart, so similar distributions imply that mean ranks are equal. The alternative to Friedman is a repeated measures ANOVA which however is limited since is wanting in the absence of normally distributed variables. The perception statements used on FMD risk factors are in Table 2.

Table 2: Variables to measure perceived risk factors of foot and mouth disease outbreak

Variables	Description
distnrb	Being within 10km to the nearest border
distnp	Being within 10km of national parks
commgraz	Producer grazing communally
distgraz	Cattle grazing more than 5km distance
distwater	Water sources beyond 5km distance
aniden	Having more than 20 animal herds
earlywarn	No access to early warning information about the outbreak
prevexp	Exposed to FMD previously
fencdam	Frequent veterinary cordon fence damage
presbuf	Presence of buffalos
theft	Frequent livestock theft
apathy	Apathy by cattle owner or herdsmen
season	Season of the year (dry season)
agecow	Age of cow in months (young ones)
breed	Type of cattle breed (indigenous)
tsamaya	Farming in Tsamaya
matshela	Farming in Matshelagabedi
matsiloje	Farming in Matsiloje

Objective 2 (To determine economic losses due to foot and mouth disease during the last outbreak among smallholder producers in North East district)

3.5.2 Following an outbreak, economic losses are recorded through morbidity, mortality and imposed trade restrictions (Alemayehu *et al*., 2014; Abdela, 2017). However, due to the notion that Botswana's control strategy is stamping out, the losses recorded then were only due to imposed trade restrictions.

Estimation of economic loss

The study determined economic losses based on the livestock restrictions imposed by the EU due to the outbreak which resulted in temporary loss of market access. As a result of the outbreak, the GoB embarked on massive stamping out of cattle irrespective of their morbidity condition. Farms were sampled for clinical testing and some tested seropositive to the virus.

Justified, stamping out was executed reason being that producers use a communal grazing system which poses the uninfected cattle a great risk of contamination or that some had already caught the disease but were yet to show the signs. Since compensation was carried out irrespective of breed, age or condition of the livestock, stamping out process only accounted for the cattle numbers possessed. Producers however were able to confirm the herd structure of their cattle and the estimated market prices they would have received had they exported. The economic losses were thus calculated as;

$$C = \sum N * M \qquad (4)$$

Where

C = the annual economic loss estimated in Pula, N = total number of cattle slaughtered following the outbreak and M = average EU market prices in Pula.

Opportunity cost

Once economic losses were determined, the study further estimated how much households had to forgo due to the last FMD outbreak given that they had received some compensation for their cattle, valued at P1700.00 (USD165.69) per animal. Opportunity cost which is explained by the benefit a household could have received, had they sold to the EU, but due to FMD, their livestock were slaughtered and were compensated. The cost was calculated as;

Opportunity cost = return of the lucrative market – return of compensation (5)

$$OP = R_L - R_C$$

Where

Return of the lucrative option was measured using EU market prices (USD 450-600) and compensation payments (valued at P1700.00 per cow).

Objective 3 (To determine factors that influence economic losses due to foot and mouth disease during the last outbreak in North East district)

3.5.3 A quantile regression (QR) model was fitted to the data to determine factors which influenced the economic losses experienced due to the last FMD outbreak of 2011. The model was first introduced by Koenker and Bassett (1978) and models conditional quantiles as a function of predictor variables. It determines the effect of covariates on the location, shape and scale of the entire response distribution (Koenker, 2005).The term quantile refers to a principle of dividing a probability distribution into contiguous intervals with equal probabilities, or simply dividing a dataset into equal size groups. These groups could be in three (tertiles), four (quartiles), fives (quintiles) all the way to 1000 quantiles (permilles). The current study data adopted quintiles where four cut points (0.2. 0.4, 0.6 and 0.8) divided the dataset into 5 groups.

Quantile regression is a linear regression model but yields better model results than Ordinary Least Squares (OLS). OLS results yields estimates that approximate the conditional mean of the response variable given certain values of the predictor variables, whereas QR aims at estimating the conditional median which goes beyond the mean boundaries hence, not affected by outliers. Thus, quantile regression estimates are more robust against outliers in the response measurement accommodating cases where error exhibits long tails, non-normality distribution and to an extent non-linear relationships with predictor variables (Koenker, 2001; Chen *et al*., 2016). Therefore, QR yields more efficient estimates which are more desirable than OLS. Furthermore, QR has been used to discover more useful predictive relationships between variables in cases where there is no relationship or a weak one exists between the means of the variables. According to Koenker and Hallock (2001) and Koenker (2005) QR is mainly merited over OLS for its flexibility to model data with heterogeneous conditional distributions.

Least squares regression addresses "on average, the socio-economic and institutional characteristics affecting the economic losses incurred by producers" since it assumes that, associations between independent and dependent variables are the same at all levels. However, it cannot answer whether the factors influenced the losses incurred differently by producers from thousands, through to hundreds of thousands and millions of Pulas. Thus, quantile regression provides a complete picture of the effect of the predictors on the response variables (Koenker and Bassett, 1978) by modelling predictor variables and specific quantiles of the economic losses and allows for comparisons between the quantiles.

A QR is attributed to a duality case implying a linear programming solution where minimizing with respect to the original variables turns into a maximization problem. The regression minimizes the objective function, where the τ^{th} regression quantile $0<\tau<1$ is defined as any solution to the minimization problem given as thus according to Koenker and Bassett (1978):

$$Q_Y(\tau|x_i) = \alpha(\tau) + \beta(\tau)x_i + \varepsilon_i(\tau) \tag{6}$$

The model can be estimated for any $\tau \in (0, 1)$ by solving the given problem,

$$\min_{b\in\Re}\left[\Sigma_{t\in\{t:y_t>b\}}\tau\left|y_t-b\right|+\Sigma_{t\in\{t:y_t<b\}}(1-\tau)\left|y_t-b\right|\right]$$

Where

Y is a function of x_i explanatory variables at a certain quantile regression distribution (τ = 0.2, 0.4, 0.6 and 0.8) and makes not distributional assumptions about the error term in the model. $\{y_t: t=1,\ldots T\}$is a random sample on a random variable Y having distribution function *F*. The least absolute error estimator is the median (τ =1/2), a special quantile describing the central location of a distribution. Table 3 presents variables used in the quantile regression model and their priori signs.

Table 3: Description of explanatory variables used in quantile regression

Variables	Description and unit of measurement	Expected sign
Dependent		
Logoppcst	Opportunity cost incurred by producers in Pula	
Independent		
age	Age of household head in years	-ve
gender	Gender of household head, 1=male and 0=female	-ve
years_of_schooling	Household head years of formal education	-ve
farm_exp	Beef farming experience in years	-ve
HHS	Number of household members	-ve
Outmktdistmin	Distance to output markets in minutes	+ve
Nextfdistmin	Walking distance to the nearest cattle farm (mins)	-ve
Nrbdistmin	Distance to the nearest border in minutes	-ve
Grazdistmin	Distance cattle walk to grazing areas in minutes	+ve
Waterdistmin	Distance cattle walk to water sources in minutes	+ve
Numext	Number of contact with extension service providers	-ve
logoff_farm	Value of off-farm income in Pula	-ve
SDVA_dummy2	Farming in Matshelagabedi	-ve
SDVA_dummy3	Farming in Tsamaya	-ve
Totlansz	Agricultural land size in hectares	-ve

Objective 4 (To determine the effect of socio-economic and institutional factors on choice of smallholder producers' ex-post response to FMD in North East district)

3.5.4 Evidence from the field survey gathered that beef producers in the district adopted 10 responses following the 2011 FMD epidemic. Principal Component Analysis (PCA) was used to reduce the responses into categories similar to Mugi-Ngenga *et al*. (2016). As the ultimate role of PCA, the dimensionality of interrelated responses was reduced, which was done while retaining most of the information in the original variables as much as possible. However, the variable reduction technique was evidenced by moderately correlated and ordered principal components resulting from oblimin and promax (oblique) rotation to be used later for MVP modelling. As a criterion, principal components with eigen values exceeding 1, also known as *Kaiser's rule*, were retained (Jolliffe, 2002).

The model representation of PCA is thus given as:

$$C_1 = b_{11}(x_1) + b_{12}(x_2) + ...b_{1n}(x_n) \quad (7)$$

Where

C_1 is principal components, b_1 - b_n are the correlation coefficients of i^{th} variable on the i^{th} factors and x_1 - x_n are the factors influencing choice of ex-post responses.

Subsequent to reduction of dimensionality, the response categories were subjected to a multivariate probit (MVP) analysis with the objective to model the effect of factors influencing choice of responses to FMD. Understanding drivers behind adoption of responses is key for policy as it directs the interventions necessary for enhanced resilience of smallholder producers' production system to FMD outbreaks.

The study employed MVP model to analyze the fourth objective. Other studies have used multinomial logit (MNL) to model the effect of factors influencing adoption of technologies, however with the assumption of Independence of Irrelevant Alternatives (IIA). Further, some studies which assumed IIA, their results violated the assumption, rendering the estimates inconsistent and ultimately model misspecification. The study employed MVP which is free from the independence assumption and has been proved more efficient and accurate than the MNL in minimizing heteroscedasticity.

The model is deemed appropriate because it allows for producers to make a choice among several measures which for this case are unordered and nominal in nature (Gujarati and Porter, 2009; Greene, 2012). The choices which may be more than two, solely depend on the responses which yield maximum utility modeled in a random utility model (RUM). Utility is observed through the producers' selection of an alternative response to FMD. A satisfying number of studies used MVP to investigate factors influencing a producers' decision to adopt a choice strategy (Kassie *et al*., 2012, Rodrigues-Entrena and Arriaza, 2013; Feleke *et al*., 2016; Mulwa *et al*, 2017; Nigussie *et al*., 2017).

Further, the model is used to jointly estimate numerous correlated binary outcomes associated with ex-post responses. Based on the conceptualization that producers are likely to adopt a combination of responses to FMD, MVP model was deemed appropriate for analysis. The model has the ability to simultaneously analyze interdependent adoption decisions of beef producers. Furthermore, MVP results can possibly report a vital characteristic of the response correlations which imply some level of dependence of the ex-post responses on each other. A univariate regression analysis presents a risk through possible omission of information that can be useful in informing policy (Kassie *et al*., 2012; Rodrigues-Entrena and Arriaza, 2013; Mulwa *et al*., 2017). The model was fitted to the data to simulate the influence of socio-economic and institutional factors on the response categories.

According to Cappellari and Jenkins (2003) and Kassie *et al*., (2012), MVP is specified as indicated:

$$y_{im}^{*} = B_{m}^{'} x_{im} + \varepsilon_{im} \quad m = 1, \ldots, M \tag{8}$$

$$y_{im} = 1 \text{ if } y_{im}^{*} > 0 \text{ or 0 otherwise}$$

Where

y_{im}^{*} is the latent variable which captures the unobserved preferences associated with the m^th^ choice that a producer makes of the response categories as well as the unobserved traits captured by the error term ε_{im}. $B_{m}^{'}$ is the beta vector that is to be estimated, assumed to be explained by a set of explanatory variables (x_{im}),which influence choice m = 1, 2, 3, 4 response categories to be modelled.

The assumption is that the error term follows a multivariate normal distribution and each error has a zero mean and they are correlated. Further on the variance- covariance matrix, values of 1 are run on the leading diagonal, and as off-diagonal elements, correlations $\rho_{jk} = \rho_{kj}$ exist. According to Cappellari and Jenkins (2003) the model is likened to that of a Seemingly Unrelated Regression (SUR) model only that the dependent variables are binary data. For SUR model there is no need to include the exact same set of explanatory variables in the equations.

Table 4 explains socio-economic and institutional independent variables used in explaining producers' ex-post response to FMD outbreaks and their expected signs.

Table 4: Description of independent variables in the multivariate probit model

Variables	Description and unit of measurement	Expected signs
Dependent		
Preventative measure	(other green zones, mending fences collectively)	
Diversification	(other livestock business, off-farm, alt. water)	
Segregated farming	(restricted movement, started crop farming)	
Controlled farming	(alt. grazing areas, collective ranching, culling)	
Independent		
age	Age of household head in years	-ve/+ve
gender	Gender of household head, 1=male and 0=female	+ve
years_of_schooling	Household head years of formal education	+ve
HHS	Number of household members	+ve
Grpmemb	Group membership, 1=yes and 0=no	+ve
outmktdistmin	Distance to output markets in minutes	-ve
nextfdistmin	Walking distance to nearest cattle farm in mins	-ve
nrbdistmin	Distance to the nearest border in minutes	-ve
grazdistmin	Distance cattle walk to grazing areas in minutes	+ve
waterdistmin	Distance cattle walk to water sources in minutes	+ve
numext	Number of contact with extension services	+ve
numtrain	Number of trainings received on FMD	+ve
fmdinc	Number of FMD incidences previous exposed to	+ve
Logoppcst	Opportunity cost incurred by producers in Pula	+ve
logassets	Value of agricultural assets owned in Pula	+ve
SDVA_dummy2	Farming in Matshelagabedi	-ve
SDVA_dummy3	Farming in Tsamaya	-ve
totlansz	Agricultural land size in hectares	+ve
Offinc	Off-farm income access, 1=yes and 0=no	+ve

CHAPTER FOUR

RESULTS AND DISCUSSION

The chapter is divided into five sections. Section 1 presents descriptive statistics of household socio-economic and institutional characteristics. Descriptive results on the risk factors of FMD are discussed in the second section. In section 3, economic losses due to the last outbreak are reported and section 4 discusses factors attributed to the losses. Finally, the last section discusses empirical results of the multivariate probit model on the effect of socio economic and institutional factors on adoption of ex-post responses to FMD. Descriptive results noted that 61% of the producers' livestock did not suffer from the disease (unaffected) while 39% were affected.

4.1 Descriptive statistics

4.1.1 Producer characteristics

Table 5 presents results on the level of education and gender of the household head. For households whose cattle were infected by FMD, the majority (53%) of household heads attained primary education similar to household heads who did not experience the disease among their livestock at 59% majority. Some beef producers had no access to formal education as noted from affected and unaffected households at 8% and 12%, respectively. A small proportion of household heads affected (3%) and not affected by FMD (4%) attained tertiary education. Unaffected household heads had relatively higher levels of education than those affected by FMD. Higher levels of education could guarantee access to information owing to years of exposure to knowledge which leads to informed farm decisions (Mulwa *et al*., 2017; Paul *et al*., 2017). This could translate to adopting measures that can deter livestock from contracting FMD.

Over half of the female headed households were mostly affected (59%) and unaffected (51%) by FMD compared to their male counterparts who recorded lower experiences on affected and unaffected livestock at 41% and 49%, respectively. The results reveal that, 54% of the producers in the district were males. Horvoka (2012) noted that beef production is still a male dominated venture. Gender is a key aspect in explaining whether livestock will get infected by FMD during an outbreak. Males, who are characterized by access to resources and skills are less likely to be affected by FMD given their resource endowments which allows them to invest in disease prevention measures. Literature notes that males are endowed with more farm resources than their counterparts and are less risk averse when it comes to investing in risk coping measures (Heffernan *et al*., 2008; Coulibaly *et al*., 2015).

Table 5: Education level and gender of the household head (%)

	FMD experience		
Variables	**Affected**	**Unaffected**	χ^2 **value**
Education level			
Non-formal	8.49	12.12	3.098
Primary	52.83	58.79	
Secondary	25.45	33.01	
Tertiary	2.83	3.64	
Gender			
Male	40.57	49.09	1.890
Female	59.43	50.91	

Results on age, farm experience and household size of the household head are presented in Table 6. The mean age of those who experienced the disease was 55 years while those who did not experienced were aged 58 years. On average, beef producers in the area are older. Farm experience of households who experienced the disease among their livestock was 22 years while those who did not had been farming for 23 years. The age of the household head and farm experience showed a strong correlation (0.60) between the two variables. Household heads with more farming experience (older producers) are more likely to make informed decisions on preventing FMD transmissions than their younger counterparts. This is based on the perception that given their long years of experience which has equipped them with more knowledge especially on indigenous techniques of FMD trends, they are able to cope better by adopting technologies (Mugi-Ngenga *et al*., 2016; Paul *et al*., 2017). In Namibia, adoption of cattle management technologies was increased with education (Musaba, 2010).

The household size of farm households whose cattle were affected and those not affected averaged to 6 and 5 members per family, respectively. Large households are endowed with family labour which can be utilized especially to facilitate on-farm activities (Kelebe *et al*., 2017). The extra labour demand as catered for by the family can enable adoption of innovations geared towards deterring FMD infection among livestock.

Table 6: Mean of producer characteristics

	FMD experience		
Variables	**Affected**	**Unaffected**	**t-value**
Age	55.49	58.45	1.579
Farm experience	22.41	23.40	0.575
Household size	5.62	5.29	-0.913

4.1.2 Farm characteristics

Table 7 presents farm characteristics: the number of cattle producers had before the outbreak, agricultural land size available to them and the value of their agricultural assets. Number of cattle was statistically related to the FMD experience at 1% significant level. The average herd size for producers who experienced the disease in their stock was 21 per household compared to 31 cattle for those who did not experience. Large herds of cattle could restrict the owner or herdsmen from traveling long distances to access grazing field. This is probably because it is difficult to manage a large herd size at pasture lands as compared to smaller herds which stand a great chance of contracting the disease during an outbreak. However, literature notes a contrary finding on cattle density and FMD infection. Muroga *et al*. (2013) and Elnekave *et al*. (2015) in Japan and Israel respectively, noted that high cattle densities were associated with high FMD transmissions thus a risk factor of FMD outbreaks.

There was a significant ($p<0.01$) relationship between FMD experience and agricultural land size owned by farm households. The land size of affected households averaged 4.43 hectares and while those not affected was 4.57 hectares. During times of plenty (harvest and good rains season), producers usually graze their livestock around their farm lands hence there was restricted contact with infected cattle. According to Sinkala *et al*. (2014) FMD spreads quickly where animals easily interact with each other which is at grazing lands.

In terms of agricultural asset value, those who experienced the disease had average assets valued at BWP120, 762.40 (USD11, 770.21) while the remainder owned an average of BWP128, 533.30 (USD12, 527.61). Households who are well endowed have access to liquidity which they can use to invest in agricultural technologies that prevent FMD transmission and contamination among their livestock. In Kenya and Ethiopia, Kebebe *et al*. (2017) noted that adoption of improved dairy technology was due to farmers' ownership of more farm resources.

There was significant relationship between FMD experience and participation in off-farm income activities at 10% significant level. Households whose farms were affected by FMD had access to BWP7, 752.64 (USD755.62) off-farm income *per annum* while households who were not affected had access to BWP11, 800.30 (USD1, 150.13). Access to extra income earning enterprises allows for investment in measures that could minimize FMD transmission hence reduced FMD infection among livestock. Musaba (2010) noted that adoption of cattle management technologies by communal farmers in Namibia was increased with off-farm income.

Table 7: Mean of farm and off-farm characteristics

	FMD experience		
Variables	**Affected**	**Unaffected**	**t-value**
Total livestock units before outbreak	21.14	31.35	-2.973***
Agricultural land size (ha)	4.43	4.57	-3.714***
Agricultural assets (BWP)	120, 762.40	128, 533.30	0.466
Off-farm income (BWP)	7, 752.64	11, 800.30	1.876*

Note: *, * =** significant at 10% and 1% level, respectively.

4.1.3 Institutional characteristics

Institutional characteristics are presented in Table 8. The average number of contact that producers had with extension service was 1.61 and 1.62 for affected households and those not affected, respectively. Agricultural extension service packages in the district are wholly provided by the government. Contact with agricultural service providers is important since it ensures access to information which provides knowledge on how to prevent livestock from FMD infection. In arid and semi-arid lands of Kenya, the number of extension visits increased adoption of natural pastures improvement technologies (Manyeki *et al*., 2013).

On average, those affected by FMD received 0.38 training while those not affected received 0.33 number of trainings. Majority (67%) of household heads did not undergo training on FMD dimension. Training equips producers with information on how to prevent FMD transmissions to their livestock in case of an outbreak. Training is important as it equips producers with the specialized skills and knowledge necessary to effectively carry out proper management practices specific to preventing contamination of FMD among livestock. Training in animal health increased adoption of cattle management technologies by farmers in Namibia (Musaba, 2010).

There was a significant relationship between distance to the nearest market and the FMD experience at 5% significant level. Distance to the nearest market was 87.74 minutes on average for producers whose livestock were affected by FMD and 48.30 minutes for household farms not affected. Farms closer to the market can easily access information on measures to implement in order to protect their livestock from FMD outbreaks as they occurred. In Ethiopia, Birhanu *et al*. (2016) noted that market provided access to information and services which contributed to increased adoption of livestock feed technologies.

Table 8: Mean of access to institutional characteristics

	FMD experience		
Variables	**Affected**	**Unaffected**	**t-value**
Number of contact with extension service	1.61	1.62	-0.088
Number of trainings on FMD	0.38	0.33	-0.686
Distance to the nearest market (min)	85.74	48.30	1.611**
Distance to the nearest neighboring cattle farm (min)	3.00	4.19	-1.916*
Distance to the nearest border point (min)	343.58	389.86	-1.157*
Distance to grazing fields (min)	167.33	137.97	1.798*
Distance to water points (min)	43.35	38.22	0.891
FMD incidences experienced	1.28	1.76	-6.782***

Note: *, **, *=**significant at 10%, 5% and 1% level, respectively.

Distance to the nearest neighboring cattle farm was statistically significant ($p<0.1$) in explaining the FMD experience. For affected household farms, they were within 3 minutes of each other whereas those not affected where 4 minutes away. Nearness of farms makes it easier for FMD to spread to the next unaffected farm. Nearby farms are likely to share pasture lands, thus interaction between livestock might predispose as a risk factor of FMD transmission mode. This is consistent to Muroga *et al*. (2013) who noted that farms far from each other were less likely to transmit the disease as compared to farms closer to each other.

There was a significant relationship between distance to the nearest border point and the FMD experience at 10% significant level. Producers farming closer to the border are at high risk of contracting the FMD virus through cross-border transmissions during outbreaks than those far away. Allepuz *et al*. (2013) and Moreki *et al*. (2016) in Tanzania and Botswana respectively, found that farms closer to borders were at high risk of FMD infection.

There was a significant difference ($p<0.1$) in the distance to grazing fields and FMD experience. For affected farms, livestock travelled an average of at least 167 minutes (2 hrs and 47 mins) and for those not affected (2 hours 18 minutes) to access pasture lands. Longer distances travelled to access grazing fields increased the probability of FMD infection. This is probably because longer distances increased livestock contact at grazing areas which increased FMD infection given that transmission of the FMD virus is usually high in case of an attack (Sinkala *et al*., 2014; Kim *et al*., 2016). Further, longer distances travelled make it difficult to manage and restrict interaction among livestock along the way as they meet in the pursuit to find pasture lands.

For affected farm households, livestock travelled an average of 43.35 minutes to access drinking water while for households not affected, livestock travelled for about 38.22 minutes. Longer distances to water sources can lead to livestock being affected by FMD during outbreaks. This is probably because long distances increase the chance of FMD infection among livestock as they interact with other livestock. This is because water sources further from farms were community resources. Further, sharing the same water reserve as was done by most producers who watered their livestock on government/community boreholes, the FMD virus if found in the water could be easily transmitted to the rest of the stock. Sinkala *et al*. (2014) noted increased FMD spread at common water sources.

There was a significant relationship between number of incidences exposed to and FMD experiences. On average, households who were exposed to the 2011 FMD outbreak had experienced FMD infections among their livestock before. Previously affected households are likely to adopt risk coping measures in order to guard against future economic effects of FMD. In Malawi, Coulibaly *et al*. (2015) noted that crop farmers faced with numerous crop failure were likely to adapt climate change strategies.

4.2 Smallholder producers' perceived risk factors of foot and mouth disease outbreaks

Eighteen variables associated with the last outbreak were evaluated to draw the perceived risk factors of FMD. Producers were given an option to select the factors they believed attributed to the outbreak. First, the reliability of the instrument was appraised. The Cronbach coefficient alpha (α) was used to gauge the reliability of the Likert questions asked, as a measure of internal consistency. According to Teo and Fan (2013) coefficient alpha is commonly used to determine if the scale is reliable. Thus, a value of 0.865 which is greater than the threshold of 0.7 indicated that the scale was certainly reliable (Appendix 2a). Further, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of 0.754 noted that the sampling was adequate.

Frequencies (%) of factors associated with the last FMD outbreak by location are presented in Figure 4. From the 18 variables evaluated, 12 variables stood out as common factors of concern. Matsiloje location recorded high frequencies on FMD risk factors as the area is most prone to FMD than the other two sub-districts.

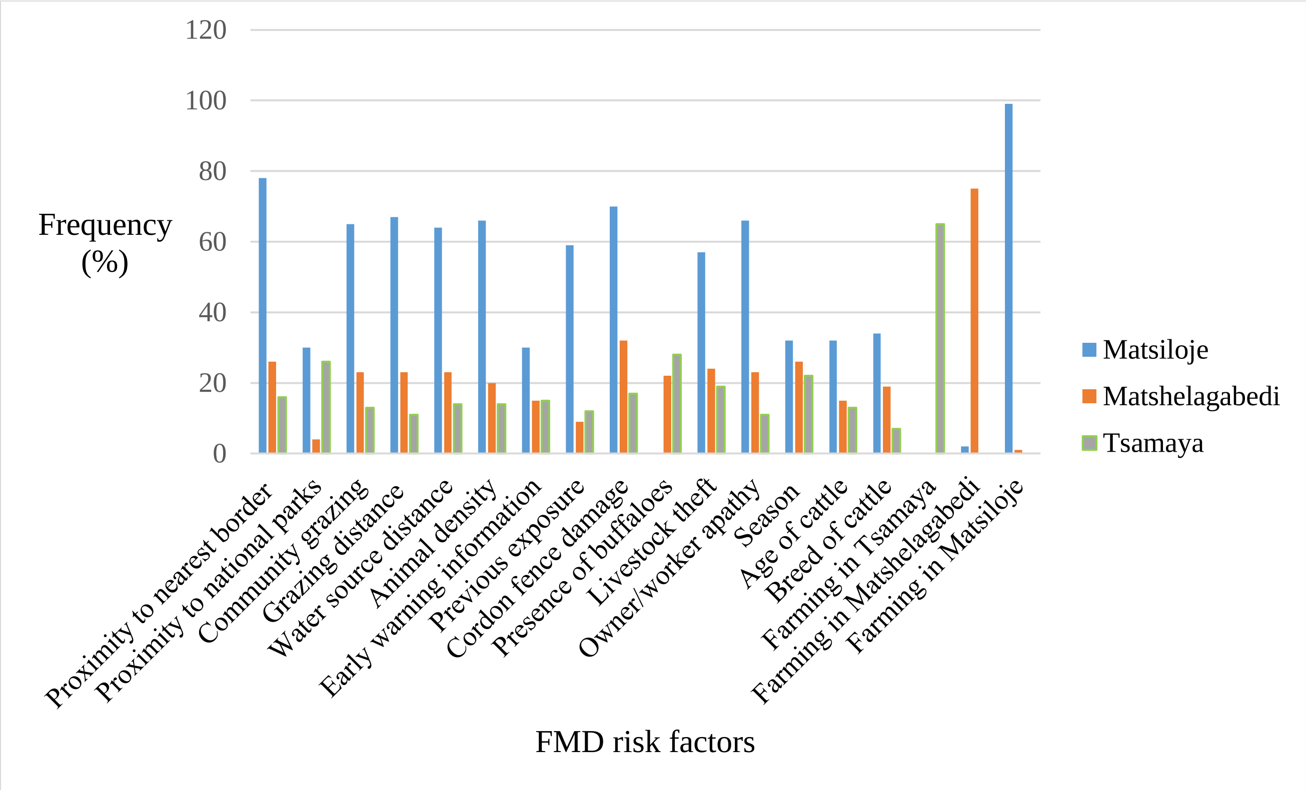

Figure 4: Frequencies of FMD risk factors by location (%)

4.2.1 Foot and mouth disease risk factors due to the last outbreak

4.2.1.1 Odds ratio

The FMD associated risk factors are presented in Table 9. Odds ratio is an effect size statistic that measures the ratio of the odds that FMD will result to the odds that it will not happen. The factors with point estimates exceeding 1 indicate a high probability of FMD occurrence as well for factors with confidence intervals spanning over an odds ratio of 1. Factor 1, distance to the nearest border, was made a reference category since it was chosen by most producers. Therefore, proximity to the nearest border, grazing communally, previous exposure to FMD, cordon fence damage, owner/ worker apathy and farming in Matsiloje were associated with higher odds of an FMD outbreak.

The 2011 FMD epidemic occurred in zone 6 which is along the border line. Outbreaks in the zone are usually due to spillover effects from the nearest border thus, farms closest to the border were at more risk of contracting FMD virus than otherwise. The current findings are similar to van Engelen *et al*. (2013), Mogotsi *et al.* (2016) and Moreki *et al*. (2016). Similarly, Allepuz *et al*. (2013) and Elnekave *et al.* (2015) found concurring trends with FMD occurrences in the vicinity of borders in Tanzania and Israel, respectively.

Community grazing by smallholder producers increased the spread of FMD during the 2011 outbreak period. This type of system allows for interactions between livestock at pasture lands and water sources which has little to no control leading to transmission of FMD during an outbreak being accelerated. Ayebazibwe *et al*. (2010) and Abdela (2017) reported that communally grazed livestock are more likely to be infected by FMD virus than those grazed otherwise. Literature has further posited that control of the disease is also difficult with this production system (Knight-Jones and Rushton, 2013; Jemberu *et al.*, 2015).

Previous exposure to the disease was another risk factor associated with the last outbreak. Households whose livestock was exposed to FMD before the 2011 outbreak, were at high risk of contracting the virus again according to survey results. The observation was applicable to households that did not have any measures in place to prevent infection.

Table 9: Odds ratio estimates of FMD risk factors

Variables	Odds Ratio Estimates			
	Effect	Point Estimate	95% Wald Confidence Limits	
Distance to national park (within 10km)	Factor 2 vs 1	0.741	0.584	0.941
Grazing communally	Factor 3 vs 1	**1.080**	**0.860**	**1.357**
Cattle grazing at more than 5km distance	Factor 4 vs 1	0.475	0.372	0.606
Cattle drinking at more than 5km distance	Factor 5 vs 1	0.640	0.513	0.799
More than 20 animal herds	Factor 6 vs 1	0.745	0.592	0.938
Access to early warning information	Factor 7 vs 1	0.599	0.475	0.755
Previous exposure to FMD	Factor 8 vs 1	0.943	**0.746**	**1.193**
Cordon fence damage	Factor 9 vs 1	1.053	**0.844**	**1.315**
Presence of buffaloes	Factor 10 vs 1	0.563	0.448	0.707
Livestock theft	Factor 11 vs 1	0.766	0.604	0.970
Owner/worker apathy	Factor 12 vs 1	**1.048**	**0.839**	**1.310**
Season (dry season)	Factor 13 vs 1	0.527	0.414	0.670
Age of cow (young ones)	Factor 14 vs 1	0.729	0.583	0.910
Breed (indigenous)	Factor 15 vs 1	0.683	0.542	0.862
Farming in Tsamaya	Factor 16 vs 1	0.615	0.488	0.774
Farming in Matshelagabedi	Factor 17 vs 1	0.551	0.438	0.693
Farming in Matsiloje	Factor 18 vs 1	0.980	**0.770**	**1.248**

Frequent veterinary cordon fence damage is a major risk factor when it comes to FMD outbreaks in zone 6. Damaged fence allows entry of livestock from neighboring regions, interaction of which leads to FMD outbreaks. The current findings are in agreement with Knight-Jones *et al*. (2016) who reported that fence damages are attributed to illegal movements by people, livestock and wildlife (especially elephants). In South Africa, Jori and Etter (2016) found that fence damages demarcating livestock and wildlife were due to elephants. Despite, maintenance of the same, damages outweigh the efforts.

Another risk factor attributed to the last outbreak was apathy by herdsmen and or livestock owners. Given the type of grazing system which involves livestock trekking for longer periods in search of better pastures, less often than not do herders or owners accompany them to ensure safety and controlled movement. As a result, producers have reported cases of missing livestock which have either gone astray or have been stolen (Mosalagae and Mogotsi, 2013; Mogotsi *et al*., 2016). Lack of interest in proper management of livestock therefore results in accelerated FMD transmissions.

Farming in Matsiloje as a geographic location was a contributing factor to FMD transmission following the 2011 epidemic. The sub-district is within the border line and according to Ayebazibwe *et al*. (2010) and Mogotsi *et al.* (2016), outbreaks of FMD hit first places within border proximities in the case of trans boundary transmissions. Furthermore, the 2002 FMD outbreak was first reported in Matsiloje and Matopi.

4.2.2 Important risk factors associated with FMD outbreak

4.2.2.1 Ranking

The Cronbach's alpha of 0.855 performed on the level of importance (ordinal data) of the risk factors attributed to the last outbreak substantiated that the constructs were reliable (Appendix 2b). The KMO measure of sampling adequacy with a value of 0.785 was also adequate. The perception statement were 18 in total following the risk factors evaluated. Prior to ranking, the Jarque-Bera normality test was carried out and a p-value <0.05 disqualified the use of repeated measures of ANOVA for ranking. The Friedman test, a non-parametric statistical test was then used since it does not assume normal distribution of data.

The mean rank scores presented in Table 10, were used as a guide in ranking risk factors attributed to the last outbreak based on the of the level of importance of the factors. The higher the mean rank, the higher the level of importance. The Friedman analysis of variance test indicated that all the FMD factors are not considered as equally important by producers. The factors are not rated the same way by producers because exposure to FMD was different in terms of location, knowledge of FMD and experience. The test was significant at 1% indicating that significant differences in the overall importance of FMD risk factors existed.

The top most rated FMD factors were nearness to the border, cordon fence damages, livestock theft, farming in the three sub-district veterinary areas, grazing cattle communally, cattle density and distance to grazing and water areas. The current results are similar to Mogotsi *et al*. (2016) who found that veterinary cordon fence damage, livestock theft, wildlife-livestock interface, lack of protection zones and owner apathy hampered control of FMD and accelerated its spread in the area.

Producers significantly considered proximity to the border as risk factor number 1 of FMD due to the last outbreak. As discussed earlier, FMD outbreaks in the North East district (zone 6b) are characterized by spillover effects across borders and farms closest to the border fall victim (Moreki *et al.*, 2016). The second major risk factor was frequent veterinary cordon fence damage. The damage is due to illegal entry and exit by immigrants, wildlife and livestock into either bordering countries. Immigrants could be moving beef products associated with FMD in case of an outbreak across the border and livestock could be carrying the FMD virus itself transmitting it across, consistent with (Mogotsi *et al.*, 2016).

Table 10: Mean ranks of FMD risk factors level of importance

Variable (Level of importance)	**Mean rank**	**Ranking**
Distance to nearest border (within 10km)	13.86	1
Cordon fence damage	13.68	2
Livestock theft	11.54	3
Farming in Matsiloje	10.69	4
Farming in Matshelagabedi	10.34	5
Cattle grazing at more than 5km distance	9.68	6
Grazing communally	9.57	7
Cattle drinking at more than 5km distance	9.45	8
More than 20 animal herds	9.37	9
Farming in Tsamaya	9.09	10
Previous exposure to FMD	8.36	11
Age of cow (young ones)	8.30	12
Owner/worker apathy	8.21	13
Access to early warning information	8.15	14
Breed (indigenous)	7.89	15
Distance to national park (within 10km)	7.81	16
Season (dry season)	7.73	17
Presence of buffaloes	7.29	18
Observations		271
Chi^2		1132.461
Asymptotic significance		0.000

Livestock theft ranked third as a major risk factor of FMD. Producers reported cross border theft which increases exposure to FMD risk across borders (Mogotsi *et al*., 2016). Ranked fourth and fifth were farming in Matsiloje and Matshelagabedi sub-districts, respectively. These veterinary areas are within a 20 km distance from the nearest border line thus, the first receiving ends of FMD during an outbreak. Though ranked 10^{th} was farming in Tsamaya which is also within the veterinary zone highly susceptible to FMD outbreak, is liable to contamination.

Grazing distance exceeding 5 km, grazing communally and water sources at more than 5 km were ranked sixth, seventh and eighth, respectively. The three variables are somewhat related to each other in the sense that communal grazing is characterized by longer distances to pasture lands and water sources. Though the government has provided common boreholes within farms, some producers reported that when these break down, they are forced to water their cattle far from the farms since repairs usually take longer. Previous studies attest to the reality that community grazing exposes livestock FMD (Sinkala *et al*., 2014; Kim *et al*., 2016; Abdela, 2017).

Cattle density was ranked the ninth risk factor of FMD. Producers indicated that having more than 20 cattle herds exacerbated the spread of FMD during an outbreak. This probably explains the reason why households with a large number of cattle experienced high morbidity levels since large herds increase the level of interaction. Similarly, Elnekave *et al*. (2015) reported that high cattle density was a risk factor of FMD. Ranked the least were previous exposure to FMD, owner/worker apathy, access to early warning information which bear little to be discussed. Also, age of cow, breed of cattle and season were ranked least probably because FMD transmission is irrespective of the three suspected factors in the case of North East district. Distance to national parks and the presence of buffaloes were probably ranked the least because FMD outbreaks in North East district are not due to buffaloes-livestock interface transmissions but to trans boundary transmissions.

4.3 Economic losses recorded due to the last outbreak

The losses (direct effects) were calculated on the basis of the forgone international market, thus mortality and morbidity was not taken into consideration. The reason was that the country still embarks on massive stamping out of livestock following an outbreak. Losses were quantified at smallholder producer level only but the study is aware of ripple effects caused across the whole beef value chain with several other actors affected. The opportunity cost forgone by producers was therefore calculated using the difference of the compensation amount that producers received and the rejection rate producers would have received for their cattle at the international market. Due to the 2011 FMD outbreak, Botswana lost access to the EU market and had to redeem its OIE status of a green zone (OIE, 2015) for continued export. During the period of the study, producers reported a market price range of USD450 (BWP4, 617.22) to USD600 (BWP6, 156.30) offered by the export market for their livestock.

Table 11 presents mean values of the losses incurred in comparison to gender. There was a significant relationship ($p<0.05$) between gender and the number of affected livestock. An average of 25 cattle were owned per farm household. Males were found possessing more cattle (average of 30) compared to their female counterparts (average of 19). Thus males have more assets (cattle) than females (Hovorka, 2012; Johnson *et al.*, 2016). Ownership of cattle is biased towards men since cattle reflect high social status (prestige) and wealth which is probably more of a concern for men. According to Coulibaly *et al*. (2015), labour in agriculture is usually dominated by men which could explain the case of cattle production.

Economic losses due to the endemic have been documented across the world but all unique to the area and by case. When it came to the amount forgone, households incurred an opportunity cost of BWP108, 263.80 (USD10, 567.78) on average. Losses were more for men at an average of BWP131, 227.20 (USD12, 813.41) most probably because they possessed a large number of cattle compared to women who incurred a cost of BWP81, 041.13 (USD7, 913.10).

Table 11: Mean values of economic loss by gender

Variables	Gender			
	Female	Male	Pooled	t-value
Cattle number affected	18.85 (1.979)	30.44 (7.039)	25.13 (3.934)	-1.471**
Opportunity cost (BWP)	81, 041.13 (8511.162)	131, 227.20 (30270.710)	108, 263.80 (16917.030)	-1.481

Note: ** = significant at 5% level. Figures in parenthesis denote standard errors.

Losses were also assessed and reported in relation to the different areas surveyed in the district (Table 12). Matsiloje area (35) was characterized by a high mean number of cattle affected per household followed by Matshelagabedi (20) and finally Tsamaya (18). Opportunity cost similarly followed the pursuit; Matsiloje, Matshelagabedi and Tsamaya incurring BWP151, 492.50 (USD14, 796.00), BWP88, 639.68 (USD8, 659.07) and BWP75, 460.78 (USD7, 371.65). Though affected at different degrees, the livestock sustained livelihoods of these producers suffer from threatened food security due to FMD susceptibility.

Due to FMD outbreaks, Botswana usually incurs enormous costs in regaining its FMD free status without vaccination which explains eradication through stamping out then compensation. Due to the last outbreak, the government rolled out a reimbursement programme which was in the form of restocking (livestock) and cash payments. A policy of 100% cash back was offered to producers with 10 or less cattle; 70% cash and 30% livestock compensation policy was for producers who had more than 10 cattle. The package was valued at P1700.00 (USD165.69) per animal (M9ogotsi *et al.*, 2016). However, field survey gathered that some producers opted for an all-out cash back while some chose to get more money than livestock.

The stamping out and compensation is an incentive for these beef producers to continue in production, similarly to promote trade. Buetre *et al*. (2013) noted that the exercise is usually resources intensive since it involves a massive destruction of livestock. Literature has also noted that the exercise is usually opted for so to regain the FMD free zone status with minimum delay following an outbreak which could be within 3 months (Forbes and van Halderen, 2014). There was a significant difference between compensation received by producers and the location at 1% significant level. By and large, the government spent an average of BWP42, 555.35 (USD4, 155.85) recompensing each household surveyed and across the 271 households surveyed in the three sub districts, at total of BWP11, 532, 500.00 (USD1, 126, 492.86) was spent.

Table 12: Mean values of economic loss by sub district veterinary areas

	Sub District Veterinary Areas				
Variables	**Matsiloje**	**Matshela**	**Tsamaya**	**Pooled**	**F-stat**
Cattle number affected	35.22	20.44	17.55	25.13	2.17
Opportunity cost (BWP)	151, 492.50	88, 639.68	75, 460.78	108, 263.80	2.16
Compensation (BWP)	59, 866.04	34, 026.98	29, 833.33	42, 555.35	2.20***

Note: * =** significant at 1% level.

Beef producers had an average of 25 cattle per household which decreased to 17 after the FMD outbreak (Table 13). Thus, there was a 32% decline in the numbers of livestock reared. Due to FMD, production has been declining thus impeding producers from realizing their returns to scale. Consequently, the decline bears ripple effects on trade. In the long run, producers fail to achieve economies of scales which has drastic consequences on food security of these livestock sustained livelihoods. The probable explanation for the decline was attributed to the decision to keep less cattle which will diminish the psychological effects (trauma, stress, loss aversion and anxiety) and economic losses they experienced in the case of future outbreaks.

Previous study by Mogotsi *et al*. (2016) noted that cattle numbers stood at 100 on average per household before the 2011 FMD outbreak in the district. This means that over time producers are gradually loosing hope in beef farming since the slim stock numbers also suggest that some have already exited the industry. This further threatens food security and trade. Discussions with some producers revealed that due to the last outbreak, they are actually keeping cattle not mainly for income generation anymore, but for security in times of crises or needs like funerals and for bride price which need not be too many. Other producers had over 150 cattle each (middle to large scale) but during the study period, the numbers qualified them for interview as smallholder producers.

An average of BWP27, 163.10 (USD2, 649.79) was derived from beef annually by these producers which decreased to BWP12, 865.31 (USD1, 255.59) per annum after the experience which translated to a loss of BWP14, 297.79 (USD1, 395.39). Income losses experienced a drastic 52% curtail due to the last outbreak. On the same note, since the study date, May-June

2017, beef producers noted that they have not been given a green light to sell to the EU again, which means that the effects of the outbreak are still felt worse by these producers who are currently selling in the local market. Moreover, finding the market is difficult given that they sell to local butcheries and events such as celebration parties, funerals and weddings which do not offer good prices. At other times they are forced to sell at any available price due to the pressure of money needs.

Table 13: Mean of cattle numbers and annual income before and after outbreak

	FMD outbreak	
Variables	**Before**	**After**
Cattle numbers	25.13 (64.759)	16.50 (18.020)
Annual income (BWP)	27, 163.10 (22118.210)	12, 865.31 (10834.350)

Note: Figures in parenthesis denote standard deviations.

4.4 Factors influencing economic losses recorded due to the last outbreak

A post estimation, significant value of the Breusch-Pagan/Cook-Weisberg test of heteroskedasticity (p=0.000) endorsed the use of quantile regression for this objective (Appendix 3). The descriptive statistics of the variables used in the QR analysis are presented in Table 14. An average of BWP108, 263.80 (USD10, 575.19) was incurred. Farm households had mean farm experience of 23 years and the total off-farm income generated by producers who had access to any, averaged BWP10, 217.08 (USD998, 19) *per annum*. A proportion of 23% and 38% households farmed in Matshelagabedi and Tsamaya regions, respectively while the remainder were from Matsiloje.

Table 14: Descriptive statistics of quantile regression estimates

Variable	Mean	Std. Dev.	Unit of measurement
Dependent variables			
Opportunity cost	108, 263.80	0.98	BWP
Independent variables			
Age of household head	57.29	15.09	Years
Gender of household head	0.54	0.50	0 or 1
Years of schooling	7.21	4.00	Years
Farm experience	23.01	13.88	Years
Household size	5.42	2.92	Number
Output market distance	62.94	96.33	Walking minutes
Next cattle farm distance	3.47	6.48	Walking minutes
Nearest border distance	361.68	321.45	Walking minutes
Grazing areas distance	155.85	131.72	Walking minutes
Water source distance	41.34	46.22	Walking minutes
Number of extension contact	1.61	1.51	Number
Log of off-farm income	10, 217.08	4.53	BWP
Matshelagabedi location (dummy)	0.23	0.42	0 or 1
Tsamaya location (dummy)	0.38	0.49	0 or 1
Total land size	4.49	2.05	Ha

Differential socio-economic and institutional effects by economic losses due to the last FMD were evaluated. The first quintile includes the 20% minimum losses incurred by households (BWP25, 800.00=USD2, 514.62). The fifth quintile with the largest losses (above BWP137, 600.00=USD13, 411.31) is excluded and forms the reference category. The median (50^{th} quantile) describing the central location of the distribution was added to better explain the results. The model presented in Table 15 generally appears to explain the economic losses better as one moves up through the conditional loss distribution. This is shown by an increase in the value of the pseudo R-squared. Johnson and Hensher (1982) noted that a pseudo R^2 above 0.2 showed a good fit of the model. As for R-squared, a value relatively above 60% is commended. Therefore, the overall results of the quantile regression clearly show efficient estimates compared to OLS results (Appendix 3a).

The QR graphs of the explanatory variables used to explain economic losses incurred by farm households are presented in Appendix 3c. On the horizontal lines (black dotted lines) are the OLS coefficients. The variables do not vary across quantiles, hence are stable. The red lines (around the dotted lines) represent the confidence intervals (CI) for the OLS. The thin grey lines at some point in the figures vary, these are the coefficients in the confidence interval (highlighted grey) of the quantile regression of which based on visual observation are deviating from the normal lines. The expectation is to see the deviations from the OLS confidence interval because these were statistically significant. The significance of the variables starts to be visible when lines are way below and above the OLS CI. The quantiles higher than the OLS show higher and big effect on the losses incurred.

The household head's years of schooling significantly increased the economic losses incurred, at 5% significant level. The effect on the losses was only experienced in the first lower quintile (20^{th}) with a ceiling of BWP25, 800.00 (USD2, 514.62) and below. This is probably because, producers with very low levels of education are likely to keep a small number of cattle thus during the FMD outbreak, they had only a few they lost to the disease. Mugi-Ngenga *et al*. (2016) noted that higher education levels place household heads at a better position of planning, access and understanding of information. Thus limited knowledge might mean limited farm expansion skills.

The results in Table 15 indicates that, conditional on economic losses experienced, many years of farm experience were significantly attributed to the effect in all quantiles, all at 1% level, except for the 20^{th} and 50^{th} quantile (p<0.05). Several producers experienced huge losses at the lower quintiles and the last upper one. This could be, given the unique experience attained over the years, some producers preferred keeping a small herd size while others preferred a large herd size. Thus during the outbreak, losses were felt more at the lower and upper extremes of the quantiles. Overall, a positive relationship signifies that household heads with more farming experience suffered more losses. This could be attributed to the notion that older producers are somewhat reluctant to adopt methods of FMD disease control which impacts negatively on their livestock during the FMD outbreak. Ashfaq *et al*. (2015) in Pakistan and Ayuya *et al*. (2015) in Kenya noted that aged farmers are usually more inclined to use traditional methods of control. Further, Howley *et al*. (2012) noted that older farmers were less likely to adopt Artificial Insemination (AI) probably because they are conservative, less flexible and more skeptical about AI benefits.

Table 15: Quantile regression results of economic losses incurred

	20th		40th		50th		60th		80th	
	Coeff.	**Std. err**	**Coeff.**	**Std. err**	**Coeff.**	**Std. err**	**Coeff.**	**Std. err**	**Coeff.**	**Std. err**
Socio-economic										
Age of household head	0.009	0.004	-0.004	0.006	-0.004	0.005	-0.002	0.005	-0.003	0.004
Gender of household head	-0.058	0.112	0.095	0.152	0.284	0.123	0.254	0.136	0.184	0.132
Years of schooling	0.047**	0.148	0.021	0.022	0.007	0.017	0.013	0.020	0.031	0.017
Farm experience	0.016**	0.004	0.205***	0.006	0.018**	0.005	0.016***	0.006	0.020***	0.005
Household size	0.015	0.020	-0.033	0.026	-0.026	0.021	-0.028	0.022	-0.017	0.022
Log of off-farm income (BWP)	-0.021	0.013	0.001	0.017	0.007	0.014	0.010	0.015	0.020	0.014
Total land size (ha)	0.051	0.028	0.004	0.037	0.041	0.030	0.028	0.032	0.010	0.025
Institutional										
Number of extension contact	0.066	0.033	-0.001	0.049	0.033	0.039	-0.002	0.043	-0.055	0.029
Output market distance (min)	0.001**	0.001	0.001*	0.001	0.001	0.001	0.002*	0.001	0.000	0.001
Next cattle farm distance (min)	0.013	0.008	0.016	0.011	0.013	0.008	0.008	0.010	0.008	0.008
Nearest border distance (min)	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.001
Grazing area distance (min)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001**	0.000
Water source distance (min)	0.004**	0.001	0.004**	0.002	0.004**	0.001	0.003	0.002	0.003	0.001
Matshelagabedi location (dummy)	0.066	0.271	-0.152	0.438	-0.338	0.539	-0.094	0.444	0.114	0.409
Tsamaya location (dummy)[1]	-0.031**	0.136	-0.242**	0.198	-0.513**	0.227	-0.783**	0.184	-0.525**	0.170
Constant	8.792	0.327	10.699	0.502	10.945	0.399	11.322	0.448	11.605	0.403
Conditional log of economic losses	10.158 (BWP25,800)		10.669 (BWP43,000)		10.851 (BWP51,600)		11.074 (BWP64,500)		11.832 (BWP137,600)	
Pseudo R^2	0.292		0.304		0.311		0.321		0.335	
Number of observations	271									

Note: *, **, *=**significant at 10%, 5% and 1% level, respectively.1 USD = BWP10.26: ha= hectares and min=minutes. [1] The reference location is Matsiloje. Coeff. means coefficient and Std. err means standard error.

Longer distances to the nearest market (walking time) resulted in increased losses incurred by producers due to FMD outbreaks. Distance to the nearest market was significant in the lower two quintiles (0.2 and 0.4) as well as the lower upper quintile (0.6). The probable explanation is that farm households that were further from the market were limited from accessing information due to high transport costs. This information could equip them with the knowledge and skills to lessen economic losses. The knowledge could be attributed to FMD control and management measures that prevent livestock from contracting the FMD virus. Birhanu *et al*. (2016) noted that access to markets provides opportunities for networking and collaboration which could lead to exchange and transfer of knowledge thus promote adoption of feed technologies.

The distance livestock tread to access pasture lands was statistically significant only in the last upper quintile of 80^{th} ($p<0.05$). All other factors held constant, the effect on the conditional loss distribution was positive on the quantile with the highest losses incurred (BWP137, 600=USD13, 411.31 and below) as the distance to grazing fields increased. The reason could be, the longer the distance livestock travelled increased the chance of FMD transmission through grazing FMD virus contaminated pastures. Thus, if a large herd size would happen to be grazing along the same path then increased FMD infection would result and huge losses incurred thereof. Literature has noted that longer distances are attributed to huge losses. This is because interaction among livestock is increased at grazing fields which predispose cattle to ease spread of FMD (Sinkala *et al*., 2014; Kim *et al*., 2016; Abdela, 2017).

The distance to water sources had a positive effect with the losses incurred. Far placed water sources resulted in huge economic losses. The variable was significant in the lower tails of the conditional loss distribution of 0.2, 0.4 and 0.5 ($p<0.05$). Far water sources implied that producers were watering their livestock in community boreholes. More losses were experienced (between BWP25, 800 and BWP51, 600) in relation to water sources. This could be, if a large herd size would happen to drink from an FMD virus contaminated water source, then the whole herd would be infected thus huge losses would occur. Therefore, cattle drinking further from their kraals stood a greater risk of contamination which translated to increased losses due to FMD. The current result is similar to Kim *et al*. (2016) who noted increased FMD transmission with greater trekking distance to water sources.

Farming in Tsamaya had a significant effect on the conditional loss distribution across all the quantiles, at 5% significant level. A negative relationship between the location and losses incurred imply that, all else equal, farming in Tsamaya region resulted in a percentage decline in the loss compared to farming in Matsiloje region. The possible reason could be that, these producers are further from direct contact with the FMD virus given that they are far from the border where outbreaks are predisposed. Thus, given their location, they incurred less losses compared to producers in Matsiloje. According to Mogotsi *et al.* (2016) FMD outbreaks in the district are transmitted first from Matsiloje which is closer to the nearest border where FMD comes from.

4.5 Effect of socio-economic and institutional characteristics on choice of responses

A pre-estimation normality test was performed to determine whether the sample data was drawn from a normally distributed population. An insignificant value (p=0.541) of the Doornik-Hansen test conducted failed to reject the null hypothesis of multivariate normality. Thus, the data was declared normal and suggested a go ahead with the analysis (Appendix 4a).

4.5.1 Principal component analysis

To group the ex-post response measures, PCA was used and their factor loadings are reported in Table 16. The ten alternative ex-post responses by producers to prevent exposure to FMD were reduced to four categories. To evaluate the appropriateness of using PCA, Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was performed. A KMO value of 0.72, which is a middling level of common variance in a correlation matrix was adequate. Furthermore, the Bartlett's test of sphericity yielded a p-value<0.05 implying homogenous variance for all samples. This suggested that I can proceed with PCA. A total explained variance of 72% points out the proportion of the original data explained, indicated by more than half of the proportion which is a good fit. Therefore, the four components with eigen values greater than 1 were vital in explaining variability in the dataset. The first component which explained 17.39% of the variance was positively correlated with moving some livestock to other FMD free zones and mending cordon fence collectively. The category was preventative measures in reference to the common purpose served as a response to FMD outbreaks.

The second component explained total variability of 19.69%. This was associated with high positive factor loadings on venturing into non-FMD prone livestock coupled with crop farming and a negative loading effect on off farm business. The component was identified as diversification because it comprised of responses that involved producers venturing into beef farming augmenting alternatives. On the third principal component (segregated farming), a high negative and positive loading effect on restricted animal movement and different drinking sources was recorded, respectively. The explained variance was 13.76%. Lastly, the fourth component which accounted for 20.78% variance, was found to be correlated with alternative grazing areas and culling which had high positive loadings and collective ranching with a high negative loading effect. Owing to the purpose they serve collectively, the component was identified as controlled beef farming.

The communalities, which estimate the total shared variability among the variables yielded an average variance of 71%, with individual communality cut off point of 60% (McCallum *et al*., 2001). Furthermore, the four categories extracted explained common variance as follows; 75% in alternative grazing areas, 69% in collective ranching, 70% in culling, 68% in restricted animal movement, 67% in different drinking points, 79% crop farming, 74% in non-FMD livestock prone business, 60% off farm business, 79% in moving some livestock to other green zones and 65% in mending cordon fence collectively. An orthogonal varimax rotation which considers high factor loadings and communalities for parsimonious results which are interpretable, was done.

Table 16: Factor loadings of the ex-post response components

	Principal components				
Response to FMD	**Comp1**	**Comp2**	**Comp3**	**Comp4**	**Com**
Alternative grazing areas	-0.237	0.270	-0.471	**0.695**	0.751
Collective ranching	-0.194	0.301	-0.509	**-0.607**	0.685
Culling	-0.315	-0.499	0.378	**0.739**	0.701
Restricted animal movement	-0.327	-0.440	**-0.644**	0.455	0.676
Different drinking points	0.461	-0.202	**0.654**	0.311	0.669
Started crop farming	-0.292	**0.637**	0.570	-0.337	0.794
Started non-FMD prone livestock business	0.233	**0.612**	0.446	-0.432	0.737
Off-farm business	0.442	**0.557**	-0.317	0.379	0.603
Moved some cattle to another green zone	**0.692**	0.395	-0.464	0.402	0.793
Mending cordon fence collectively	**0.566**	-0.332	0.257	-0.410	0.653
Eigen values	1.792	1.999	1.432	1.877	
Eigen value % contribution	17.387	19.694	13.764	20.777	
Cumulative %	17.387	37.078	50.841	71.621	
KMO	**0.718**				
Bartlett's test of Sphericity, Sig.	**0.000**				

Note: Com means Communalities

4.5.2 Ex-post response categories

The descriptive statistics of the ex-post responses adopted by beef producers are presented in Table 17. The four response categories were adopted at this rate; preventative measures (PM) at 12.55%, diversification (DV) (20.30%) while controlled (CF) and segregated farming (SF) responses were 40.22% and 52.03% respectively.

Table 17: Descriptive statistics of ex-post responses adopted

Dependent variables	Reply	Frequencies (%)
Preventative measure	Yes	**12.55**
	No	87.45
Moved some cattle to another green zone	Yes	10.70
	No	89.30
Mending cordon fence collectively	Yes	2.58
	No	97.42
Diversification	Yes	**20.30**
	No	79.70
Started crop farming	Yes	10.70
	No	89.30
Started non-FMD prone livestock business	Yes	12.18
	No	87.82
Off-farm business	Yes	8.12
	No	91.88
Segregated farming	Yes	**52.03**
	No	47.97
Restricted animal movement	Yes	46.49
	No	53.51
Different drinking points	Yes	2.21
	No	97.79
Controlled beef farming	Yes	**40.22**
	No	59.78
Alternative grazing areas	Yes	31.73
	No	68.27
Collective ranching	Yes	14.02
	No	85.98
Culling	Yes	1.85
	No	98.15

Category one (preventative measures) comprises of two responses beef producers adopted; the first being transferring some of their cattle to other green zones, zones 3c, 5 and 6a since they are not threatened by trans boundary transmissions. This was adopted by 10.70% of the producers. Some producers (2.58%), especially those in farmer groups had a role of mending damaged veterinary cordon fences at the nearest border as a group. Damage to the fence is usually due to an influx of elephant and illegal movements by immigrants into either Botswana or Zimbabwe (Mogotsi *et al*., 2016).

Category two (diversification) is made up of three responses, the first which defines producers who extended their farming to rear livestock which are not prone to FMD attacks (12.18%) such as poultry which in this study were turkey, chicken, guniea fowl, peacock and ducks. The second response was venturing into off-farm businesses (8.12%) which were also free from FMD susceptibility. Some producers reported that their compensation package enabled them to use some of the reimbursed amount to invest in the venture. The third response consisted of some producers who ventured into crop farming (10.70%) for income generation with its challenges free of FMD.

Category three (segregated farming) is defined by two responses which are restricted animal movements and different water sources adopted at 46.49% and 2.21%, respectively. The former was implemented to prevent livestock from grazing towards the nearest border fence, especially away from the red zone line between the borders where if an animal is found, is killed on the spot to avoid any imminent outbreaks with the assumption of possible cross contamination. The latter response involved producers who resorted to alternative water points. These moved from watering their livestock in government/ community boreholes and used their own or collectively with other producers.

The last category (controlled beef farming) is made up of three responses, alternative grazing areas, collective ranching and culling. Some producers who were grazing towards the border side (east of the railway line) have shifted their grazing areas west of the railway line, (for Tsamaya district beef producers). Those further from the line have moved away from grazing towards the nearest border fence as was the case before. The response was adopted at the rate of 31.73%. With the second response, collective grazing, some producers have gone into ranching (paddock arrangement) which is shared among producers (14.02%). This ranch system involves having a common borehole away from the community water point and grazing at different areas given the new location where livestock is kept (van Engelen *et al*., 2013). The current results showed that producers are usually 4 to 5 in such an institution. The last response involved some producers who reported that they keep their animals in different kraals (enclosures for livestock) according to different ages, adopted by 1.85% of producers. The calves are separated from the adults until a certain age when they are believed to be of a mature age for mixing.

4.5.3 Multivariate probit results

To evaluate the appropriateness of MVP, the underlying correlations of the categories were investigated which allowed for correlation of the error terms of the responses (Table 18**)**. The model is qualified for use because the binary data on the ex-post responses are correlated, implying a degree of interdependence among responses. The correlations point out an important feature of complementarity of the responses when jointly executed given the positive correlation (Kassie *et al*., 2012; Rodriguez-Entrena and Arriaza, 2013).

Table 18: Correlation coefficients of response categories for the MVP model

	PM	**DV**	**SF**	**CF**
PM	1			
DV	0.307***	1		
SF	0.141***	0.099	1	
CF	0.189***	0.073	0.321***	1

Note: ***=significant at 1% level. PM=preventative measure, DV=diversification, SF=segregated farming and CF=controlled beef farming.

Table 19 presents results on the role of socio-economic and institutional characteristics on producers' adoption of ex-post responses to FMD. The Wald test reports a significant model ($\chi^2_{(76)}$ = 200.160***) implying that the data fits the MVP model. The likelihood ratio (LR) test is also significant ($\chi^2_{(6)}$ = 22.160***) with the implication of dependence of the several responses on each other.

Table 19: Multivariate probit model results of FMD responses adopted

	Preventative measures		Diversification		Segregated farming		Controlled farming	
	Coeff.	**Std. err**	**Coeff.**	**Std. err**	**Coeff.**	**Std. err**	**Coeff.**	**Std. err**
Socioeconomic								
Age of household head	-0.004	0.012	0.005	0.008	-0.002	0.007	0.004	0.007
Gender of household head	0.106	0.307	0.041	0.214	-0.125	0.184	-0.084	0.175
Years of schooling	0.019	0.041	0.031	0.030	-0.014	0.025	0.022	0.025
Household size	-0.001	0.052	0.086**	0.042	0.0173	0.032	-0.030	0.029
Total land size (ha)	0.056	0.063	0.069	0.051	-0.065	0.043	-0.026	0.044
Log agricultural asset value (BWP)	0.059	0.229	0.036	0.173	-0.003	0.155	0.226	0.149
Off farm income access	-0.136	0.347	-0.013	0.232	-0.462**	0.195	-0.092	0.186
Log opportunity cost (BWP)	0.900***	0.241	0.783***	0.161	0.204*	0.123	0.186	0.117
Group membership	2.788	1.948	0.700	0.682	0.999	0.757	-0.264	0.655
Institutional								
Number of extension contact	0.071	0.092	0.089	0.071	0.101*	0.060	0.070	0.057
Number of training on FMD	-0.193	0.332	0.140	0.214	0.980***	0.192	-0.024	0.179
Distance to output market (min)	-0.003	0.003	-0.003**	0.001	0.001	0.002	0.004**	0.002
Next cattle farm distance (min)	-0.024	0.027	-0.036***	0.014	0.021	0.015	-0.003	0.013
Nearest border distance (min)	0.000	0.001	-0.001	0.001	-0.002***	0.001	-0.000	0.001
Grazing area distance (min)	-0.004	0.003	-0.001	0.001	0.003*	0.002	0.003*	0.002
Water point distance (min)	0.008**	0.004	0.001	0.003	-0.003	0.002	-0.000	0.002
FMD incidences exposed	-0.129	0.287	-0.201	0.246	-0.281	0.196	-0.420**	0.178
SDVA dummy2 (Matshelagabedi)	-0.119	0.838	1.012	0.692	1.132	0.698	0.546	0.577
SDVA dummy3 (Tsamaya)[1]	-0.650	0.492	0.370	0.326	-0.680**	0.310	-0.681**	0.280
Constant	-1.040***	2.985	-1.261***	1.924	-0.630	1.575	-4.922***	1.502
Wald $chi^2_{(76)}$	200.16***							
Log likelihood	-433.084							
Iterations	200							
Number of observations	271							

Note: *, **, *=**significant at 10%, 5% and 1% level, respectively. 1 USD = BWP10.26: ha= hectares and min=minutes. [1] The reference location is Matsiloje.

The size of a household had a significant (p<0.05) positive effect towards adoption of diversification responses only. Holding all factors constant, a one member increase in household size generally increases the probability that a household would respond to FMD through diversified income earning portfolios by 8.6%. The findings suggest that large households who are usually endowed with the capacity to smoothen out labour needs through family labour are enabled to cater for extra labour demand resulting from extra enterprise activities. The current finding is in agreement with past studies by (Kenamu and Maguza-Tembo, 2016; Ali and Erenstein, 2017; Kelebe *et al*., 2017) attributed to the labour supply that large households provide which promote adoption of agricultural innovations. Further, high consumption needs as presented by larger households may drive producers to respond through diversification to increases household liquidity. This may cushion them against the risks of the FMD shock following adoption of agricultural innovations. Contrary, Uddin *et al*. (2014) noted that the negative relationship was on the basis that if opportunities presented by off-farm labour are adequate in terms of being capable to increase household income more than on-farm activities, then labor will be pulled away from on-farm activities. Thus farmers are less likely to adopt agricultural measures.

Household head participation in off-farm income generating activities like formal and informal employment reduced the probability that a household would adopt segregated farming as a response to FMD outbreak. Producers who engaged in off-farm activities were less likely to adopt segregated farming responses by 46.2%, *ceteris paribus*. The probable explanation for this is that farm households could use the income to bridge out household expenses. Thus none was left to invest in segregated farming since the FMD response requires financial enabling to adopt. The results are consistent with Beshir (2014) who noted that there could exist a trade-off between investing in adoption of agricultural technologies and participation in off farm income.

The opportunity cost was measured by income that producers forgone by not selling to the EU market during the last FMD outbreak and instead received some compensation for the lost cattle. The variable had a significant positive effect towards adoption of preventative (p<0.01), diversification (p<0.01) and segregated farming (p<0.1) responses to the disease. The results suggest that the higher the opportunity incurred, the more producers adopted preventative measures and segregated farming responses. This is probably because the responses focus on preventing transmission of FMD virus during an outbreak, through restricting animal movements and alternative pasture lands. This eventually leads to minimal losses in terms of morbidity and mortality. As for diversified income earning portfolios, livelihood diversification activities provide alternative sources of income. These are a significant necessity for farm households during FMD outbreaks as they assist in meeting household consumption and other needs. Generally, the decision to adopt the responses rested on the ‘once bitten, twice shy’ principle to avoid higher loss in future. Kgaphola *et al*. (2011) and Knight-Jones (2013) note that losses resulting from FMD outbreaks have a huge impact on the poor where livelihoods are directly dependent on livestock.

The number of contact with extension officers increased the likelihood of adopting segregated farming responses at 10% significant level. All else held constant, a positive relationship means that a unit increase in contact resulted in 10.1% increase in adoption of segregated farming responses than to those who had less or no access to agricultural service packages. Extension service played a central role in adoption of responses to FMD by producers. Discussions with extension officers in the area brought to light the fact that they have embarked on disseminating low cost responses to FMD which encouraged adoption of innovation measures. Specifically, the results suggest that information dissemination included the element of FMD which promoted the adoption of segregated farming responses. On the same note, extension service access promoted willingness to adopt to climate changes in a study by Kibue *et al*. (2015), Ali and Erenstein (2017) and Zamasiya *et al*. (2017). In the area, agricultural extension services are wholly provided by the government thus this presents impeding factors in terms of effective delivery of services. The extension officers from the study emphasized that at times they are wanting when it comes to information on FMD when producers need advice. Further, due to financial limitations from the government, farm visits are usually difficult to carry out at the adequate frequency needed owing to shortage of transport.

The frequency of training received on FMD significantly ($p<0.01$) increased the adoption rate of segregated farming responses. An extra training received on FMD by extension agents increased the probability of adopting segregated farming as a response to FMD. More precisely, training offered on FMD exposed producers to knowledge and skills which favored segregated farming responses than other measures. A follow up on extension services offered asserted to a training on FMD which focused on producers restricting livestock movements thus prevent grazing towards the border fence where FMD outbreaks are predisposed. Therefore, training led to a positive change of attitude which promoted adoption of agricultural innovations. The current results are consistent with Rodriguez-Entrena and Arriaza (2013) who found increased adoption rates of agricultural techniques fueled by access to training. The reason was that the technologies are usually knowledge intensive and specialized to an extent.

Distance to the nearest market significantly influenced adoption of diversification and controlled beef farming responses to FMD outbreaks at 5%, ($p<0.05$). A minute increase in the distance (walking time) to the nearest market reduced the likelihood of adopting diversification responses by 0.3% whereas it increased the propensity to adopt controlled beef farming responses by 0.4%, *ceteris paribus*. The probable reason for the negative effect is that, nearness to markets may provide farm households with other non-farm opportunities such as business and these longer distances limit such opportunities because of higher transportation cost. The reason is, ease access of markets could be a source of information on opportunities for non-farm activities. The current finding is consistent with Birhanu *et al*. (2016) and Kelebe *et al*. (2017) who found a negative relationship between nearness to markets and adoption of agricultural technologies. The reason was attributed to access to services and information as well as better institutions which facilitate collaborations and networking for enhanced adoption rates. A positive effect between market distance and adoption of controlled farming was probably because producers who lived far from the market depended on livestock keeping as a source of livelihood. In that regard, they had to look for an alternative to sustain their lives in case of an FMD attack. Thus they opted to adopt controlled beef farming responses to protect against FMD outbreaks.

Distance to the nearest cattle farm (walking time in minutes) had a significant negative influence towards adoption of diversification responses to FMD ($p<0.01$). Holding other factors constant, the closer the farms the more producers were likely to adopt diversification measures by 3.6%. The probable explanation is that farm proximity could facilitate faster spread of FMD to another farm. This finding suggest an important element in terms of the local transmission mode of FMD after the disease broke out. In this regard, producers sought out to diversify their incomes sources so to increase household liquidity. This would come in handy especially during FMD outbreaks to smoothen household requirements. A study by Muroga *et al*. (2013) in Japan found that local spread of FMD in the area as was the case with the 2001 FMD outbreak in the United Kingdom, the major transmission mode in the area was local spread. This could be attributed to farm proximities. However, literature has noted increased adoption of agricultural innovations through observation as relating to nearness of farms. According to Ayuya *et al*. (2015) and Kenamu and Maguza-Tembo (2016), the neighborhood effect impacts directly on farmers that are close to each other by dwelling. This facilitates practical observations of what their colleagues are implementing in their farms and can even understand it better in their native language.

The adoption of segregated farming responses was found to be negatively influenced by distance to the border in walking minutes. The closer a household's farm was to the nearest border, *ceteris paribus*, the higher the likelihood of adopting segregated farming responses by 0.2%. The plausible reason could be that, households closer to the border stand high chances of FMD attack because it is a cross-boundary disease. Segregated farming will help the producers by preventing their livestock from contracting FMD facilitated by restricted animal movements which deter grazing closer to the border fence. In evaluating international border transmissions of FMD in Tanzania, Allepuz *et al*. (2013) found that farms closest to the border were at high risk of transmission.

The distance livestock travel from the farm to grazing areas positively influenced the uptake of both segregated and controlled farming response categories ($p<0.1$). An additional walking minute increased the likelihood of adopting both responses by 0.3%. The probable explanation is that longer distances are associated with higher risks of contracting FMD through increased contact with other livestock at pasture lands. Moreover, grazing the same pasture facilitates transmission of the FMD virus between livestock. Thus, segregated and controlled farming responses ensured limited contact with other livestock through restricted animal movements during grazing. In Cameroon, Kim *et al*. (2016) found a positive relationship where multiple outbreaks were likely to result with increased grazing distances. In Turkey, Senturk *et al*. (2013) found positive correlations between pasture lands and outbreaks.

In the same regard, the distance livestock travel from the kraal to the nearest water source positively influenced the adoption of preventative measures at 5% significant level. As was the case with distance to grazing areas, the longer distances could mean increased chance of contracting FMD virus during an outbreak. More often than not, the FMD virus could be contained in the water if infected animals were watered in the same water trough earlier which will quickly spread the FMD virus to the next stock during drinking. Thus, producers' decision to adopt preventative measure as a response to FMD. The response measures safeguard animals from contamination through deterring entry and spread of FMD within a locality of livestock. In Zambia, Sinkala *et al*. (2014) also observed that FMD was likely to spread rapidly where livestock shared pasture lands and water points.

The number of past FMD incidents that households were exposed to, significantly reduced the probability of adopting controlled beef farming category ($p<0.05$). Households whose cattle were affected by the FMD outbreak on more than one count were less likely to adopt controlled farming response by 42%. The probable explanation is that the livelihoods of these producers which are much dependent on livestock were severely paralyzed by FMD epidemics. Resource wise, producers were incapacitated from adopting controlled beef farming responses owing to the financial needs associated with the establishment and management of the particular response measures. The expectation about numerous FMD incidences is that with frequent exposure, households should be motivated to adopt controlled beef farming responses to prevent transmission of FMD on the bases of drastic effect felt before. The statement is supported by Coulibaly *et al*. (2015) who noted a contrary finding bearing a positive relationship between risk incidences and adoption of coping measures. The reason was that farmers who faced numerous crop failures were likely to adopt climate change response strategies to protect against future occurrences.

A dummy variable for location, reduced the probability of adopting segregated and controlled beef farming response categories at 5%, ($p<0.05$). Farming in Tsamaya reduced the probability of adopting segregated and controlled farming responses compared to farming in Matsiloje sub-district which was the reference category. The probable explanation is that Tsamaya household farms are further from the nearest border fence where outbreaks originate from compared to Matsiloje which is closer. In this regard, given the location of Tsamaya, beef producers were reluctant to adopt segregated and controlled beef farming responses. The probable explanation was that these ex-post responses are about preventing FMD transmissions through discouraging livestock grazing closer to the border fence where outbreaks emanate from. The current results are supported by Mogotsi *et al*. (2016) who noted that FMD outbreaks are usually reported first in Matsiloje and Matopi which are closest to the border fence.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. The major FMD risk factors due to the 2011 FMD outbreak in the district were proximity to the nearest border, damage to veterinary cordon fence, stock theft, grazing communally (attributed to longer distances to grazing and water areas) and farming in Matsiloje.
2. In terms of economic losses, Matsiloje household farms had more losses and men owned more cattle than women thus incurred more losses. The average cattle numbers and annual incomes declined after the outbreak and in total the government spent BWP11, 532, 500.00 (USD1, 126, 492.86) reimbursing producers in North East district.
3. Socio-economic and institutional characteristics also contribute to increased loss and these were few years of schooling, more farm experience and the long distance to: the market, grazing and water areas.
4. Adoption of ex-post responses by beef producers was relatively low. However, for those who adopted, socio-economic and institutional factors such as household size, opportunity cost, contact with extension service providers, training, market distance, distance to grazing and water areas as well as proximity to other household farms had a positive influence.

5.2 Recommendations

A policy for provision of better agricultural extension service packages for effective dissemination of information may help producers enhance the adoption rates of existing ex-post responses to FMD. Further, it may lead to reduced economic losses incurred by producers thereof. The efficiency and effectiveness of extension officers can be enhanced through workshops to improve their understanding on FMD to better assist beef producers. To enhance cost effectiveness of services, the role of collective action in the area should be engaged. Strengthened farmer groups leverage extension services to promote and create awareness about existing FMD responses innovations better than at individual level which is gradual.

Owing to FMD trans boundary transmissions, interventions are needed to effectively prevent transmission. Active engagement of all relevant stakeholders is necessary to monitor and give particular attention to activities along the border fence where outbreaks are predisposed.

Producers, supported by the government together with the community at large should be incentivized to keep the border fence to prevent FMD transmissions.

Stamping out as the only FMD eradication strategy for cross border transmissions should be revised. Other countries in the same predicament have successfully managed FMD through vaccination, zoo-sanitary measure, culling and quarantine or a combination. This could contribute to minimized economic losses incurred by beef producers due to export restrictions because uninfected livestock cattle could be vaccinated and fetch local prices which are better than compensation value.

5.3 Further Research

This research only investigated economic losses and ex-post response of FMD among beef cattle producers in the three sub-districts of North East district. Further research can be conducted to involve other FMD prone livestock such as small stock (sheep and goats) which play a significant role in the lives of Batswana. The current study evaluated direct effects of FMD but not entirely so there is need to further investigate other direct losses as well as indirect losses associated with FMD. Furthermore research needs to explore losses across the beef value chain since ripple effects are incurred by other chain actors as well as in other sectors.

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APPENDICES

APPENDIX 1: HOUSEHOLD QUESTIONNAIRE

My name is Charity Masole and I am part of the Egerton University team who are studying aspects to do with agricultural development with emphasis on understanding smallholder beef cattle farmers' perception to FMD, economic losses and ex-post response measures due to the last 2011 FMD outbreak in North-East district, Botswana. Your participation in answering these questions is highly appreciated. Your response will be **completely confidential** and used solely for research purposes together with other households under study in the case you indicate your voluntary consent by participating in this interview. If you have any questions or comments about this survey, you may contact the Project coordinator through the following address; **Charity Masole, P/Bag 004, Masunga. Cellphone: +267 75226050.**

PART 1: GENERAL INFORMATION (**1**=currently **2**= in year 2011)

Q1. Profile

Questionnaire No______________________ Village________________________________

Date (day/month) ______________________ Enumerator name______________________

SDVA________________________________

PART 2: FARM AND PRODUCER'S CHARACTERISTICS

1.1 Name of HH__________________________

1.2 Telephone ___________________________

1.3 Age of Household head (**Age)** _______________

1.4 Gender of HH *1=Male [ ] 0 = Female [ ]* (**Gen)**

1.5 Education level of the household head (**Edulev1)** ____ and (**Edulev2)** ____?

Codes for education: **1=** Non-formal **2=** Primary **3=** Junior **4=** Senior **5=** Tertiary **6=**

Years of schooling _______________

1.6 Farm experience (**Fexp**) _______________

1.7 Household size (**HHS1**) ______ (**HHS2**) ______

LAND

2.1 Do you have access to land for agricultural activities? *1= Yes [ ] 0 = No [ ]* (**Faccess)**

2.2 How much land is allocated for;

Livestock (ha) (**Sizelvt1)** ___ (**Sizelvt2)** ___ Cropping (ha) (**Sizecrp1)** ___ (**Sizecrp2)** __

2.3 Nature of main livestock production system. (**Natureps1)** _______ (**Natureps2)** _______

Codes for system: 1*= Communal* ***0*** *= Private*

2.4 How long have you been grazing as above? (**Grazp1**) _______ (**Grazp2**) _______

LIVESTOCK

3.1 What category of breeds do you keep and their specific breeds? (**Tybrd) and** (**Brd)**

	Name of breed						
Category	*Tick*		*Tick*		*Tick*		*Tick*
1= Indigenous		Tuli		Tswana		Others, __________	
2= Exotic		Brahman		Simmental		Others,__________	
3= Cross		Musi		Others,_________		Others,__________	

ASSETS

4.1 Number and estimate the current value of physical assets owned as of April 2017. (**Fassets**)

Livestock	**Number**	**Value (P)**
1. Cattle		
2. Goats		
3. Sheep		
4. Chicken		
5. Others, (*specify*) ____________		

Items	**Number**	**Value (P)**
6. Farm implements		
7. Spray pumps		
8. Crushes		
9. Kraal		
10. Tractor		
11. Mouldboard plough		
12. Disk plough		
13. Storage		
14. Weighing scale		
15. Borehole		
16. Vehicle		
17. Mobile phone		
18. Radio		
19. TV		
20. Others, (*specify*)_____________		

GROUP MEMBERSHIP

5.1 Is anybody in the household a member of Botswana Cattle Producers Association (BPCA)? *1= Yes [ ] 0 = No [ ]* (**Groupmem**)

5.2 If yes in 5.1), fill the tables below.

Group type	No. of female members	No. of males members	Year started	Group activities	No. of scheduled meetings per 6 months	No. of meetings attended per 6 months	Savings/contribution per month in Pula (or in kind contribution)	No. of members in the household belonging to the group	No. of days household members claim they have worked for the group in 1 year	On a scale of 0-10 how would you rank your participation in decision making in group?	On a scale of 0-10 how would you rank the level of trust to the members of group?
Grptyp	**Nfem**	**Nmale**	**Gyear**	**Gactv**	**Smetin**	**Mtnatd**	**Scontrib**	**Nmembs**	**Ndays**	**Decisions**	**Trust**

Group types: 1= Cooperative society; 2= Others, (*specify*) ______________

Group activities: 1= Marketing; 2= Production; 3= Others, (*specify*) ______________

5.3 Continued

Group type	Please describe the characteristics of members in each of the groups (*1= Yes, 0= No*) **Are the members of the group from the same;**							
	Neighborliness	Occupation	Kinship	Economic status	Religion	Gender	Age	Education level
Grptyp	**Neibor**	**Occup**	**Kin**	**Ecstat**	**Relig**	**Gender**	**Age**	**Heduc**

5.4 What role does your group play during FMD outbreaks? (**Grprole**) _____________________________

1= Providing information *[ ]* **2=** Others, (*specify*) ______________

PART 3: INSTITUTIONAL CHARACTERISTICS

Facility/ institution	**Distance from farm (Km)**		**Walking time in minutes**	
	1	**2**	**1**	**2**
Extension service office (**Extdist**)				
Abattoir (**Abtdist**)				
Input market (**Mktdist)**				
Output market (**Mktdist)**				
Next cattle farm (**Nextfdist**)				
Zimbabwe border (**Zimdist**)				
Grazing areas (**Grazdist**)				
Water points (**Waterdist**)				

6.1 Do you have access to extension services? (**Extsv1) ____ (Extsv2) ____**
Codes for extension access: 1*= Yes* ***0*** *= No*

6.2 If yes in 6.1) how many contacts with extension service providers did you have? (**Numext1)_____** (**Numext2) _____**

6.3 What extension services do you access? (**Servacc**)

1= Veterinary services *[ ]* **2=** Information *[ ]* **3=** Others, (*specify*) ______________

6.4 Source of services (**Sourcserv**)
1= Government *[ ]* **2=** Private *[ ]* **3=** NGO's *[ ]* **4=** Others, (*specify*) ______________

6.5 What informs you of FMD outbreaks? (**Fmdsourc**)

1= Extension officers *[ ]* **2=** Media *[ ]* **3=** Farmer *[ ]* **4=** Others, (*specify*) ______________

6.6 Did you receive any FMD related training from 2011 to date? *1= Yes [ ] 0= No [ ]* (**Trainacc**)

6.7 If yes, how many trainings sessions? (**Numtrain**)______________

6.8 Do you belong to a credit/savings association? *1= Yes [ ] 0 = No [ ]* (**Membcred**)

6.9 Have you had access to credit in the last 5 years? *1= Yes [ ] 0 = No [ ]* (**Credacc)**

6.9.0 If yes in 6.9) state the amount last accessed. (**Ataken**) ***P***_______________

6.9.1What challenges do you face in accessing credit? (**Credchal**)

1= Collateral *[ ]*

2= Others, (*specify*) ______________

PART 4: FOOT AND MOUTH DISEASE, ECONOMIC LOSSES AND RESPONSE

7.1 How much do you derive from beef annually? (**Beefinc1) *P*______** (**Beefinc2) *P*_______**

7.2 Do you have off-farm income? (**offinc1) ______** (**offinc2) ______**

Code for off-farm: 1*= Yes* ***0*** *= No*

If yes in 7.2) above, fill the table below.

Off-farm activity (**offact**)		Period in months (**peroff**)		Income annually in Pula (**Incpa**)	
1	**2**	**1**	**2**	**1**	**2**

Codes for activities: **1**= Salaried job; **2**= Pension; **3**= Casual labour; **4**= Others, (*specify*)

7.3 Please fill the table below concerning the effect of the 2011 FMD outbreak on your stock.

Cattle number before outbreak (**Lhold**)	Cattle lost (**Clost**)	
	Number	Value (*P*)

7.4 What psychological effects did you or any household member suffer from the last outbreak? 7.5 Do you have livestock insurance? 1= Yes *[ ]* 2= No *[ ]* (**Insur)**

7.6 If yes in 7.5), from which company? (**Insurcomp**)_____________

7.7 If not, in 7.5) why not? (**Noinsur**)

1= Expensive *[ ]* **2=** Requirement *[ ]* **3=** Others, (*specify*) ________________

7.8 What ex-post response measures have you adopted since the last outbreak of year 2011?

Ex-post responses	(*Tick*)
a. Alternative grazing areas (**Resp1**)	
b. Collective ranching (**Resp2**)	
c. Zero grazing (**Resp3**)	
d. Restricted animal movement (**Resp4**)	
e. Zoo-sanitary measures (**Resp5**)	
f. Culling (**Resp6**)	
g. Started crop farming (**Resp7**)	
h. Ventured into non-FMD prone livestock farming (**Resp8**)	
i. Others, (*specify*) ______________	

7.9 What assistance did you receive after the outbreak? (**Rhelp**)

1= Financial *[ ]* **2=** Livestock *[ ]* **3=** Counseling *[ ]* **4=** Others, (*specify*) _______________

7.9.0 How much was the assistance worth? **(Ahelp) *P*______________**

7.9.1 Source of assistance. (**Sourchelp)**

1= Government *[ ]* **2=** NGO's *[ ]* **3=** Others, (*specify*) ________________

7.9.2 Time taken to access the assistance. (**Helptime) ________________**

7.9.3 Has the assistance impacted positively on your well-being? (**Helpwell***) 1= Yes [ ]*
0= No [ ]

7.9.4 Has the assistance impacted positively on livestock productivity? (**Helprod**) *1=Yes [ ] 0=No [ ]*

PART 5: PERCEPTION MEASUREMENT

8.1 Number the incidences of FMD exposed to before. (**Numexp**)________________

8.2 What years were these recorded? (**Yearecor**)________________

SUSCEPTIBILITY

9.1 Frequency of FMD in the last 15 years. (**Freqfmd)**

1= Once *[ ]* **2=** Twice *[ ]* **3=** Thrice *[ ]* **4=** Other, (*specify*) _______________

9.2 Trend of FMD occurrence. (**Trenfmd)**

1= None *[ ]* **2=** Decreasing *[ ]* **3=** Unchanging *[ ]* **4=** Increasing *[ ]*

9.3 If there was an outbreak in your area, how likely would your herd get it? (**Likelifmd**)

1= Less likely *[ ]* **2=** Moderately likely *[ ]* **3=** Very likely *[ ]*

9.4 How severe was the 2011 outbreak? (**Sevrtyfmd**)

1= Less severe *[ ]* **2=** Severe *[ ]* **3=** Very severe *[ ]*

9.5 How long did the outbreak last before it was eradicated? (**Durafmd)**

1= 1-3 months *[ ]* **2=** 4-6 months *[ ]* **3=** 7-9 months *[ ]* **4=** 10-12 months *[ ]*

9.6 How was the level of morbidity of the last outbreak among your herd?

1= None *[ ]* **2=** Low *[ ]* **3=** Medium *[ ]* **4=** High *[ ]*

9.7 In the table provided below, please tick the risk factors attributed to the last outbreak, then comment on how important they are in increasing the likelihood of your herd contracting FMD.

Risk factors	*(Tick)*	Level of Importance			
		0	**1**	**2**	**3**
Being within 5km from nearest border					
Being within 10km from a national park					
Grazing communally beyond 5km distance					
Cattle grazing at more than 5km distance					
Cattle drinking at more than 5km distance					
Having more than 20 animal herds					
No access to early warning information					
Previous exposed to FMD					
Frequent veterinary cordon fence damages					
Presence of buffalos					
Livestock theft					
Owner/worker apathy					
Season (dry season)					
Age of cow (young ones)					
Breed (indigenous)					
Being a producer from Tsamaya SDVA					
Being a producer from Matshelagabedi SDVA					
Being a producer from Matsiloje SDVA					

***Codes for level of importance*: *0*=** Not important ***1*=** Less important; ***2*=** Moderately important; ***3*=** Very important

Thank you for your valuable contribution!

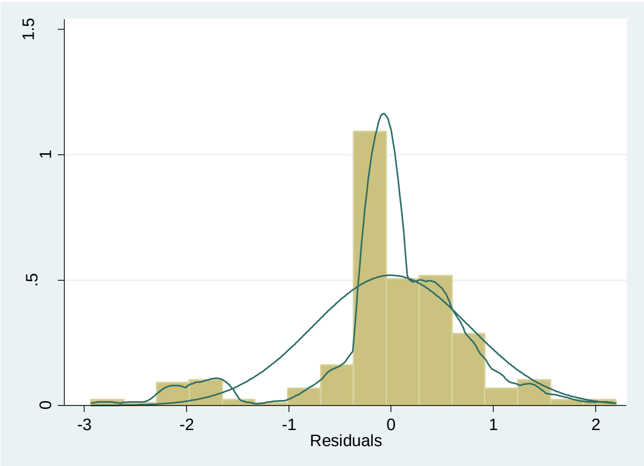
APPENDIX 2: OBJECTIVE 1 ESTIMATES

A. Reliability tests for FMD risk factors (Odds ratio)

```
 alpha distnearestborder distnp commgraz distgraz distwater aniden earlywarn prevexp
fencedam presbuf theft apathy season agecow breed tsamaya matshela matsiloje

Test scale = mean(unstandardized items)
Reversed item:  tsamaya

Average interitem covariance:     .0439846
Number of items in the scale:           18
Scale reliability coefficient:      0.8654
```

```
. estat kmo

Kaiser-Meyer-Olkin measure of sampling adequacy

    ----------------------
        Variable |     kmo
    -------------+--------
    distneares~r |  0.8694
          distnp |  0.6736
        commgraz |  0.8820
        distgraz |  0.9033
       distwater |  0.8267
          aniden |  0.8634
       earlywarn |  0.8382
         prevexp |  0.8631
        fencedam |  0.9047
         presbuf |  0.7051
           theft |  0.8905
          apathy |  0.8692
          season |  0.8564
          agecow |  0.8596
           breed |  0.8394
         tsamaya |  0.5303
        matshela |  0.2087
       matsiloje |  0.5212
    -------------+--------
         Overall |  0.7542
    ----------------------
```

B. Reliability tests for FMD risk factors' level of importance (Ranking)




```
.jb  res_fmd
Jarque-Bera normality test:  7.705 Chi(2)  .0212
Jarque-Bera test for Ho: normality:
```

```
alpha impdistnrborder impdistnp impcommgraz impdistgraz impdistwater
impaniden impearlywarn impprevexp impfencedam imppresbuf imptheft impapathy impseason
impagecow impbreed imptsamaya impmatshela impmatsiloje

Test scale = mean(unstandardized items)
Reversed item:  imptsamaya

Average interitem covariance:     .2605666
Number of items in the scale:           18
Scale reliability coefficient:      0.8550
```

```
. estat kmo

Kaiser-Meyer-Olkin measure of sampling adequacy

    -----------------------
        Variable |     kmo
    -------------+---------
    impdistnrb~r |  0.7910
       impdistnp |  0.8413
     impcommgraz |  0.8795
     impdistgraz |  0.8949
    impdistwater |  0.8310
       impaniden |  0.7927
    impearlywarn |  0.9033
      impprevexp |  0.8982
     impfencedam |  0.8793
      imppresbuf |  0.6369
        imptheft |  0.8968
       impapathy |  0.8432
       impseason |  0.8642
       impagecow |  0.7877
        impbreed |  0.8130
      imptsamaya |  0.5897
     impmatshela |  0.2621
    impmatsiloje |  0.6563
    -------------+---------
         Overall |  0.7848
    -----------------------
```

APPENDIX 3: OBJECTIVE 3 ESTIMATES

A. Ordinary least square results

```
.reg logoppcst  age gender_of_HH years_of_schooling farm_experience household_size
 logToToff_farm_income totlansz numext outmktdistmin nextfdistmin nearestbordermin
 grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3

      Source |       SS       df       MS              Number of obs =     271
-------------+------------------------------           F( 15,   255) =    3.19
       Model |  40.6086682    15  2.70724455           Prob > F      =  0.0001
    Residual |  216.706011   255  .849827495           R-squared     =  0.1578
-------------+------------------------------           Adj R-squared =  0.1083
       Total |  257.314679   270  .953017331           Root MSE      =  .92186

------------------------------------------------------------------------------------------
            logoppcst |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------------+-------------------------------------------------------------------
                  age |   .0034342   .0046809     0.73   0.464    -.0057839    .0126523
         gender_of_HH |   .1157938   .1168523     0.99   0.323    -.1143247    .3459122
   years_of_schooling |   .0292827   .0165591     1.77   0.078    -.0033273    .0618927
      farm_experience |   .0176037   .0047363     3.72   0.000     .0082764    .0269311
       household_size |   -.014238   .0202287    -0.70   0.482    -.0540745    .0255985
logToToff_farm_income |  -.0030418   .0132766    -0.23   0.819    -.0291875    .0231039
             totlansz |   .0350446   .0282171     1.24   0.215    -.0205236    .0906129
               numext |   .0162491   .0385448     0.42   0.674    -.0596576    .0921558
        outmktdistmin |   .0006935   .0006614     1.05   0.295    -.0006089    .0019959
         nextfdistmin |   .0142309   .0092339     1.54   0.125    -.0039536    .0324154
     nearestbordermin |  -.0002577   .0004338    -0.59   0.553     -.001112    .0005967
          grazdistmin |  -.0005409   .0004514    -1.20   0.232    -.0014299     .000348
         waterdistmin |   -.003477   .0012759    -2.73   0.007    -.0059896   -.0009644
          SDVA_dummy2 |   .0458306     .35946     0.13   0.899    -.6620578     .753719
          SDVA_dummy3 |  -.3074319    .153917    -2.00   0.047    -.6105423   -.0043215
                _cons |   10.34868   .3883393    26.65   0.000     9.583923    11.11344
------------------------------------------------------------------------------------------
```

B. Quantile regression estimates

```
. qreg logoppcst age gender_of_HH years_of_schooling farm_experience household_size
  logToToff_farm_income totlansz numext outmktdistmin nextfdistmin nearestbordermin
  grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3, quantile (0.2)
```

```
.2 Quantile regression                              Number of obs =        271
  Raw sum of deviations 139.7119 (about 10.15813)
  Min sum of deviations 124.4579                    Pseudo R2     =     0.2920
```

logoppcst	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	.0086438	.0037953	2.28	0.024	.0011697	.0161179
gender_of_HH	-.058309	.1119671	-0.52	0.603	-.278807	.162189
years_of_schooling	.0470834	.0147724	3.19	0.002	.0179919	.076175
farm_experience	.0163339	.0044621	3.66	0.000	.0075466	.0251212
household_size	.0145104	.019746	0.73	0.463	-.0243756	.0533964
logToToff_farm_income	-.0209811	.012573	-1.67	0.596	-.0457413	.0037791
totlansz	.0508448	.0276969	1.84	0.368	-.003699	.1053886
numext	.065809	.0333192	1.98	0.849	.0001931	.1314248
outmktdistmin	.0012111	.0005074	2.39	0.018	.0002119	.0022104
nextfdistmin	.0129951	.0083042	1.56	0.119	-.0033586	.0293487
nearestbordermin	.0000499	.0003137	-0.16	0.874	-.0006676	.0005678
grazdistmin	.0001888	.0002042	-0.92	0.356	-.000591	.0002134
waterdistmin	.0037236	.0011497	-3.24	0.002	-.0059877	-.0014595
SDVA_dummy2	.0659615	.2710572	0.24	0.808	-.4678343	.5997574
SDVA_dummy3	-.0309488	.1355687	-0.23	0.004	-.2979257	.236028
_cons	8.792397	.3271592	26.87	0.000	8.148119	9.436675

```
. qreg logoppcst age gender_of_HH years_of_schooling farm_experience household_size
  logToToff_farm_income totlansz numext outmktdistmin nextfdistmin nearestbordermin
  grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3, quantile (0.4)
```

```
.4 Quantile regression                              Number of obs =        271
  Raw sum of deviations 194.5231 (about 10.668956)
  Min sum of deviations 179.9158                    Pseudo R2     =     0.3037
```

logoppcst	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	-.0039508	.0059542	-0.66	0.508	-.0156764	.0077748
gender_of_HH	.0953808	.1520377	0.63	0.531	-.2040287	.3947902
years_of_schooling	.0211373	.0221717	0.95	0.341	-.0225256	.0648003
farm_experience	.0205463	.0061587	3.34	0.001	.0084179	.0326748
household_size	-.033032	.0258714	-1.28	0.203	-.0839807	.0179168
logToToff_farm_income	.0006169	.017244	0.04	0.971	-.0333418	.0345757
totlansz	.0041421	.0374782	0.11	0.912	-.0696642	.0779484
numext	-.0009095	.0494161	-0.02	0.985	-.0982251	.0964061
outmktdistmin	.0005728	.000798	0.72	0.074	-.0009987	.0021443
nextfdistmin	.0160329	.0105165	1.52	0.129	-.0046774	.0367432
nearestbordermin	.0001525	.0005212	-0.29	0.770	-.0011789	.0008739
grazdistmin	.0003654	.0003062	-1.19	0.234	-.0009683	.0002376
waterdistmin	.003812	.001644	-2.32	0.021	-.0070495	-.0005745
SDVA_dummy2	-.15215	.4384749	-0.35	0.729	-1.015643	.7113432
SDVA_dummy3	-.2415434	.1983687	-1.22	0.024	-.632193	.1491062
_cons	10.69904	.5016094	21.33	0.000	9.711212	11.68686

```
. qreg  logoppcst  age gender_of_HH years_of_schooling farm_experience household_size
  logToToff_farm_income totlansz numext outmktdistmin nextfdistmin nearestbordermin
  grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3, quantile (0.5)
```

Median regression Number of obs = 271
Raw sum of deviations 206.0024 (about 10.851277)
Min sum of deviations 188.5123 Pseudo R2 = 0.3108

logoppcst	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	-.0039532	.0048593	-0.81	0.417	-.0135228	.0056163
gender_of_HH	.2836384	.1225875	2.31	0.421	.0422256	.5250512
years_of_schooling	.0067256	.0173816	0.39	0.699	-.0275042	.0409554
farm_experience	.0178635	.0049674	3.60	0.003	.0080812	.0276458
household_size	-.0263055	.0212186	-1.24	0.216	-.0680915	.0154805
logToToff_farm_income	.0073496	.0139026	0.53	0.598	-.020029	.0347281
totlansz	.040874	.0300519	1.36	0.175	-.0183075	.1000556
numext	.0332574	.0388602	0.86	0.393	-.0432705	.1097853
outmktdistmin	.0011109	.0007002	-1.59	0.114	-.0024899	.0002681
nextfdistmin	.0128909	.0083447	1.54	0.124	-.0035424	.0293242
nearestbordermin	.0000128	.0004584	-0.03	0.978	-.0009155	.0008899
grazdistmin	.0002894	.0002412	-1.20	0.231	-.0007643	.0001856
waterdistmin	.0039639	.0013226	-3.00	0.003	-.0065686	-.0013593
SDVA_dummy2	-.3375512	.3803548	-0.89	0.376	-1.086588	.4114855
SDVA_dummy3	-.5133437	.161806	-3.17	0.002	-.8319899	-.1946974
_cons	10.94465	.3992036	27.42	0.000	10.1585	11.73081

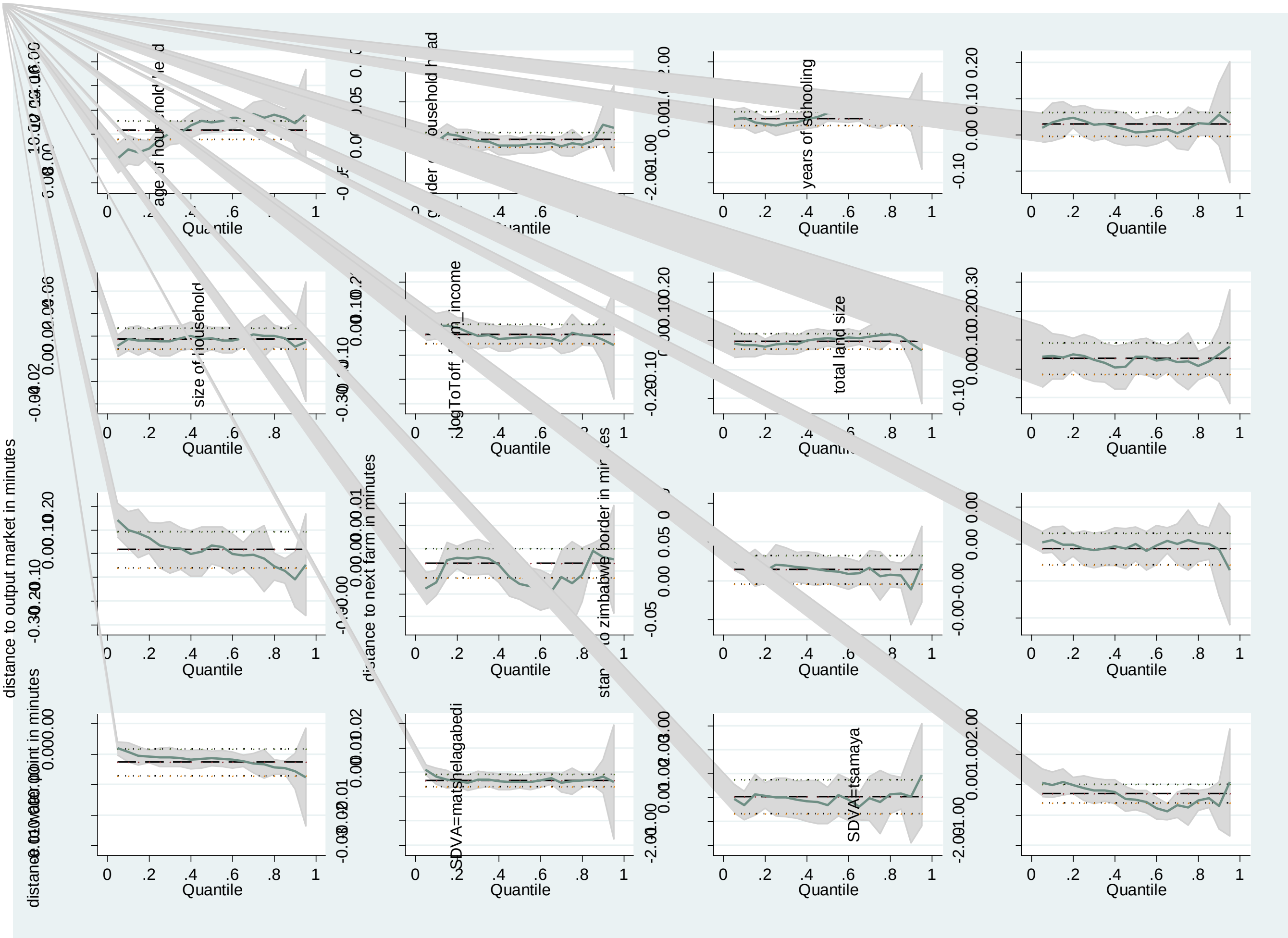
```
. qreg  logoppcst  age gender_of_HH years_of_schooling farm_experience household_size
  logToToff_farm_income totlansz numext outmktdistmin nextfdistmin nearestbordermin
  grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3, quantile (0.6)
```

.6 Quantile regression Number of obs = 271
Raw sum of deviations 205.2481 (about 11.074421)
Min sum of deviations 182.9953 Pseudo R2 = 0.3208

logoppcst	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
age	-.0017029	.0053289	-0.32	0.750	-.0121972	.0087914
gender_of_HH	.2540421	.1358957	1.87	0.863	-.0135787	.5216629
years_of_schooling	.0134814	.0195583	0.69	0.491	-.0250349	.0519977
farm_experience	.0163786	.0056123	2.92	0.000	.0053263	.0274309
household_size	-.0275481	.0220674	-1.25	0.213	-.0710056	.0159094
logToToff_farm_income	.0098679	.0153771	0.64	0.522	-.0204144	.0401503
totlansz	.0277083	.0318064	0.87	0.384	-.0349283	.090345
numext	-.0022892	.0425032	-0.05	0.957	-.0859911	.0814127
outmktdistmin	.0016799	.0008843	-1.90	0.059	-.0034213	.0000615
nextfdistmin	.0084969	.0101994	0.83	0.406	-.0115889	.0285828
nearestbordermin	.0000697	.0005402	-0.13	0.897	-.0011335	.000994
grazdistmin	.0003845	.0002645	-1.45	0.147	-.0009055	.0001364
waterdistmin	.0032836	.0015606	-2.10	0.236	-.006357	-.0002102
SDVA_dummy2	-.0943009	.4443015	-0.21	0.832	-.9692685	.7806667
SDVA_dummy3	-.7828423	.1841624	-4.25	0.005	-1.145515	-.4201693
_cons	11.32232	.4478086	25.28	0.000	10.44045	12.2042

```
. qreg  logoppcst  age gender_of_HH years_of_schooling farm_experience household_size
  logToToff_farm_income totlansz numext outmktdistmin nextfdistmin nearestbordermin
  grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3, quantile (0.8)

.8 Quantile regression                            Number of obs =       271
  Raw sum of deviations 154.5865 (about 11.832107)
  Min sum of deviations 134.2312                  Pseudo R2     =    0.3347

------------------------------------------------------------------------------------------
            logoppcst |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------------+-------------------------------------------------------------------
                  age |  -.0032458   .0044266    -0.73   0.464    -.0119631    .0054714
         gender_of_HH |    .184101   .1318876     1.40   0.164    -.0756267    .4438287
   years_of_schooling |   .0312935   .0167572     1.87   0.763    -.0017067    .0642937
      farm_experience |   .0200593    .004904     4.09   0.000     .0104018    .0297169
       household_size |  -.0170563   .0223017    -0.76   0.445    -.0609753    .0268627
logToToff_farm_income |   .0203396   .0138608     1.47   0.143    -.0069567    .0476359
             totlansz |   .0104512   .0251871     0.41   0.679    -.0391501    .0600525
               numext |  -.0549955   .0291566    -1.89   0.860     -.112414     .002423
        outmktdistmin |   .0003279   .0011937    -0.27   0.784    -.0026787     .002023
         nextfdistmin |   .0078915    .008336     0.95   0.345    -.0085247    .0243078
     nearestbordermin |   .0000251   .0005131     0.05   0.961    -.0009853    .0010355
          grazdistmin |   .0008587   .0002456    -3.50   0.004    -.0013423   -.0003751
         waterdistmin |   .0034381   .0014362    -2.39   0.017    -.0062664   -.0006098
          SDVA_dummy2 |   .1136246   .4091402     0.28   0.781    -.6920995    .9193487
          SDVA_dummy3 |  -.5252195   .1702675    -3.08   0.002     -.860529   -.1899099
                _cons |   11.60538    .402896    28.80   0.000     10.81195    12.39881
------------------------------------------------------------------------------------------

. quietly qreg logoppcst age gender_of_HH years_of_schooling farm_experience household_size
  logToToff_farm_income totlansz numext outmktdistmin nextfdistmin nearestbordermin
  grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3

. grqreg, cons ci ols olsci

. quietly reg logoppcst age gender_of_HH years_of_schooling farm_experience household_size
  logToToff_farm_income totlansz numext outmktdistmin nextfdistmin
  nearestbordermin grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3

. estat hettest age gender_of_HH years_of_schooling farm_experience household_size
  logToToff_farm_income totlansz numext outmktdistmin nextfdistmin nearestbordermin
  grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3,iid

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: age gender_of_HH years_of_schooling farm_experience household_size
                    logToToff_farm_income totlansz numext outmktdistmin nextfdistmin
                     nearestbordermin grazdistmin waterdistmin SDVA_dummy2 SDVA_dummy3


         chi2(15)      =    30.95
         Prob > chi2   =   0.000
```

C. Quantile regression graphs



QR confidence interval

OLS confidence interval

QR estimates

OLS estimates

APPENDIX 4: OBJECTIVE 4 ESTIMATES

A. Multivariate normality test

```
. mvtest normal age gender_of_HH   years_of_schooling household_size groupmem
outmktdistmin nextfdistmin nearestbordermin grazdistmin waterdistmin numext numtrain
numexposed SDVA_dummy2 SDVA_dummy3  logoppcst totlansz logttassetval offinc

Test for multivariate normality

    Doornik-Hansen                  chi2(38) =29237.967   Prob>chi2 =  0.5412
```

B. Multivariate probit estimates

```
. mvprobit (Prev_Msur=age gender_of_HH years_of_schooling household_size groupmem
outmktdistmin nextfdistmin nearestbordermin grazdistmin waterdistmin numext numtrain
numexposed SDVA_dummy2 SDVA_dummy3 logoppcst totlansz logttassetval offinc) (Diversf=
age gender_of_HH years_of_schooling household_size groupmem outmktdistmin nextfdistmin
nearestbordermin grazdistmin waterdistmin numext numtrain numexposed SDVA_dummy2 SDVA_dummy3
logoppcst totlansz logttassetval offinc) (Segre_Fming= age gender_of_HH years_of_schooling
household_size groupmem outmktdistmin nextfdistmin nearestbordermin grazdistmin waterdistmin
numext numtrain numexposed SDVA_dummy2 SDVA_dummy3 logoppcst totlansz logttassetval offinc)
(Contr_Fming= age gender_of_HH years_of_schooling household_size groupmem outmktdistmin
nextfdistmin nearestbordermin grazdistmin waterdistmin numext numtrain numexposed SDVA_dummy2
SDVA_dummy3 logoppcst totlansz logttassetval offinc), nolog iterate (200) draws (20)
```

```
Multivariate probit (MSL, # draws = 20)          Number of obs    =        271
                                                  Wald chi2(76)    =     200.16
Log likelihood = -433.08405                       Prob > chi2      =     0.0000
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Prev_Msur						
age	-.0035294	.0115762	-0.30	0.760	-.0262182	.0191595
gender_of_HH	.1060578	.3065369	0.35	0.729	-.4947435	.7068591
years_of_schooling	.0194779	.0405241	0.48	0.631	-.0599479	.0989038
household_size	-.0013535	.051978	-0.03	0.979	-.1032284	.1005215
groupmem	2.787939	121.9478	0.05	0.962	-233.2253	244.8012
outmktdistmin	-.0028079	.0029015	-0.97	0.333	-.0084947	.0028789
nextfdistmin	-.0238918	.0269567	-0.89	0.375	-.076726	.0289423
nearestbordermin	.0003798	.0009917	0.38	0.702	-.001564	.0023236
grazdistmin	-.0035782	.0033177	-1.08	0.281	-.0100808	.0029244
waterdistmin	.0075588	.0036114	2.09	0.036	.0004806	.0146371
numext	.0713263	.0923495	0.77	0.440	-.1096753	.2523279
numtrain	-.1927293	.3322428	-0.58	0.562	-.8439133	.4584546
numexposed	-.1289388	.2865179	-0.45	0.653	-.6905036	.4326261
SDVA_dummy2	-.1185264	.8380269	-0.14	0.888	-1.761029	1.523976
SDVA_dummy3	-.6497218	.4915223	-1.32	0.186	-1.613088	.3136441
logoppcst	.9001954	.2406126	4.53	0.000	.6179564	1.56114
totlansz	.0562074	.0633769	0.89	0.375	-.0680091	.1804239
logttassetval	.0590053	.2291216	0.26	0.797	-.3900648	.5080754
offinc	-.1362229	.3468463	-0.39	0.695	-.8160291	.5435833
_cons	-1.04017	2.984948	-4.70	0.000	-19.89057	-8.189784

Diversf						
age	.0051998	.0082167	0.63	0.527	-.0109047	.0213043
gender_of_HH	.0406784	.2141114	0.19	0.849	-.3789722	.460329
years_of_schooling	.0314068	.0297284	1.06	0.291	-.0268597	.0896733
household_size	.0856678	.0423576	-2.02	0.043	-.1686873	-.0026484
groupmem	.7001312	.6823818	1.03	0.305	-.6373125	2.037575
outmktdistmin	-.0025352	.0011532	-2.20	0.028	-.0047954	-.0002751
nextfdistmin	-.0363908	.0141596	2.57	0.010	.0086384	.0641432
nearestbordermin	-.0013085	.0008394	-1.56	0.119	-.0029537	.0003367
grazdistmin	-.0005401	.0008718	-0.62	0.536	-.0022488	.0011686
waterdistmin	.0007091	.0026293	0.27	0.787	-.0044442	.0058624
numext	.0888123	.0708367	1.25	0.210	-.050025	.2276496
numtrain	.1400936	.2143115	0.65	0.513	-.2799492	.5601364
numexposed	-.2006641	.2463219	-0.81	0.415	-.6834461	.2821179
SDVA_dummy2	1.01151	.6915355	1.46	0.144	-.3438744	2.366895
SDVA_dummy3	.3703168	.3260615	1.14	0.256	-.2687521	1.009386
logoppcst	.7834199	.1605226	4.88	0.000	.4688014	1.098038
totlansz	.0691067	.0506988	1.36	0.173	-.0302611	.1684745
logttassetval	.036173	.1731584	0.21	0.835	-.3032113	.3755573
offinc	-.0130101	.2317901	-0.06	0.955	-.4673103	.44129
_cons	-1.26134	1.923848	-5.33	0.000	-14.03201	-6.490668

Segre_Fming						
age	-.0020934	.0070335	-0.30	0.766	-.0158788	.011692
gender_of_HH	-.1249149	.1835972	-0.68	0.496	-.4847588	.2349291
years_of_schooling	-.0142814	.0252951	-0.56	0.572	-.0638588	.035296
household_size	.0167065	.03223	0.52	0.604	-.0464631	.0798762
groupmem	.9990029	.7568758	1.32	0.187	-.4844463	2.482452
outmktdistmin	.0012068	.0017074	0.71	0.480	-.0021398	.0045533
nextfdistmin	.0211298	.0150319	1.41	0.160	-.0083322	.0505918
nearestbordermin	-.0022538	.0008638	-2.61	0.009	-.0039468	-.0005608
grazdistmin	.0033464	.0017707	1.89	0.059	-.000124	.0068169
waterdistmin	-.0025026	.0022172	-1.13	0.259	-.0068484	.0018431
numext	.1012642	.0604865	1.67	0.094	-.0172873	.2198156
numtrain	.9800304	.1917658	-5.11	0.000	-1.355884	-.6041764
numexposed	-.281047	.1961536	-1.43	0.152	-.665501	.103407
SDVA_dummy2	1.13248	.6979446	1.62	0.105	-.235466	2.500427
SDVA_dummy3	-.6797037	.3097704	-2.19	0.028	-1.286843	-.0725648
logoppcst	.2037163	.122958	1.66	0.098	-.037277	.4447095
totlansz	-.0652014	.0425019	-1.53	0.125	-.1485035	.0181008
logttassetval	-.002614	.1547742	-0.02	0.987	-.3059659	.3007379
offinc	-.4617609	.1946702	-2.37	0.018	-.8433075	-.0802144
_cons	-.630209	1.575056	-0.40	0.689	-3.717262	2.456844

Contr_Fming						
age	.0039487	.0066371	0.59	0.552	-.0090599	.0169572
gender_of_HH	-.0844825	.1748248	-0.48	0.629	-.4271328	.2581679
years_of_schooling	.0215335	.0254289	0.85	0.397	-.0283062	.0713732
household_size	-.0301513	.029414	-1.03	0.305	-.0878016	.0274991
groupmem	-.2641224	.6552569	-0.40	0.687	-1.548402	1.020158
outmktdistmin	.0036841	.0016062	2.29	0.022	.0005361	.0068322
nextfdistmin	-.002706	.0128556	-0.21	0.833	-.0279025	.0224905
nearestbordermin	-.0000645	.0006996	-0.09	0.927	-.0014357	.0013067
grazdistmin	.0030405	.0016872	1.80	0.072	-.0002663	.0063473
waterdistmin	-.0002108	.0020138	-0.10	0.917	-.0041578	.0037362
numext	.0703823	.0570239	1.23	0.217	-.0413824	.1821471
numtrain	-.0235248	.1787065	-0.13	0.895	-.3737831	.3267336
numexposed	-.4196655	.1777754	-2.36	0.018	-.7680988	-.0712322
SDVA_dummy2	.5456236	.5771466	0.95	0.344	-.5855629	1.67681
SDVA_dummy3	-.6806847	.2800565	-2.43	0.015	-1.229585	-.1317841
logoppcst	.185769	.1170752	1.59	0.113	-.0436943	.4152322
totlansz	-.0255863	.0436791	-0.59	0.558	-.1111958	.0600231
logttassetval	.2262121	.1488333	1.52	0.129	-.0654958	.51792
offinc	-.0915665	.1858287	-0.49	0.622	-.4557841	.2726512
_cons	-4.922476	1.501927	-3.28	0.001	-7.866199	-1.978752

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0:
chi2(6) = 22.1602 Prob > chi2 = 0.0011

APPENDIX 5: OTHER TESTS PERFORMED

```
. vif

    Variable |       VIF       1/VIF  
-------------+----------------------
   abtdistmin |      4.79    0.208650
  cattlevalue |      4.56    0.219361
   ttassetval |      4.28    0.233515
   extdistmin |      3.24    0.308834
  cattlnumbef |      2.84    0.351699
 nearestbor~n |      2.54    0.394253
 outmktdist~n |      2.19    0.456439
   numexposed |      2.04    0.490025
 farm_exper~e |      1.85    0.541573
          age |      1.56    0.640901
 years_of_s~g |      1.46    0.687210
 waterdistmin |      1.37    0.731177
     trainacc |      1.33    0.754668
 ToToff_far~e |      1.20    0.836631
  grazdistmin |      1.18    0.846161
 nextfdistmin |      1.14    0.876342
 household_~e |      1.13    0.885872
       numext |      1.12    0.889361
     totlansz |      1.10    0.910331
-------------+----------------------
     Mean VIF |      2.15

. estat hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity 
         Ho: Constant variance
         Variables: fitted values of Oppcost

         chi2(1)      =     1.03
         Prob > chi2  =   0.3113
```

```
. pwcorr SDVA gender_of_HH groupmem extsv trainacc offinc FMDcond edulevl distnearestborder
  distnp commgraz distgraz distwater aniden earlywarn prevexp fencedam presbuf theft
  apathy season agecow breed tsamaya matshela matsiloje
```

	SDVA	gender~H	groupmem	extsv	trainacc	offinc	FMDcond
SDVA	1.0000						
gender_of_HH	-0.1423	1.0000					
groupmem	-0.1542	0.0158	1.0000				
extsv	0.0717	-0.1113	-0.0125	1.0000			
trainacc	0.0208	0.0343	0.0198	0.1673	1.0000		
offinc	0.1680	-0.0044	0.1065	0.0154	0.1028	1.0000	
FMDcond	-0.5648	0.0835	0.0025	-0.1910	0.0289	-0.1257	1.0000
edulevl	-0.0558	0.1540	0.0013	0.0486	-0.0852	-0.0495	0.1011
distneares~r	-0.6348	0.0923	0.0404	-0.0267	-0.2721	-0.2155	0.3670
distnp	-0.1632	0.1571	0.0459	0.0491	-0.1038	0.0435	0.0111
commgraz	-0.3770	0.0748	0.0916	-0.2112	-0.2159	0.0269	0.2438
distgraz	-0.4168	0.1031	0.0860	-0.1941	-0.2524	-0.0651	0.2803
distwater	-0.3395	0.1140	0.1006	-0.2162	-0.2036	-0.0144	0.2385
aniden	-0.3692	-0.0302	0.0327	-0.0629	-0.3489	-0.1637	0.1514
earlywarn	-0.2543	0.0272	0.0976	-0.0659	-0.0505	0.0490	0.0715
prevexp	-0.3270	0.1759	0.0155	-0.2405	-0.0703	0.0219	0.1900
fencedam	-0.5115	0.0841	0.0394	-0.0443	-0.1788	-0.2386	0.3778
presbuf	0.1677	0.0049	-0.0254	-0.0833	-0.1307	-0.0314	-0.0642
theft	-0.4210	0.1423	0.1336	-0.1571	-0.2063	-0.1192	0.2818
apathy	-0.2667	-0.0174	0.2371	0.1158	0.0720	0.1147	0.1392
season	-0.1069	0.0582	0.0459	-0.1826	-0.0776	0.0935	0.1121
agecow	-0.2691	0.0389	0.0219	-0.0713	-0.1998	-0.0696	0.2099
breed	-0.2476	0.1324	0.0459	-0.1495	-0.0253	-0.0065	0.1373
tsamaya	0.5000	-0.0968	-0.1065	0.1215	0.0505	0.1926	-0.5759
matshela	-0.0005	-0.0648	-0.0762	-0.1254	-0.0785	-0.1002	0.1596
matsiloje	-0.4999	0.1661	0.1697	-0.0047	0.0075	-0.1013	0.4509

	edulevl	distne~r	distnp	commgraz	distgraz	distwa~r	aniden
edulevl	1.0000						
distneares~r	0.1909	1.0000					
distnp	0.0583	0.2125	1.0000				
commgraz	0.0665	0.3786	0.1088	1.0000			
distgraz	0.0352	0.4131	0.0967	0.3082	1.0000		
distwater	0.0358	0.3694	0.0450	0.6744	0.5607	1.0000	
aniden	0.0355	0.3055	0.0306	0.3503	0.3777	0.3358	1.0000
earlywarn	-0.0626	0.2324	0.0700	0.4605	0.4409	0.4922	0.2138
prevexp	0.0665	0.2260	0.1590	0.4718	0.4077	0.4139	0.1659
fencedam	0.0799	0.6123	0.0800	0.3403	0.3076	0.3130	0.3014
presbuf	0.0544	0.0894	-0.0617	0.2864	0.2320	0.3024	0.0624
theft	0.1466	0.5642	0.0530	0.3232	0.3498	0.3487	0.2840
apathy	0.0404	0.2522	0.1542	0.4170	0.3756	0.4039	0.0699
season	-0.0074	0.1864	0.1362	0.3789	0.3631	0.3768	0.1119
agecow	-0.0253	0.2495	0.1444	0.3800	0.3617	0.3622	0.2228
breed	0.0846	0.2125	0.2596	0.3519	0.3631	0.3768	0.0306
tsamaya	-0.0560	-0.6172	-0.0804	-0.3358	-0.3725	-0.3052	-0.3140
matshela	0.0090	0.1051	-0.1560	0.0020	0.0031	0.0102	-0.0508
matsiloje	0.0414	0.5313	0.2354	0.3544	0.3890	0.3182	0.3456

	earlyw~n	prevexp	fencedam	presbuf	theft	apathy	season
earlywarn	1.0000						
prevexp	0.5311	1.0000					
fencedam	0.2078	0.2232	1.0000				
presbuf	0.0390	0.0886	0.0010	1.0000			
theft	0.1974	0.1807	0.4326	0.0982	1.0000		
apathy	0.4092	0.2744	0.2283	0.1976	0.2889	1.0000	
season	0.3131	0.3276	0.1061	0.3509	0.2009	0.3547	1.0000
agecow	0.2147	0.2535	0.1357	0.1587	0.2523	0.1901	0.4603
breed	0.3131	0.3613	0.1322	0.0759	0.2256	0.3213	0.4652
tsamaya	-0.1944	-0.2332	-0.5927	0.1536	-0.3858	-0.2388	-0.1058
matshela	-0.0599	-0.1226	0.3034	-0.0061	0.0204	-0.0092	0.0181
matsiloje	0.2598	0.3517	0.3346	-0.1497	0.3794	0.2585	0.1094

	agecow	breed	tsamaya	matshela	matsil~e
agecow	1.0000				
breed	0.4603	1.0000			
tsamaya	-0.2100	-0.2076	1.0000		
matshela	-0.0547	-0.0109	-0.4320	1.0000	
matsiloje	0.2925	0.2606	-0.6275	-0.4136	1.0000