INFLUENCE OF DAIRY BUSINESS MODELS ON ECONOMIC PERFORMANCE AND EFFICIENCY OF SMALLHOLDER DAIRY FARMERS IN NYANDARUA AND NANDI COUNTIES

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DECLARATION AND RECOMMENDATION

DECLARATION

I declare that this thesis is my original work and has not been presented in this or any other University for the award of a degree.

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RECOMMENDATION

This thesis has been submitted with our approval as candidate's Supervisors.

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DEDICATION

I dedicate this thesis to my parents who have always encouraged me to pursue post graduate studies.

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ABSTRACT

With the declining public investments in extension services in Kenya, smallholder farmers are accessing inputs and advisory services from private sector through diverse business models, namely producer organization driven, milk processor driven or direct procuring. However, farmers' choice of the business models and their influence on dairy performance and technical efficiency is empirically unclear. Using data from random sample of 246 smallholder dairy farmers in a cross- section survey in Nyandarua and Nandi Counties, this study sought to establish the factors that determine the choice of dairy business models, the effects of the chosen model on dairy performance and the associated technical efficiency. Results from logit model showed farm characteristics as well as institutional factors that influenced the farmers' choice of dairy business model were distance to the input market, milk price and access to credit and extension services. Gross margins analysis revealed that the dairy enterprises were profitable and the profitability was 7% to 27% higher in farms linked to milk processor driven model than in direct procuring and producer organisation driven models. However, gross margin per litre of milk did not statistically differ across the dairy business models. The mean technical efficiency of farmers linked to milk processor driven model was 78%, direct procuring (77%) and producer organisation driven (75%). Technical efficiency attained by farmers linked to the three business models did not differ statistically. The efficiency model showed that feeds pasture and fodder land and veterinary services had positive effect on milk output while labour had negative effect on milk output. The use of artificial insemination (AI) as well as the age, education level and primary occupation of the dairy decision maker significantly influenced efficiency. It was concluded that farmers can better obtain credit facilities through producer organisation and milk processor driven dairy business models to improve performance of their dairy enterprises. Innovative dairy business models can play a role in reduction of cost production which impacts on performance of smallholder dairy farms. Promoting the use of artificial insemination can reduce inefficiency in smallholder dairy farms.

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LIST OF ABBREVIATION AND ACRONYMS

AI	Artificial Insemination
APP	Average Physical Product
COLS	Corrected Ordinary Least Square
DEA	Data Envelopment Analysis
DBM	Dairy business model
FAO	Food and Agricultural Organisation
GDP	Gross Domestic Product
GM	Gross Margin
GPV	Gross Productive Value
GOK	Government of Kenya
MoALF	Ministry of Agriculture, Livestock and Fisheries
MoLD	Ministry of Livestock Development
MNL	Multinomial Logit
MPP	Marginal Physical Product
PSV	Productive Stock value
ROK	Republic of Kenya
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency
TPP	Total Physical Product
TVC	Total Variable Cost

CHAPTER ONE
INTRODUCTION

1.1 Background Information

The dairy industry in Kenya plays an important role in the economy and also in the general welfare of the Kenyan population. It contributes towards enhancement of food security, employment creation and income generation thus enhancing the livelihood of different actors along the entire milk value chain (MoLD, 2010). Smallholder farmers owning one to three cows dominate the industry and account for 80% of the total production (Gachuiri *et al.* 2012). Their production systems range from zero grazing to extensive grazing on unimproved natural pasture (Wambugu *et al.* 2011).

The smallholder dairy enterprises have been characterised by declining farm size, low use of external inputs, low quality and insufficient feeds and a declining genetic base (MoLD 2010; MoALF, 2013). As a result, on-farm milk production has remained low with the average productivity per cow estimated at 7-8 liters per day (MoALF, 2013). On the other hand, there is a growing demand for milk and dairy products driven by expanding urbanization and a rising middle class population (McDermott *et al.*, 2010). The pathway to meeting this increasing milk demand lies in raising animal productivity.

Improving productivity and performance of dairy enterprises require innovative and commercial orientation that eases access to inputs and advisory services. Farmers with low access and limited use of inputs and services are likely to attain poor enterprise performance and consequently low income, which impede investment in quality inputs and services (Technoserve, 2008). In Kenya, this is the scenario resulting from the declining role of public sector in provision of agricultural inputs and extension. In response, the situation has opened opportunities for growth of private service providers.

Smallholder farmers, however, employ small quantities of inputs due to their low scale of production. This coupled with low infrastructure development raises the cost of inputs and services. In addition, lack of suitable collateral in acquisition of dairy loans from commercial banks results into higher cost of credit which discourage farmers from borrowing. Thus, they operate their dairy enterprises without some essential inputs and services needed to produce competitively. A robust input and service supply system therefore can effectively support farmers towards becoming more market oriented with intensified but sustainable farming system. Rademaker *et al*. (2016) observes that a robust supply chain will enhance efficient and trusted interactions between supply chain partners, thereby reducing transaction costs while strengthening sustainability. There has been a shift towards a pluralistic extension system where government, non-governmental organizations, private companies, and farmers' organisations complementarily play a role in service provision as noted by Wongtschowski *et al*. (2013).

Currently, dairy inputs and services in Kenya are being provided by diverse public and private agro-input suppliers and service providers (Rademaker *et al*., 2016). The services are offered either for free, subsidized or fully paid for by the farmer. Private companies provide advisory services which are integrated in business transactions such as sale of inputs. Milk processors have taken a more proactive role in provision of inputs and services to farmers giving rise to milk processor driven model of input access. This has been necessitated by the seasonal fluctuation in production that lowers processed volumes in dry months to 40% of installed capacity (Setpro, 2013) resulting in incurred losses due to underutilization of available capacity. Producer organization models such as co-operatives and farmer groups are also playing a significant role in facilitating members' access to inputs. This is especially so in areas with poor road network where high cost and inaccessibility of dairy production inputs and support services is a major challenge.

Innovative business models that offer quality inputs and services in a competitive manner can enable smallholder farmers to lower the cost of milk production. There are three business models with which smallholders may overcome the production challenges through access to inputs, extension services, capacity building and output markets. These are producer organization driven, milk buyer driven and direct procuring.

1.2 Statement of the problem

Following a declining trend in public investments in extension services in Kenya, smallholder dairy farmers are accessing inputs and advisory services from private sector through diverse organizational arrangement namely: producer organisation driven, milk processor driven or direct procuring dairy business models. The farmers' choice of the models and the influence that the models have on dairy performance and technical efficiency, however, is unknown. Moreover, rural dairy enterprise operators are less resource endowed and they produce milk where road and market infrastructure is poor, which likely restricts their access to a range of services. In addition, variety of the inputs and services they access and the extent to which this could be dependent on the dairy business model adopted is unknown. It is expected that accessing a wide range of inputs and services will improve efficiency and performance of the dairy enterprises.

1.3 General objectives

The general objective was to assess performance and efficiency of dairy enterprises to inform interventions for improving the economic welfare of smallholder dairy farmers in Nyandarua and Nandi Counties.

1.3.1 Specific objectives

i. To determine factors influencing the choice of dairy business model among smallholder dairy farmers

ii. To determine the influence of dairy business models on economic performance of smallholder dairy enterprises

iii. To compare the technical efficiency among the dairy business models

1.4 Research questions

i. Do farmer and farm characteristics and institutional factors significantly influence farmers' choice of a dairy business model?

ii. Does the choice of any of the three dairy business models result into significantly different economic performance of smallholder dairy enterprise?

iii. Does the technical efficiency of smallholder dairy farmers significantly differ among the dairy business models?

1.5 Justification

Dairy farming is among major enterprises selected for value chain promotion in both Nyandarua and Nandi counties due to its importance in spurring economic and social development in the rural areas. This will require improving access and use of quality inputs and services. The effectiveness of the different dairy business models in provision of these inputs and services may differ and thus there is need to compare the dairy farm's performance and efficiency across the different business models. This will provide dairy stakeholders with empirical evidence for decision making on the effectiveness of the different models. With the knowledge, farmers will prioritize intervention areas at the farm level to become more competitive.

1.6 Scope and limitations

The study was limited to smallholder dairy farmers accessing inputs through producer organisation driven model, milk processor driven model or direct procuring from the market. About half of the sampled farmers did not keep dairy records. Thus, probing was done for farmers to recall data.

1.7 Definition of terms

Smallholder dairy farmers: Farmers practicing mixed farming and purchased some or all of dairy inputs and services

Dairy business models: Organizational arrangements employed by farmers to access dairy inputs and output markets and dairy services

Performance: Profitability of smallholder dairy enterprises

Access to credit: To obtain dairy credit facility

Access to extension: To obtain extension services

Technical efficiency: Maximum milk output at the given level of input use

CHAPTER TWO
LITERATURE REVIEW

2.1 Business models in dairy

In Kenya, spot markets for raw milk are not common. Instead, raw milk is mostly mediated through diverse contractual arrangements designed to address high transaction costs associated with smallholder production systems. Smallholder farmers organize themselves into producer groups to minimize the cost of accessing inputs and services as individuals. Through producer groups, farmers are able to buy inputs in bulk and therefore benefit from trade discount and reduce transport cost. They are also able to negotiate for better output prices. On the other hand, milk processors are concerned with volumes of milk supply per collection point so as to reduce transport cost. Also due to asset specificity, the processor is interested in utilising the full processing capacity. This drive the processors to support farmers in improving productivity through facilitating access to dairy inputs and services to allow operation at full capacity.

Vorley *et al.* (2008) observed that smallholder farmers access markets through business linkages with the various value chain participants. According to Vorley *et al*. (2008) farmers can be linked to the market by business models that are driven by farmers themselves, by produce buyers or can be supported by intermediaries such as non-governmental organizations (NGOs). Business models describe how an enterprise regardless of its size or structure source markets for its products as well as inputs and finance needed (Kelly *et al.*, 2015). The business models thus allow the linkage of small holder farmers to agricultural value chains.

Business models can influence worth creation and how it is shared between farmers and other value chain participants. Business models led by the small scale farmers allow producers to access input and output market collectively despite differing farm assets (Vorley *et al*., 2008). Buyer driven models like out-grower arrangement can be successfully used in linking up smallholder farmers to modern-day markets where funds, expertise, and market access are major constraints.

Measures to improve farmers' access to input and output markets are known to stimulate agricultural production in order to generate income and reduce poverty among the smallholder farmers (Tara, 2012). Farmers are offered to varying degrees, the space to collectively face the demands of modern agriculture with the coordination of activities such as bulk buying of inputs, marketing, negotiating credit and contracts and lobbying policy makers.

Kelly (2012) noted that smallholder farmers suffer from low access to inputs, technical assistance and finance and this is common across all smallholder-based agricultural commodities in developing countries. Thus smallholder organizational models which are vertically integrated into value chains, organisations negotiating on behalf of farmers and informal farmer groups assist in overcoming these constraints. Where effective farmer groups do not exist, external actors seek to organise individual farmers through contractual arrangements. According to Tara (2012), a good model should support smallholder in skills acquisition, better farming techniques, access to input and output market and supply chain enhancement.

Pingali *et al*. (2005) argued that increased transaction costs deter smallholder farmers from entering the market, and thus do not benefit from commercialised agriculture. Through business models, transaction cost are reduced thus encouraging increased farmer participation in competitive markets and this enhances access to inputs and consequently increase productivity.

2.2 Choice of dairy business model

According to Morgan and Dugdill (2009), effective business models in engaging smallholders should offer better economic returns and are backed by the private sector milk processing firms. The processing enterprises should not only offer market for output but also technical information that enables farmers produce quality products.

Different business models offer varying bundles of goods and/ or services. Subramaniam and Venkatesh (2009) noted that a model offering "one stop bundle" may be preferred not because it provides additional value in itself; rather, farmers are attracted by reliability of accessing inputs and services. Farmers may be interested in getting a complete package and therefore go for a business model offering a variety of inputs and/ or services. Provision of products and services combined into innovative offerings can attract farmers and increase input demand among existing ones. The preference for a given business model can also be based on low transaction costs in accessing quality inputs and services, given the poor road networks in the rural areas.

In dairy, the output (milk) marketing channel to a large extent determines the input access model since the milk buyers often facilitate the supply of inputs. Thus, milk marketing channels that also offer dairy inputs and services are regarded as dairy business models in this study. Previous studies on milk marketing channels that also provided some dairy inputs are reviewed.

Mburu *et al.* (2007) used a logit model to determine factors influencing farmers' milk marketing channels choice either through direct selling or through the dairy cooperative in Kenya highlands. Cooperatives channel was preferable in cases where it acted as source of technical and market information. The choice of producer group (cooperative) was also influenced by need to access credit as the proceeds from milk delivered were used in repayments.

Mutura *et al*. (2015) analysed the determinants of market channel among smallholder dairy farmers in lower Central Kenya, using multinomial logistic regression. Cooperative channel was used as the base category. The study found herd size owned by a household, access to training, total milk produced, access to market information, transaction costs incurred and the education level of the head of the house-hold significantly influenced choice of a marketing channel. The choice of cooperative was favoured by farmers with larger herd size, higher level of education and higher milk output due to the need for an assured market. There was a positive relationship between choosing direct selling over cooperative societies in cases where government extension agents offered farmers training.

Nkwasibwe (2014) analysed the factors influencing choice of milk marketing channels by dairy farmers in Kiruhura District, using a probit model where the channel choice was between formal (cooperatives) and informal (milk vendors) channels. The study found that the total milk produced, the raw milk price offered, payment period and source of market information were significant factors with positive influence on farmers' choice of the formal milk marketing channel. Direct selling was preferred by farmers with larger households and who covered less distance to the milk collection centres. The author argued large household were expected to have higher demand for cash to cater for domestic needs hence the choice for a channel paying on a daily basis. Longer distance to collection centre was argued to increase marketing cost and this hindered farmers' participation in formal market.

Moturi *et al*. (2015) used multinomial logit to analyse the factors determining milk marketing channel choice in the Kenyan highlands. The channels under consideration were cooperative, private and traditional channels (direct selling). The results showed distance to collection centre and education level had significant influence on the marketing channel chosen. The distance to major market, a proxy for access to alternative markets reduced the likelihood of farmers being in a traditional channel and this was attributed to the higher transaction cost. The results also showed the being a member of an agricultural organization increased the possibility of being in a cooperative (producer organized) channel compared to traditional channel. This could have been attributed to the role of collective action in attaining greater bargaining power and enabling reduction of transaction costs in access of dairy production and marketing information.

From literature reviewed, farm and farmer characteristics as well as institution factors have influence on the choice of the input and output market. Since smallholder farmers are unable to negotiate or pay for various services as individuals, organisation structures driven by producers or milk processors facilitate access to dairy inputs and services by lowering transaction costs especially in accessing credit, extension and training.

2.3 Performance of dairy enterprises

Smallholder dairy farms suffer from insufficient quantity and quality of feeds, less utilization of manufactured cattle feeds, poor access to artificial insemination services and animal health as well as to credit services (Wambugu *et al.*, 2011). In addition, Muia *et al*. (2011) identified high costs of dairy production in terms of inputs and support services and the inappropriate dairy production technologies as major causes of low production and market output thereby reducing dairy income. Dairy business models can play an important role not only in improving access to dairy inputs and services but also in reducing the dairy production cost. The inputs used and their cost structure as well as the productivity of farms linked to each business model impacts on the performance of a dairy enterprise.

Various tools are used to measure performance of an enterprise among them, cost benefit analysis and gross margin analysis (Nyekanyeka 2011). Cost benefit analysis compares the cost and benefits of an enterprise. Cost includes direct and indirect costs and opportunity costs while benefits include all direct and indirect revenues and intangible benefits. M'buru *et al.* (2007) did a cost benefit analysis of smallholder dairy cattle enterprises in different agro-ecological zones in Kenya highlands. Though the non- market value from dairy firms was omitted due to lack of data, the results showed dairy farming had positive returns. The cost benefit analysis is useful where there is possibility of quantifying all the benefits and cost. Profitability as a measure of performance incorporates the variable cost and also fixed or administrative costs such as asset depreciation, interest, land rent and salaries, which have to be paid regardless of the size of enterprise. Gross margin analysis, however, has the advantage of easy computation as only the enterprise income and variable costs are considered (Kahan, 2010).

Gross margin analysis has been widely used in farm planning. Wambugu *et al.* (2011) noted that the performance of the dairy enterprises at the farm level can be defined through estimation of firm's gross margin. Gross margin analysis allow evaluation of actual enterprise performance as well as comparison of similar enterprises when only variable cost and gross income is available, thus providing a basis for decision making on the farm's overall enterprise mix.

Kahan (2010) argues the use of gross margins as a model to deciding on the farms' overall enterprise mix should be interpreted with caution as it does not include capital expenditure, fixed and overhead cost. However, it does give a useful tool in farm management, making budgets and estimating the probable profits or losses of a given agricultural business.

Previous studies on gross margin analysis in dairy production have compared relative profitability across production systems, across different agro-ecological zones and also among different herd size, a proxy for scale of production. However, no study was found comparing gross margin across the dairy business models. Some of these studies are reviewed.

Nyekanyeka (2011) analysed profitability of improved and local breeds among smallholder dairy farmers in Lilongwe. The value of milk produced was used as the gross income while variable cost included feed (concentrates), veterinary, breeding and labour (hired) cost. The results found, on average farmers had positive gross margins which implied that smallholder dairying generates income to dairy farmers. The gross margin for the improved production system (improved breeds) was higher than that of local system due to higher production. Improving access to credit among low income farmers and capacity building of dairy farmers through informal training were found to ensure sustainable improvements in smallholder dairy farming.

Wambugu *et al.* (2011) employed gross margin analysis to determine the performance of dairy farming in Kenya across agro-ecological zones. Revenue consisted, a sum of value of milk sales and consumed by the household while variable costs included cost of fodder, concentrates, labour, veterinary expenses, transport cost, salt lick and consumables. The results found dairy was an economically viable enterprise and could perform better when marketing is collectively done. In addition there should be linkages to processing markets and improved access to production information and credit.

Mumba (2012) analysed the viability of smallholder dairy farming in various provinces of Zambia. Revenue utilised in the analysis was the value of milk produced. That is, the value of milk sold, consumed on the farm and fed to calves. Variable cost consisted of cost of feeds (hay and silage and cost of concentrates), hired labour, deworming, vaccination, dipping, treatment and artificial insemination (AI). The results showed that the cost of production differed with the level of intensification. The gross margin, however, was not significantly different due to the differences in milk productivity and prices which had a buffering effect in the respective provinces.

Mawa (2013) assessed the profitability of smallholder dairy farmers in the Kenyan highlands. Revenue was computed by summing value of milk sold and value of milk utilised at home. Milk sold was valued at market price while unsold milk was valued at the unit cost of milk production. On deducting total variable cost from total revenue, the difference, that is, the gross margin attained was positive indicating dairy farming was profitable. The results showed that feed resources constituted a major cost component of milk production, contributing 79% of total variable cost.

Semerci *et al*. (2014) analysed gross margin in dairy cattle in Hatay province where data obtained from the research was reviewed according to the enterprises' size that was defined by herd size. It was found that the enterprises with large herd size, that is, greater than ten, had higher gross margin. This could have been attributed to the economies of scale where cost per unit reduced with the level of production. The study established the cost of feeds as being the highest cost with about 81.6% of total cost.

Yielmaz *et al.* (2016) did an economic analysis of dairy cattle farms in East Mediterranean region of Turkey. The gross productive value was calculated as a summation of the total value of farm milk, manure sales and the increment in stock value, that is, the productive stock value (PSV). The gross productive value was used to derive the revenue. The variable cost, that is, direct expenses were cost of feed for the milk cows, veterinary costs, milking machines expenses and artificial insemination expenses. In this study, labour was considered as a fixed cost and thus excluded in computing gross margin. The results showed feed costs was the highest variable cost (86.52%). This was followed by the veterinary drug costs (7.67%) and breeding costs (2.95%). Of the total feed cost, 56.88% was concentrate feed cost while 43.12% was forage cost. From the total production cost, feed cost was the highest followed by labour cost.

2.4 Productivity and efficiency

The efficiency of a firm is made of two components; technical and allocative efficiency (Coelli, Rao, Donnell and Battese, 2005). When the two components are combined they give a measure of total economic efficiency. An enterprise can be inefficient if it obtains less than the highest output attainable from a given level of inputs (technically inefficient) or if it does not purchase the optimal package of inputs given their prices and marginal productivities (allocative inefficient). A producer is technical efficient (TE) if he cannot produce more of an output without using more of some input or producing less of some other output.

The productivity of a dairy farm is determined by the existing production technology, that is, the level of factors of production employed versus the quantity of output and/ or the environment where production occurs (Kokhinou 2010). Nevertheless, in a given period of time, with similar technology and production environment, farms show differing productivity levels as a result of varying production efficiency (Korres, 2007) thus the need to determine farm's efficiency. Dairy business models offer farmers not only the dairy inputs and services but also skills to enable them make right decisions in optimisation of the factors of production used.

Efficiency varies across producers and also through time. Thus, in seeking determinants of this variation, some studies have adopted a two-step procedure to investigate the relationship (Kibirige, 2008; Kibiego, Lagat and Bebe, 2015). In the first step, observation specific inefficiency is estimated and the index regressed on a vector of independent variables in stage two. A negative coefficient of the exogenous variable in the regression indicates that firms with larger values of the variable tend to have a lower level of inefficiency, that is, they are more efficient. This method, that is, the two-step procedure, has the disadvantage of being biased since the model estimated in the step one is mis-specified (Battese and Coelli, 1995). It is argued that social economic variables have an effect on efficiency. The alternative is to use a single stage approach, where the independent variables are incorporated directly into the inefficiency error component. The mean or the variance of the inefficiency error component then, is hypothesised to be a function of a vector of independent variables (Kumbhakar and Lovell, 2000; Ng'ang'a *et al.,* 2010; Mawa *et al.,* 2014).

No previous studies were found comparing efficiency across dairy business models even though they play a great role in facilitating access to extension services and training.
Nakanwagi and Hyuha (2015) used a Cobb-Douglas stochastic production frontier to determine technical efficiency of milk enterprises in Kiboga District, Uganda. The resources under consideration were the area under pasture land, veterinary cost, labour (person days), farm assets and the breed of cattle kept. The results showed farmers achieved a mean technical efficiency level of 68%. All the resources in the production frontier model were positive and significant indicating they had positive effect on milk output. Determinants of

technical efficiency were number of cattle, better breeds, hired labour, land ownership, water source and extension services. Farmers with large herd size and higher land acreage were expected to be risk takers and technology adopters. A water source within the farm saved time and resources that would have been spent while searching for water hence the positive impact on efficiency.

Kimenchu *et al*. (2013) evaluated the technical efficiency of dairy farms in Kenya's Eastern Central highlands using stochastic production frontier. The model used amount of mineral supplement, concentrates, roughage feed, labour, herd size and land size as variables. The results showed the herd size and quantity of feeds (mineral supplement and roughage) had a positive effect on total milk output. The size of land owned had no significant effect probably because feeds could be purchased. The mean technical efficiency of the farms was 85.5%, implying that milk production would increase by 14.5% through better use of available resources, given the current state of technology and without extra cost. Roughage and labour costs were the main determinants of dairy farming costs.

Majiwa *et al.* (2012) examined the technical efficiency of smallholder dairy farms of rural Kenya. The Cobb-Douglas stochastic production frontier model was used to identify the determinants of technical inefficiency. The inputs employed in the production model were cost of feeds, labour in man-days, type of breed kept, land size while output was milk produced in litres. The findings revealed that the mean efficiency was 79% which suggested that 21% of potential production was not produced due to technical inefficiency. Use of artificial insemination which was a proxy for access to extension services, water source and the level of schooling had positive influence on efficiency. Land size was not significant probably because fodder could be purchased.

Ayele and Muriithi (2012) measured technical efficiency among smallholder dairy farms in East Africa. Data envelopment analysis (DEA) was used where a number of dairy inputs and outputs were considered. Outputs included value of milk sold and consumed, value of animals sold and manure sales while inputs were cost of labour, fodder, animal health, breeding, extension and cattle housing. The results showed a mean efficiency score of 48.8% implying farmers had the potential to improve their production by 51.2% at the same level of input use.

About a third of the sampled farmers achieved less than 50% technical efficiency score while only a fifth operated at the production possibility frontier. Efficiency was influenced by the proportion of improved breed in the herd, own farm production of proteinous fodder, production system (zero grazing) employed and the milk market accessed. Farmers who sold milk to final consumers were more efficient possibly because of higher prices offered that could enable more investment in dairy. None of the household head characteristics considered had significant effect on the efficiency score attained.

Al-Sharafat (2012) analysed the technical efficiency of dairy farms in Jordan using a stochastic frontier. Output was the value of milk produced while inputs included; number of lactating cows, quantity of feeds in kilograms, labour input in man-days, value of veterinary services and drugs, and fixed inputs cost. The mean technical efficiency achieved was 40%, indicating farms could increase their production by 60% with the available input quantities. The study found education (number of schooling years), dairy experience and the herd size to have positive influence on efficiency. However, 'extension contact' had a negative influence on efficiency and this was argued to be as a result of lack of participatory approach and poor extension program design.

Cabrera *et al.* (2010) analysed the technical efficiency among dairy farms in Wisconsin using a stochastic production frontier simultenously with an inefficiency model. The production frontier used six inputs namely; number of adult cows in the herd, cost of purchased feedstuffs, capital, total expenses related to crop production, labour (family and hired labour) and livestock expenses (breeding expenses, veterinary and medicines). The results showed all the inputs except capital had positive and significant effect on the quantity of milk produced. The mean technical efficiency was 88% indicating there was room for improving the productivity. Technical efficiency was positively influenced by own feed formulation, use of family labour and feed purchased per cow.

Hussein (2011) examined the performance of mixed crop - livestock production system in Northern Ethiopia using cross section data. Efficiency was estimated by data envelopment analysis (DEA) model. The results indicated the mean technical efficiency of the household was 55% and thus, production could be improved by 45% at the same level of input use.

Efficiency improvement was thus an opportunity for improving productivity with available resources and technology. The production efficiency was influenced by size of the farm, owning of livestock, labour availability, other income sources outside the farm and improved technology adoption.

Mung'ayo (2009) analysed the influence of production system on technical efficiency of smallholder milk production in Trans-nzoia and Kakamega districts, Kenya. Stochastic production frontier was employed where dependent variable was the annual milk production per cow. Inputs used included amount of fodder and concentrate per cow, capital investment, labour in man hours, land area under fodder and pasture and amount of mineral salt per cow. The results showed all the inputs had positive effect on milk production. The mean technical efficiency score was 75.48%. Technical efficiency increased with the level of intensification; extensive/ free range grazing (71.22%), semi zero grazing (75.93%) and stall feeding (77.73%). Inefficiency increased with age while education, access to credit, extension and market accessed significantly reduced inefficiency.

Masuku (2014) estimated technical efficiency of dairy farmers in Swaziland where inputs employed included the number of cows in the herd, grazing land and concentrate feeds in kilogram while the output was milk yield per cow. The results showed the elasticity of all inputs was positive and significant, indicating they had positive effect on milk output. The mean technical efficiency score was 66%. This meant 34% of potential milk output was lost due to technical inefficiencies. Efficiency was positively influenced by area of land under pasture, dairy experience (in years), access to credit and training. Distance to market measured in kilometres had negative influence and this could have been as a result of more time spent away from the farm and cost of delivering inputs.

2.4.2 Factors influencing efficiency

Identifying the determinants of efficiency informs management and policy decisions. From literature, various factors have been identified to influence efficiency among them age, education level, off-farm income, technology and access to credit and extension. In this study, some of these factors are reviewed.

Age of household head has sometimes been used as a proxy for experience. Musemwa *et al.* (2013); Otieno *et al.* (2012) found age to be positively correlated with high efficiency. Older farmers may have more resources at their disposal, and can afford quality inputs. However, Mussa *et al*. (2012); Sajjard and Khan (2010); Kibaara (2005) found otherwise, where technical efficiency of younger farmers was found to be higher. The ability to access wide and reliable information from different media can contribute to better decision making even without previous production experience.

Laure *et al.* (2004) studied determinants of efficiency in crops and livestock and found farmer's education as the most important determinant for technical efficiency. These findings were similar to those of Kibaara (2005); Musemwa *et al*. (2013) who found the parameter estimate of level of education to be positive and statistically significant at 5%. Farmers with a higher level of education are in a better position to obtain, analyse and interpret information. Low level of education can be a major constraint impeding the adoption of new technologies and consequently influence the level of efficiency.

Adoption of technology plays a great role in improving productivity and efficiency. Cabrera, Solis and Corral (2010) determined technical efficiency among dairy farmers in Wisconsin and found the use of total mixed ration (TMR) technology increased efficiency. In TMR, all feedstuffs are blended into a complete ration with the required level of nutrients. Technologies like rearing of improved breeds and growing of leguminous fodder improve efficiency as established by Ayele and Muriithi (2012). Other management practices like conservation of feeds, feeding regime and use of improved bull or artificial insemination (AI) positively influence milk productivity.

The interaction among farmers impacts on acquisition of skills as well as access to credit, extension and input, and output market information. The ease of this access has a great influence on productivity. Kibaara (2005) found that farmers who were able to access credit planted hybrid seeds which have higher yield potential and are resistant to diseases and this increased efficiency. This was echoed by Nyekanyeka (2011) who found access to credit also reduced inefficiency. Availability of credit enabled farmers to purchase quality inputs on time.

Accessibility to input and output market reduces transaction cost and consequently total cost. Kibiego *et al.* (2015) measured market access by the distance to the shopping centre and found the nearer farmers were to the centre, the higher the efficiency score. Otieno *et al*. (2012) study on determinant of technical efficiency in beef cattle production in Kenya found that access to market contracts influenced efficiency positively. Also extension officers empower farmers through information on better production technologies, recommended farm practices and better output market. Majiwa *et al.* (2012); Debebe *et al.* (2015) found farmers who had higher frequency of field visits by extension officers, improved their access to quality inputs and farm management practices thus increasing their productivity.

From the efficiency literature reviewed, dairy enterprises are not efficient and the level of inefficiency varies widely among smallholders dairy farmers. Thus, potential production is lost due to the inefficiency. Various factors have been identified to influence the level of technical efficiency attained by smallholder dairy farmers. These can be categorised as farm and farmer characteristics among them, education level, age and dairy experience. Institutional factors identified include access to credit and extension while management practices include use of improved breeds, production of quality fodder and feed formulation (use of total mix ration, TMR).

2.5 Theoretical framework

This study is based on production theory. Production is the economic process of transforming inputs into output through a given production technology (Rasmussen, 2012). The description of production technology is based on the relationship between inputs and outputs. Production theory, on the other hand, is an economic theory of choices that producers make to maximize their objectives.

A production technology can consist of a number of inputs and one output, described as

$$Y = f(X_1, X_2, \ldots . X_m)$$

where *Y*, is the level of output, *f*(.) is the process that changes the inputs into outputs and X_i, for *i* = 1, 2, …, m is the quantity of input i.

Technical efficiency can be measured from by comparing the observed input levels with the minimum potential input required to produce the output or by comparing the observed output with the potential output obtainable from the given level of inputs.

A neoclassical production frontier (upper half of Figure 1) describes production relationship in agriculture (Debertin, 2002). The production frontier (total physical product, TPP) represents the maximum output attainable from each input level. As the farmer use more of input X_1, the productivity of the input also increases but at a variable rate as shown by the marginal physical product (MPP) curve in the lower half of Figure 1. The TPP function reaches a maximum beyond which, increase in the use of the variable input X_1 result in a decrease in total output (stage 3). The optimal point of production is where the productivity (average physical product$= Y/X_1$) is highest. Figure 1 shows various lines drawn out from the origin. The slope of each line drawn from the origin to a point on the production function represents the average physical product (APP) for the function at that point. Only one line is tangent to the frontier and it is at this point where productivity (average physical product) is highest. At this point, marginal product equal average product as illustrated by the lower half of Figure 1.

APP =MPP, that is, *y/x = dy/dx.*

Along and below the frontier indicate all the possible input-output combinations that are feasible to produce. Firms will operate on the frontier if they are technical efficient. Firms that are technically inefficient operate beneath the frontier. Point A and B show points of inefficiency because technically it is possible to increase the output without increase in quantity of input X. Point C, represent efficient point since it is at the frontier. Thus, though all points on the frontier are points of technical efficiency, only one point has the highest productivity.

Various factors could make a producer fail to operate along the frontier and these are categorised into two. Statistical noise which include factors beyond the control of an agricultural producer, for example, weather, disease and pest infestation. Secondly is the inefficiency error term which may arise from failure on the producer to allocate available resources in a way that optimises production. This could arise from factors such as inexperience in production process and lack skills. To identify the deviation from the frontier resulting from inefficiency, stochastic production frontier is used since it has the advantage of accounting for statistical noise.

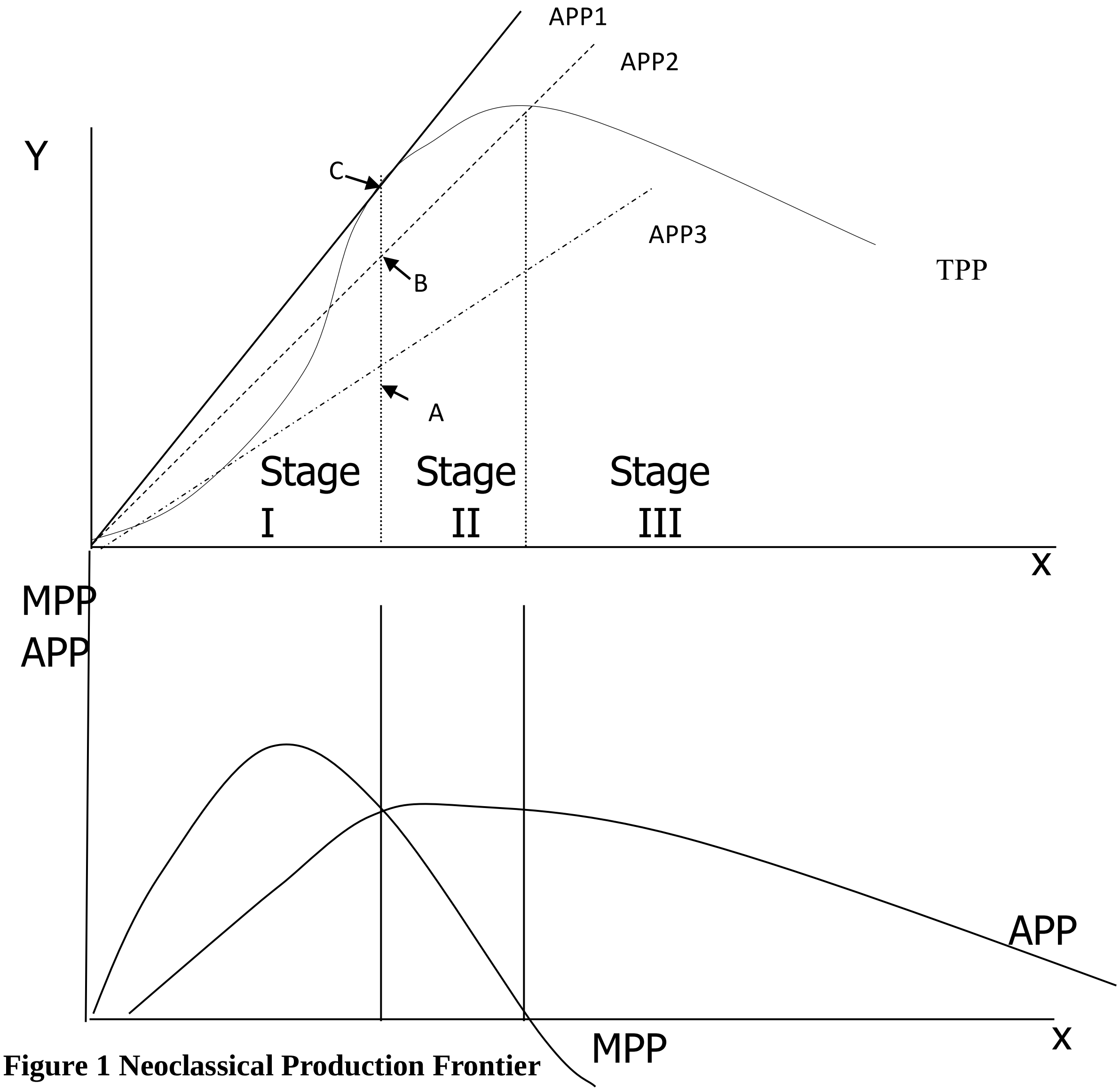

Figure 1 Neoclassical Production Frontier

2.6 Conceptual framework

Figure 2 illustrates the conceptualised interrelations influencing the choice of a dairy business model and the influence on performance and technical efficiency.

A farmer is likely to choose a dairy business model based on several decision criteria, including the farm and farmer characteristics and institutional factors.

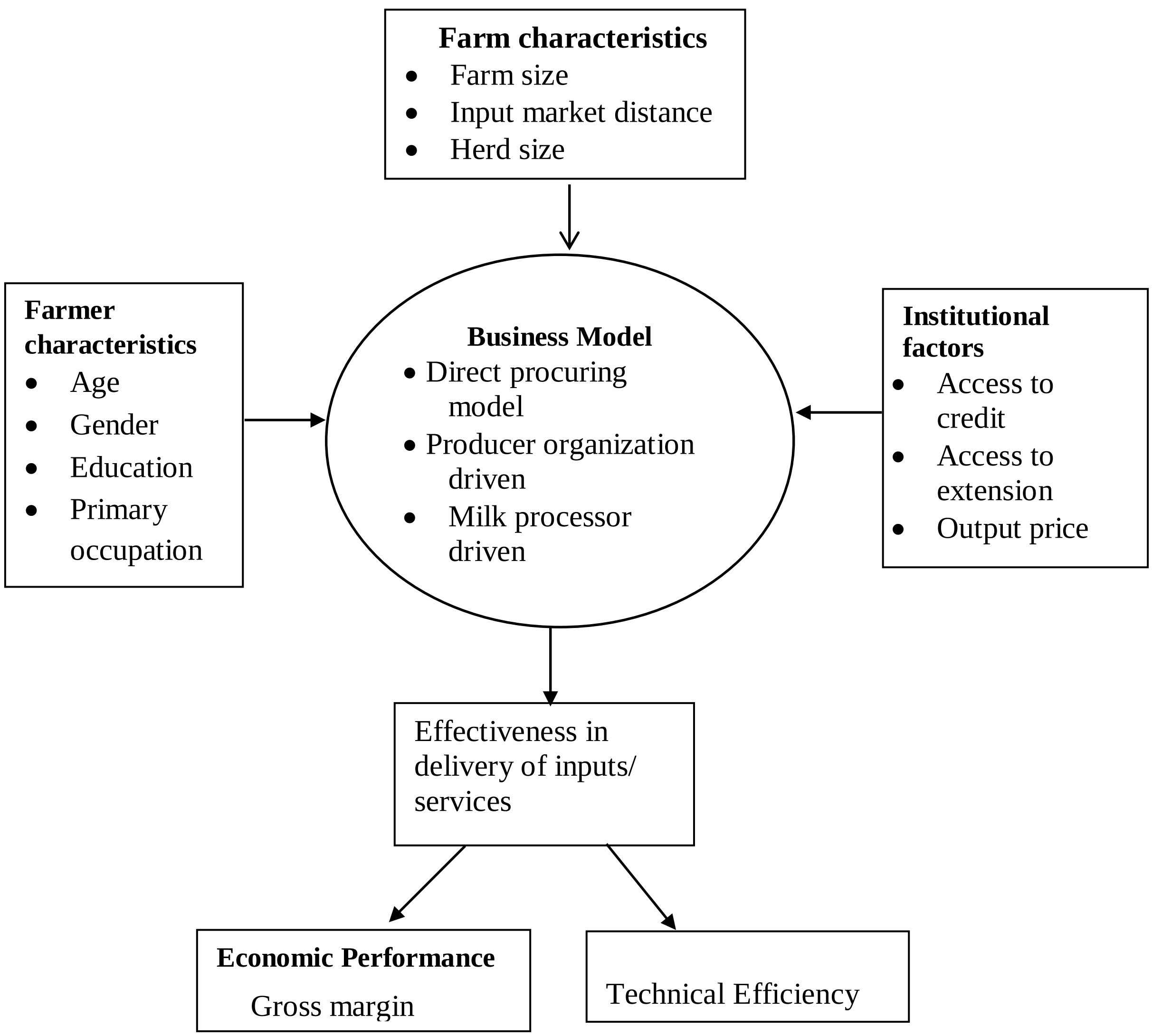

Figure 2: Interrelations determining choice of dairy business models and their influence on performance and efficiency

Farm and farmer characteristics as well as institutional factors can influence farmers' decision on the model of accessing dairy inputs and services. For instance, farmers who are far from the input market may prefer an arrangement than can ease the access of the dairy inputs. The ability to source funds and knowledge/skills in dairy farming may also influence the business model a farmer will choose. In the two counties, there are three dairy business models; direct procuring, producer organisation driven and milk processor driven models operating to varying degrees. Thus, the business model chosen determines the access to diverse range of inputs, extension and credit needed to support dairy enterprises. The product (inputs and output) and service flow for each business model is shown in Figure 3, Figure 4 and Figure 5. Given the wide range of inputs and services in dairy production as well as the heterogeneity of smallholder dairy farmers, the dairy business models are likely to be successful to varying degrees. The effectiveness of each business model in delivery of inputs and services is hypothesised to influence the performance (gross margin) and technical efficiency attained by the dairy farm enterprises.

The dairy business models' inputs and services chart are as follows.

Producer organisation driven model

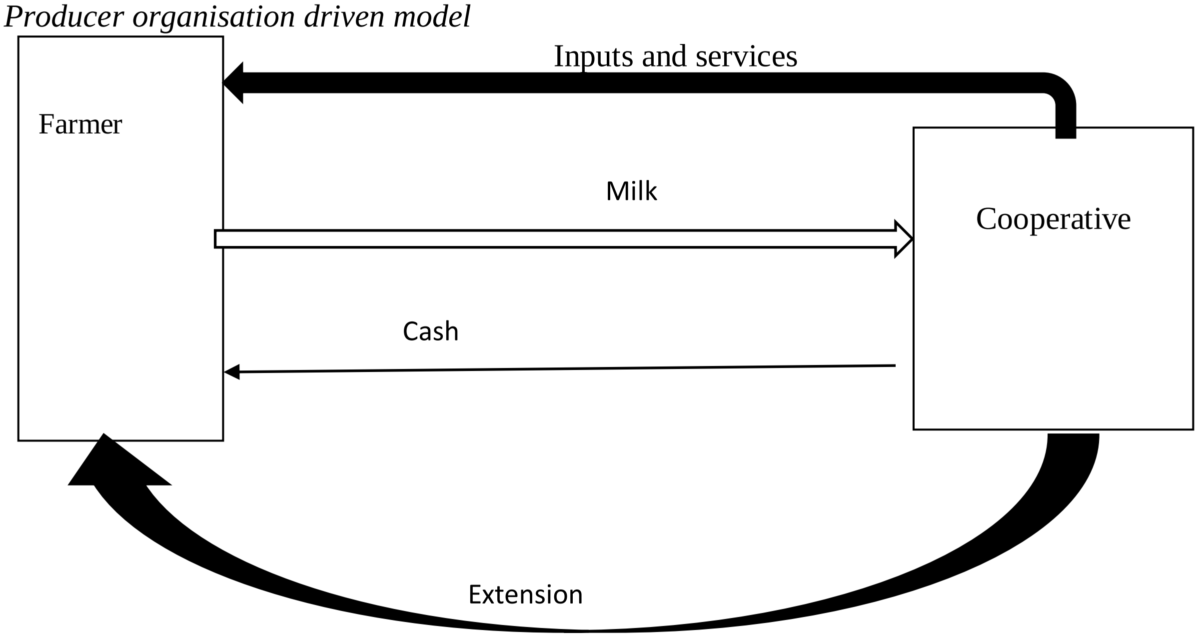

Figure 3 Producer organisation driven dairy business model

Figure 3 illustrates a producer organisation driven dairy business model. In this business model, dairy farmers have formed cooperatives through which they sell their milk and acquire the dairy production inputs and services. The dairy cooperatives own agro-inputs shops (agrovets) located at the milk bulking centres. The whole range of inputs and services are offered through these outlets; concentrates and mineral salts, veterinary drugs, fodder seeds, dairy equipment, animal health, artificial insemination and extension services. The services are offered by qualified technician employed by the cooperative. Farmers pay for the inputs and services through check off system from the milk proceeds at the end of the month and the balance is paid directly into their bank accounts.

Milk processor driven model

Figure 4 illustrates milk processor driven model. In this dairy business model, farmers sell their milk directly to a specific milk processor, like new Kenya Cooperative Creameries (nKCC) and Brookside dairy. The processor facilitates the farmers to acquire dairy inputs and services by contractual arrangement with private inputs and service providers since the processor does not own agro-inputs shops. The processor, however, has employed extension agents who provide extension services. Farmers pay for inputs through check off system. The processor then pays the inputs and service providers. The balance after deduction of inputs cost is paid into farmers' bank accounts.

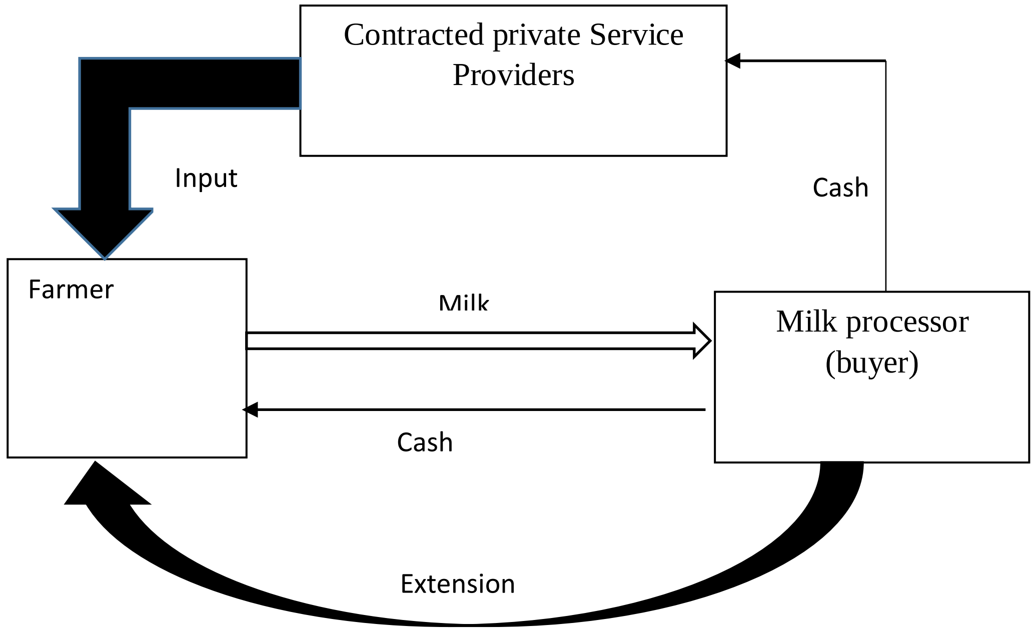

Figure 4 Milk processor driven dairy business model

Direct procuring

In this dairy business model (Figure 5), farmers search for dairy inputs and services by themselves and payment is on cash basis. Milk is sold to varied markets such as mobile milk traders, institutions, cooperatives and milk processor. Depending on the market outlet, farmers are paid weekly, fortnight or monthly for their milk supply.

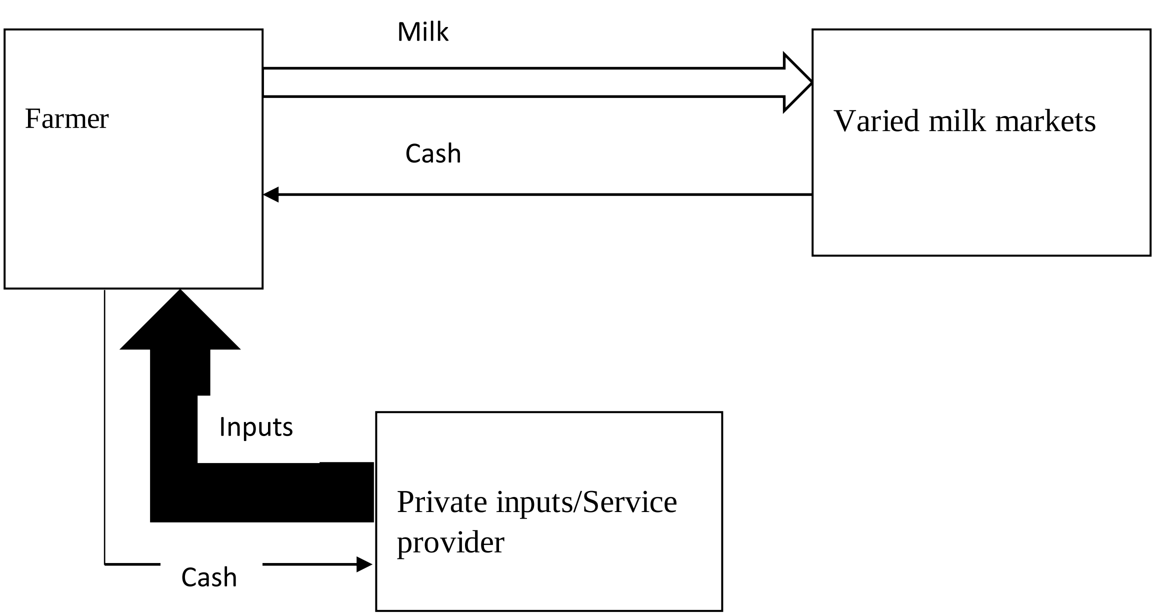

Figure 5 Direct procuring dairy business model

CHAPTER THREE
METHODOLOGY

3.1 Description of study area

The study was conducted in Nyandarua and Nandi Counties where dairy is a productive farm enterprise with a contribution of over 30% of gross production (MoALF, 2014). In the two counties, dairy value chain enterprise is a prioritised development agenda (MoALF, 2014).

Nyandarua County is within the Central Kenya highlands with an altitude range of 2350 to 3000 metres above sea level and has bimodal rainfall from March to May (long rains) and September to November (short rains). The mean annual rainfall ranges between 700mm and 1,600mm while the temperature ranges between 12^{o} C and 25^{o} C. Agriculture is the economic mainstay of the county with 98% of agricultural land categorized as high potential. Most land is held by small-scale farmers who practice mixed farming with average farm size of 1.2 ha. Dairy and horticulture are the leading enterprises in the county (County government of Nyandarua, 2013).

Nandi County is found in the North Rift and receives an average rainfall of about 1200mm to 2000mm per annum. In the areas with 1500 mm and above of rainfall per annum, tea is the dominant crop while in the relatively drier areas to the East and North East receiving an average rainfall of 1200mm per annum grow maize and sugarcane. Dairy production, however, is practiced in the entire county. The average farm size in the county for small scale farms is 1.32 ha, and large scale farms, 11.2 ha (County government of Nandi, 2013).

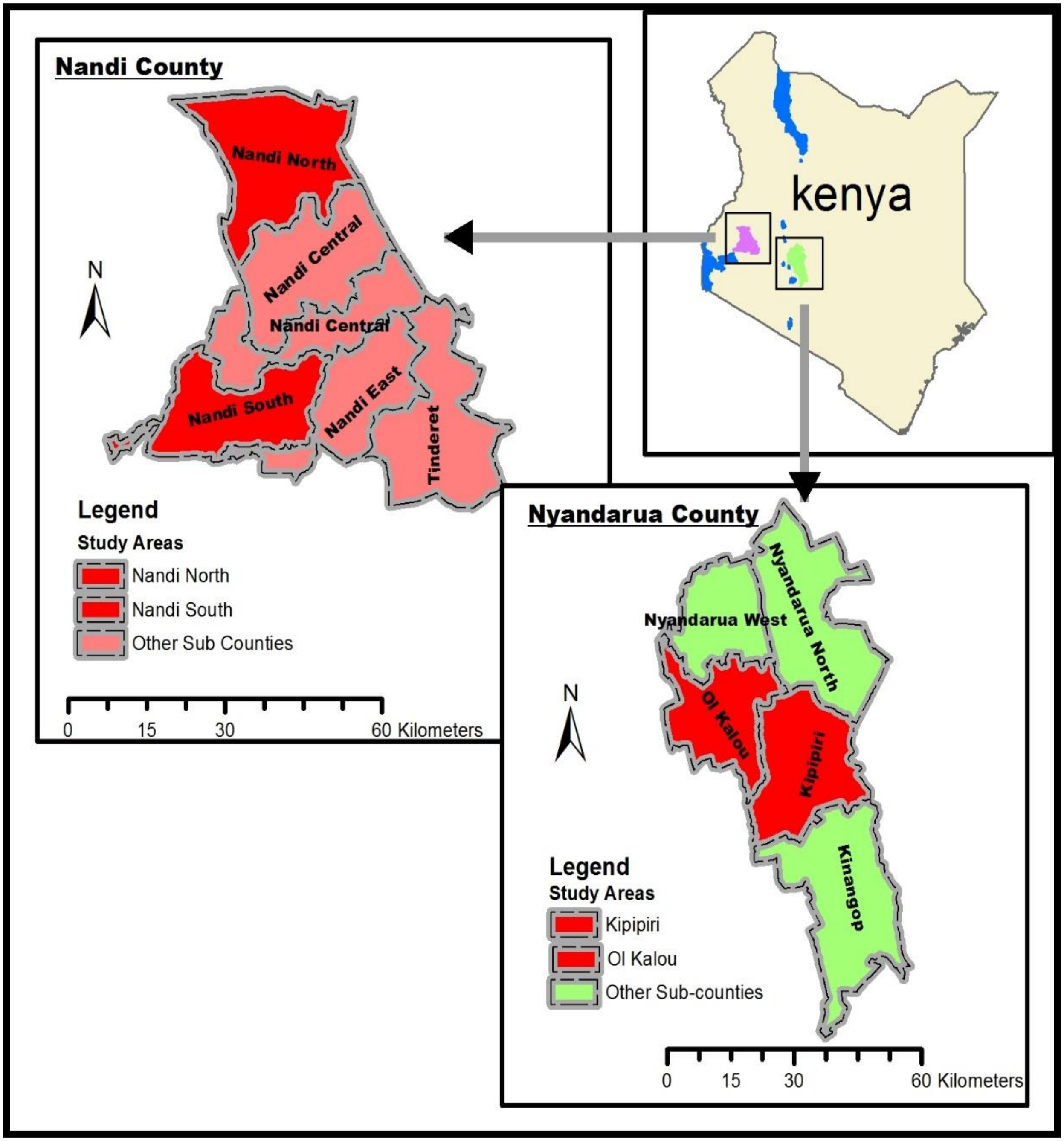

Figure6 Map of Nandi and Nyandarua counties

Source: IEBC County maps (2010)

3.2 Sampling procedure

The sample size was determined by the formula based on Kothari (2004) given by equation one.

$$n = \frac{p(1-p)Z^2}{E^2} \quad \text{-- } 1$$

where n = sample size, p = proportion of population containing major interest, z = confidence level ($\alpha = 0.05$), E = acceptable error.

The proportion of smallholder farmers in Nyandarua and Nandi counties is 80% as was established by Thorpe *et al*., (2000). Thus, in equation one above, p = 0.8, Z = 1.96 and E = 0.05.

$$n = \frac{0.8(1-0.8)1.96^2}{0.05^2} = 246 \text{ -- } 2$$

To select the individual farm households, Nyandarua and Nandi counties were purposively selected. Two sub-counties in each county where the three dairy business were employed were then selected; Olkalou and Kipipiri sub-counties in Nyandarua, Nandi Central and Nandi North in Nandi county. Three locations were then randomly selected in each sub-county. Individual farm households were finally randomly sampled.

3.3 Data collection

The data were collected between the month of July and August 2016. Structured questionnaires were administered to smallholder farmers to collect primary data on demographic characteristics, livestock production and costs, production practices and institutional factors. Data were cleaned and analyzed using STATA 12 Statistical software. The factors influencing choice of a business model were established in a regression model while stochastic production frontier model was used to predict efficiency.

3.4.1 Determining factors influencing choice of dairy business model

Multinomial Logit Model (MNL) was preferred for determining the factors influencing the choice of dairy business model because it allows analysis of decision across more than two categories in the dependent variable. Multinomial Logit model is used for estimating unordered and multi category dependent variables (Gujarati, 2004) in which a base alternative is chosen for relative comparison to explain the other alternatives. Multinomial logit also allows a single decision among alternatives.

The MNL model was specified as;

$$P_J = \beta_J X_{IJ} + \varepsilon_{IJ} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

where P_j is the probability of choosing dairy business model (DBM) j from a vector of the three dairy business models namely (j = 1, 2, 3), β_j is a vector of parameters to be estimated, ε_{ij} is the error term assumed to have a distribution with mean 0 and variance σ^2, X_{ij} is a vector of factors affecting choice of business model. If a farmer chooses model j, then utility U_{ij} attained through provision of effective dairy inputs and services is higher compared to that of any other business model.

MNL estimates the odds of choosing dairy model i relative to the reference category. X_i are the factors affecting choice.

$$Prob\ (Y_i = j) = \frac{e^{\beta jXi}}{1+\sum_{k=1}^{k=I} e^{\beta jXi}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

The odds ratio are computed as

$$In\frac{Pij}{Pi1} = \beta jXi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

where, the dependent variable is the odds of choosing model j relative to base category and β_j is a vector of parameters that reflect the impact of changes in the variables X, on the log odds of choosing model j. Variables used in the multinomial logit are shown in Table1.

The multinomial model for the dairy business model choice is modelled as:

$$P_{ij} = \beta_0 + \sum_{n=1}^{n} \beta_n + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

The empirical model to estimate the relationship between dairy business model and factors influencing the choice is expressed as:

$$P\,(DBM) = \beta_0 + \beta_1 Age + \beta_2\, Gender + \beta_3\, Educ + \beta_4\, PrimOcc + \beta_5\;Farmsize + \beta_6\, Dherd + \beta_7 Mktdist\; + \beta_8 Price\; + \beta_9 Conty\; + \beta_{10} Accrd\; + \beta_{11} Extacc + \varepsilon \quad \ldots\ldots 7$$

Table 1 Variables in Multinomial Logit

Code Variable	Variable	Measurement of variable	Expected sign
Dependent variable			
DBM	Farmer's choice of business model	1 = Direct procuring, 2 = Producer organisation driven model, 3 = Milk processor driven model	
Independent variables			
AGE	Age of dairy decision maker	Years	+
GENDER	Gender of dairy decision maker	Dummy (male =1, Female = 0)	-
EDUC	Education level	1 = Primary, 2 = secondary, 3 = Tertiary,4 = No formal	+
PRIMOCC	Primary Occupation	Dummy (Farming = 1, otherwise = 0)	+/-
FARM SIZE	Land owned	Ha (continuous)	+
DHERD	Milking cows	Number	
MKTDIST	Market distance	Time taken to the nearest input centre	-
PRICE	Output price	Kenya shillings (KES)	
COUNTY	County of study	Dummy (Nandi =1, Nyandarua=0)	+/-
ACCRD	Access to credit	Dummy (Yes = 1, No = 0)	-
EXTACC	Access to extension	Dummy (Yes = 1, No = 0)	-

3.4.2 Determining the influence of dairy business models on economic performance

The proxy for economic performance was gross margin which was computed to relate to the influence of the dairy business models. Gross margin is defined as the difference between the value of an enterprise's gross output and total variable costs.

$$GM = GPV - TVC \quad \ldots\ldots 8$$

Where, GM is gross margin, TVC is total variable cost associated with milk production and GPV is gross production value which is the value of milk produced and increment in stock value. Dairy production not only yield milk but also calves without any addition cost hence the inclusion of the increment in stock value. Gross production value was thus computed as the sum of value of total milk produced and productive stock value (PSV), which was, the increment in value of stock within one year.

Total variable cost included total veterinary cost, that is, cost of treatment and vaccination, deworming, acaricide and breeding (artificial insemination or use of bulls) cost. It also included cost of purchased feeds, concentrates and minerals as well as cost of fodder produced on the farm. Labour cost was calculated as time in hours used in dairy activities and included both family and hired valued at the local wage rate as the study assumed that if the family labour is not available, then the local labour would be hired. Most farmers did not keep records and therefore probing was done so as to get the production and cost data.

To determine the influence of dairy business model on performance, a Kruskal –Wallis test was conducted. This is a rank-based non parametric test that is used to determine if the difference between two or more groups of an independent variable on a continuous or ordinal dependent variable is statistically significant. With this test, comparison of mean across groups with varying sample size and is also useful when the dependent variable is not normally distributed for each group of independent variable unlike ANOVA which has the assumption of normality (Kothari, 2004).

Gross margin was the dependent variable while the dairy business model, a categorical variable for direct procuring, producer organisation driven and milk processor driven dairy business models was the independent variable.

3.4.3 Estimating technical efficiency across the dairy business models

Efficiency is the success of a firm in producing maximum output from a given set of inputs. The highest output attainable from each input level is represented by the production frontier. The production frontier also reflects the level of technology employed by the farm. In practice, the efficient production frontier is estimated from the observations of the inputs and outputs of a number of firms. The individual firm's efficiency is then measured relative to the frontier. The methods used to estimate efficiency frontiers fall under two categories, parametric and non-parametric. Parametric categories include stochastic frontier and deterministic models while non-parametric category includes data envelopment analysis (DEA). The choice of the particular method depends on whether functional form is known, whether or not random errors are to be accounted for and the probability distribution assumed for the inefficiency (Coelli *et al*., 2005).

The deterministic model just like data envelopment analysis (DEA) has the disadvantage of not accounting for the statistical noise and all the deviation from the frontier is assumed to be the result of inefficiency (Coelli *et al*., 2005). To overcome the challenge of deterministic models, stochastic frontier approach of the form below is used;

$$Y = f(X_i; \beta). \exp(v_i - u_i)$$

Where,

Y is the output, X_i is a vector of inputs, β is a vector of parameters to be estimated, v_i represent statistical noise and μ_i represent one sided inefficiency term.

Statistical noise arises from exogenous shocks beyond the control of a farmer as well as omission of important variables from the vector X_i, measurement errors and approximation errors associated with the choice of a functional form (Coelli *et al*., 2005). In respect to the one-sided (inefficiency) error, μ_i, there are a number of distributions assumptions in literature. The half-normal, exponential, and truncated from below at zero are the most commonly used distribution assumptions (Murillo and Vega, 2000).

With the two error terms, v_i and u_i, that are assumed to be independent of each other and of the input variables, the likelihood functions are defined and maximum likelihood estimates established. The ranking of predicted technical efficiency is quite robust to distributional choice, however, the principle of parsimony favours half normal and exponential (Coelli *et al.*, 2005). If no assumptions are made regarding the distribution, the frontier is estimated by corrected ordinary least squares method (COLS). However, the maximum likelihood estimates (MLE) are more efficient than COLS (Coelli *et al.*, 2005).

Stochastic frontier model was thus employed for predicting technical efficiency attained across the farms linked to the different business models. Stochastic production frontier is the most appropriate approach in studies related to the agriculture. This is because of its capability to deal with stochastic noise as well as enabling hypothesis testing (Coelli *et al.*, 2005). According to Kumbhakar *et al.* (2016), the parameters of the stochastic frontier and those of inefficiency model are estimated simultaneously in a single step procedure that accounts for the exogenous influences on inefficiency. This is achieved by parameterizing the distribution function of the inefficiency term, *ui,* as a function of exogenous factors *(zi*) that are likely to affect inefficiency.

The dependent variable was the milk output and dependent variables consisted of feed, land (area under fodder and natural pasture), veterinary cost and labour.

The model used is of the form;

$$InY = \beta 0 + \sum \beta_i In\mathrm{X}_i + vi - ui \quad \text{..........} \quad 9$$

$$ui = \gamma' zi + \varepsilon i \quad \text{..........} \quad 10$$

Where, Y is the milk output, X_i is a vector of inputs, β is a vector of parameters to be estimated, v_i represent random noise in production process and u_i captures the inefficiency. The inefficiency component, u_i, has a systematic component $\gamma' z_i$ associated with exogenous variables and random component ε_i.

The single stage production frontier model is given as

$$InY = \beta 0 + \sum \beta_i In\mathrm{X}_i + v_i - (\gamma' z_i + \varepsilon_i) \quad \text{..........} \quad 11$$

Since $u_i \geq 0$, then $\varepsilon_i \geq - \gamma' z_i$

In predicting technical efficiency, the parameters of stochastic production frontier model (equation 13) are estimated using Maximum Likelihood (ML) method. The method is preferred to 'the corrected ordinary least squares' (COLS) because the maximum likelihood estimators have several advantageous large sample properties (Coelli *et al*., 2005). The likelihood function is parameterized in terms of

$$\mu i = \frac{\sigma_v{}^2 \gamma' zi - \sigma^2{}_u ei}{\sigma_v{}^2 + \sigma_u{}^2}$$

$$\sigma_*{}^2 = \frac{\sigma_v{}^2 \sigma_u{}^2}{\sigma_v{}^2 + \sigma_u{}^2}$$

Where, $e_i = InY - Inf(X_i, \beta)$

The distribution assumptions of the two random variables, the symmetric error, v_i, and non-negative error random variable, u_i, are made as;

$v_i \sim iidN(0, \sigma_v{}^2)$

$u_i \sim N^+(\gamma' zi, \sigma_u{}^2)$

u_i and v_i are independent

A Cobb-Douglas production function is chosen since it is the most commonly used in the farm efficiency analyses for both developing and developed countries (Majiwa *et al*, 2012) and is specified as

$$In\ Output = \beta_0 + \beta_1\ Feeds + \beta_2\ Land + \beta_3\ AVetcost + \beta_4\ Labour + v_i - u_i \quad \text{.........12}$$

Where,

$$ui = \delta_0 + \delta 1\ Educ + \delta 2\ Age + \delta 3\ Gend + \delta 4\ Dexp + \delta 5\ primocc + \delta 6\ Accrd + \delta 7\ Extacc + \delta 8\ FDtype + \delta 9\ Record + \delta 10\ AI \text{..13}$$

Variables used in the stochastic production frontier are shown in Table 2 below. The dependent variable is the annual milk output per cow in litres. Independent variables consist of feeds, land, average veterinary cost and labour. The variable, feeds, consist of sum of cost of concentrates, purchased feeds and fodder production cost divided by the herd size. Land is the area under natural pasture and grown fodder while average veterinary cost included cost of deworming, acaricide, treatment and AI per animal. Labour variable is calculated as time taken in dairy activities in man-days which is then divided by herd size.

Variables in the inefficiency model are categorised into three; Farmer characteristics which include age, gender, education level, dairy experience and primary occupation of the dairy decision maker. Institutional factors which include access to extension and access to credit. Management practices; type of fodder produced (grasses or legumes), use of artificial insemination (AI) and keeping of dairy records.

Table 2 Variables in stochastic frontier model

Code	Variable	Measurement of variable	Expected sign
Efficiency model			
Y	Milk output	Kilogram	
X1	Feed cost	Kenya shillings	+
X2	Land (pasture and fodder)	Hectares	+
X3	Average veterinary cost	Kenya Shillings	+
X4	Labour	Man-days	+
Inefficiency model			
EDUC	Education level of household head	1 = Primary 2 = secondary, 3 = Tertiary, 4 = No formal	-
AGE	Age of household head	Years (continuous)	-
ACCRD	Access to credit	Dummy (Yes = 1, No = 0)	-
EXTACC	Access to extension	Dummy (Yes = 1, No = 0)	-
DEXP	Experience in dairy	Years (continuous)	-
GENDER	Gender of household Head	Dummy(Male = 1, Female = 0)	-
PRIMOCC	Primary occupation	Dummy (Farming = 1, Otherwise = 0)	+
FDTYPE	Type of fodder grown	Dummy (Legumes = 1, Grasses = 0)	-
RECORD	Dairy record keeping	Dummy (1 = Yes, 0 = No)	-
AI	Use of AI	Dummy (1 = Yes, 0 = No)	-

3.5 *A priori* assumptions

This section describes the priori assumptions of the variables used and their support by past literature.

Age: Age of a dairy decision maker was hypothesised to increase the log odds of direct procuring. Moturi *et al.* (2015) found younger farmers were more likely to participate in producer organisations. Older farmers are expected to have more resources and thus could afford to purchase inputs without being facilitated by producer groups or the milk processor. Age was also expected to reduce inefficiency in dairy farming. Since older farmers are likely to have more resources at their disposal, they can afford to employ better farming techniques. Otieno *et al.* (2012) found increase in age was associated with higher levels of efficiency.

Gender: Gender of the dairy decision maker, a dummy variable (male = 1, female = 0) was hypothesised to reduce the log odds of direct procuring. Male decision makers were expected to choose producer or processor driven models so that milk proceeds can accumulate and so receive a lumpsum at the end of the month. Kadigi (2013) found female decision makers preferred direct channels so as to get cash on dairy basis for household needs. Gender was also hypothesised to reduce inefficiency since most training and farm tours are attended by men. Kibiego *et al*. (2015) found gender to have significant influence on efficiency and this was attributed to the fact that men owned most productive resources.

Education: Education of the dairy decision maker was measured as a categorical variable (1 = no formal education, 2 = primary level, 3 = Secondary, 4 = Tertiary level). Education was hypothesised to increase the log odds of direct procuring since educated farmers were likely to have other sources of income and thus could afford to pay for dairy inputs and services. Education was also hypothesised to reduce the inefficiency. Farmers who are educated are more receptive to adoption of improved farming techniques and thus likely to reduce inefficiency as found by Ng'ang'a *et al.* (2010) in the analysis of efficiency among Kenyan smallholder milk producers.

Primary occupation: This was a dummy variable where 1 = farming, 0 = Otherwise. Farming as the primary occupation was expected to increase inefficiency since farmers had no other income that could be used to source dairy inputs and services on time. Hussien (2011) observed farmers with non-farm income attained higher efficiency scores compared to their counterparts who had farm income only. Diversified source of income ensured farmers were able to purchase quality inputs on time.

Distance to input market: This was measured as walking time in minutes. It was hypothesised to reduce the log odds of direct procuring. Distance covered has an implication on the transaction cost incurred, thus farmers choose the channel that lower these cost. Nkwasibwe (2014) observed farmers preferred direct selling as opposed to formal channels as the market distance increased.

Farm size: Farm size was a continuous variable for the total land owned, and was hypothesised to increase the log odds of choosing direct procuring. Farmers with large parcels of land were likely to be well off economically and could afford dairy inputs without being facilitated by producer groups or milk processor. Mburu *et al*. (2007) found farmers with larger farms were less likely to choose producer model. Mutura *et al*. (2015) in the analysis of determinants of market channel choice among smallholder dairy farmers in Lower Central Kenya, found farmers with smaller land acreage were resource constrained and therefore needed support from producer organisation driven groups to access dairy production inputs.

Access to extension: This was measured as a dummy (access to extension = 1, no access to extension = 0). The need to obtain extension services was hypothesised to reduce the log odds of choosing direct procuring. Producer organisations plan trainings, field days, farm visits and field tours through which dairy farmers learn new technology as found by Kuma *et al*. (2013). Access to extension was also expected to reduce inefficiency as observed by Majiwa *et al*. (2012); Debebe *et al.* (2015). Dairy information regarding practices like feeding, breeding and general management of dairy enterprises is disseminated through extension forums.

Access to credit: It was measured as a dummy (access to credit = 1, no access = 0) and was hypothesised that need to obtain credit would reduce the log odds of choosing direct procuring dairy business model. Mburu *et al.* (2007) found the choice of producer model was favoured by farmers who needed credit facility since cooperatives offered credit linked market where farmers could repay from their milk proceeds. It was also hypothesised to reduce inefficiency as found by Kavoi *et al*. (2010); Nyekanyeka (2011) on dairy efficiency studies. The use of credit enables the acquisition of inputs on time. Farmers are able to purchase more production inputs and pay for new technology such as high yielding cattle breeds.

Dairy experience is a continuous variable measured in number of years the household has been keeping dairy cattle. Experience was hypothesised to reduce inefficiency since farmers are able to identify practices that work for them and are best suited to their local environment. Ng'ang'a *et al*. (2010); Nyekanyeka (2011) observed farmers with more years in dairy farming reduced inefficiency. This was attributed to the stock of knowledge gained over time.

Land: Acreage of land allocated to fodder production and natural pasture was hypothesised to have positive effect on milk output as found by Masuku (2014).

Feed cost: Quantity and cost of concentrates and minerals was computed by multiplying the quantity (in kilogram) of concentrates and minerals per purchase by the frequency of purchase in the previous year. Purchased fodder cost was also computed by multiplying the frequency of purchase by cost per purchase. Fodder production cost was computed by taking into account the annual cost of seeds, fertilizer, herbicides and labour. A summation of cost of; concentrates, purchased fodder and own fodder production cost gave the variable feed cost. It was hypothesised to have positive effect on milk output as found by Al-Sharafat (2013)

Veterinary cost: The annual cost incurred in treatment of cattle was computed by summing the costs incurred per treatment during the previous year plus vaccination cost which was computed as vaccination per animal multiplied by the number of animals. The cost of deworming and acaricide was computed by multiplying the frequency of purchase with cost per purchase for each. Veterinary cost was the summation of annual cost of, treatment, deworming, acaricides and breeding (whether AI or Bull service). This variable was hypothesised to have a positive effect on the milk output as found by Cabrera *et al.* (2010).

Labour: Labour comprised of hours consumed in dairy activities by both family and hired labour. Hours involved in fodder production were not considered as these were included in fodder production cost. The local daily farm-wage rate was converted into wage per hour and used to compute labour cost. Labour was hypothesised to have a positive effect on milk output as found by Cabrera *et al.* (2010)

Dairy management practices: the use of improved dairy technology; use of AI, growing of improved fodder and keeping of dairy records was hypothesised to reduce inefficiency as was observed by Ayele and Muriithi (2012) and Cabrera *et al.* (2010) in the analysis of technical efficiency among dairy farms in Wisconsin. These management practices enables farmer to increase milk output. Keeping of dairy records serves as a management tool on enterprise decisions.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Descriptive characteristics of the sample smallholder dairy farmers

Descriptive statistics defining the characteristics of the sample farming households and their main dairy business models are presented in Tables 3 and 4. Most of the sampled farmers accessed inputs and services through direct procuring (58%) relative to producer organisation driven model (28%) or milk processor driven model (14%). Direct procuring model dominated among the sampled farmers probably because it was associated with freedom to choose the output market. Farmers employing producer organisation or milk processor driven models sold their output to cooperatives or processor through arrangements in which the cost of inputs and services are deducted from milk proceeds.

Decision making in dairy enterprises in the two counties was male dominated (79%). This was similar to the findings of Njarui *et al*. (2012) who attributed this to the fact that most productive resources including land are owned by men even though women carry out most (over 50%) of the dairy activities. Failure to access resources is more likely to constrain women's participation in smallholder dairying, even in situations where women are the main dairy operators as found by Tangka *et al*. (1999).

Majority of the sampled farmers (43.90%) had primary level of education while the minority (5.70%) had no formal education. Among farmers linked to direct procuring model, majority (39.20%) had secondary level of education. However, primary level of education was achieved by majority of farmers linked to producer organisation driven (53.62%) and milk processor driven models (50%). Farmers with no formal education were the minority across all the business models. The level of education achieved was not significantly different across the three dairy business models.

Of the agricultural enterprises on smallholder farms, dairy farming was the highest earning enterprise for the majority (68.7%), being a regular income source throughout the year. This agrees with the findings of Makokha (2005) that with the dairy sector restructuring, smallholder farmers stand to benefit more from dairy than from other farming enterprises. The variable, 'highest earning enterprise' was significantly different across the three dairy business models, (p<0.01). Producer organisation driven model had the highest percentage (79.7%) of farmers earning more from dairy. This could be explained by the fact that farmers under this dairy business model had the lowest acreage of land and as Omore *et al*. (1997) established, returns per acre in smallholder mixed farming systems in Central Kenya is higher in dairy than in major crops grown in the area.

Table 3 Number of respondents by their farm and farmer characteristics

Factor	Level	Overall	Dairy business models			
			Direct	Producer	Processor	
		N=246	n=143	n= 69	n=34	χ^2
Gender	Female	53	35	13	5	1.97
	Male	193	108	56	29	
Education	No formal	14	10	1	3	10.16
	Primary	108	54	37	17	
	Secondary	91	56	26	9	
	Tertiary	33	23	5	5	
Primary occupation	Farming	196	111	58	27	
	Non- farm	50	32	11	7	1.19
Rank of income from farm activities	Dairy	169	94	55	20	6.02**
	Non-dairy	77	49	14	14	
Extension frequency	Monthly	36	25	7	4	5.68
	Quarterly	42	27	13	2	
	Yearly	85	44	29	12	
Access to extension	No	83	47	20	16	3.94
	Yes	163	96	49	18	
Access to credit	No	196	122	51	23	7.26**
	Yes	50	21	18	11	

Significant level **: 95%

One fifth (20%) of the farmers had obtained credit in the previous year and mainly from farmer cooperative. More farmers linked to milk processor driven model obtained credit (32%) relative to those linked to producer organisation driven (26%) or direct procuring model (15%). Compared to the direct procuring model, the milk processor and producer organisation driven models offer a credit linked market which enable farmers to reduce transaction costs. This is also supported by Wollni *et al*. (2010) who observed that farmer-based groups can considerably reduce transaction costs which are especially high in remote areas for smallholder production systems.

About two thirds (67%) of the sampled farmers had obtained extension services with more access observed among farmers linked to producer organisation driven model (72%) compared to direct procuring (67%) or milk processor driven model (53%). Majority of the farmers (45.83%) obtained extension services yearly and this was observed across the three dairy business models. The main extension providers were farmer cooperatives (42%), government extension (20%), milk processor (14%) and media (12%). Farmer cooperatives, a form of collective action, reduces the cost of information search hence the preference by majority of the farmers.

The dominant output market was farmer cooperatives which was accessed by about half (49%) of the sampled farms. Farms linked to the direct procuring model accessed the three major output markets (cooperative, processor and middlemen) in almost equal proportions. However, majority of farms linked to producer organisation driven model (97%) and milk processor driven model (79%) supplied their output to farmer cooperative and processor respectively. This implied farmers linked to direct procuring had greater freedom in choosing output market unlike the rest who had to honour milk supply agreements to facilitate deduction of the provided inputs and services' cost.

The mean estimates for farmers and farms characteristics by the three dairy business models and by county are summarized in Table 4 and 5 respectively. The mean age of dairy farmers was 45.34 years. It was found that dairy farmers in Nyandarua were older (47.54 years) compared to those in Nandi (43.14 years). This was way below the average age of a Kenyan farmer, sixty years, according to FAO (2014). Unlike older farmers, relatively younger farmers were more likely to introduce modern technology. Among the sampled dairy farmers, relatively older farmers accessed inputs through milk processor driven model compared to direct procuring and producer organisation driven models, and this was significant *($p<0.05$)*. This could be attributed to the long relationship with the milk processor thus creating trust. It would appear that producer organisation driven model favoured younger farmers who are likely to be resource constrained to acquire resources like skills, material inputs and credit facility.

The farm size was statistically different between the county and across the dairy business models. The average farm size in Nyandarua and Nandi was 2.94 Ha and 2.14 Ha respectively. Farmers linked to direct procuring model had larger farms, 2.97 Ha compared to 1.91and 2.01 Ha for farmers linked to producer organisation and milk processor driven models respectively and this was significantly different ($p<0.01$). The mean farm size (2.54 Ha) seems to have declined within time compared to earlier reports including that of Muia *et al.* (2011) for Nyandarua (3.52 Ha) and that of Makokha (2005) for Nandi (2.76 Ha), probably related to subdivision. Land is highly valued asset in Kenya and farmers with large farms are likely to be better off economically and can use land as collateral to access credit for inputs such as improved breeds of cows, adequate and high quality feeds and improved animal husbandry practices.

Distance to input market measured in time taken to reach the nearest input centre was shorter for farmers linked to milk processor driven model (26 minutes) and producer organisation driven model (32.9 minutes) compared to farmers linked to direct procuring model (49.5 minutes) and this was statistically significant ($p<0.01$). Farmers linked to milk processor and producer organisation driven models actually purchased their inputs when delivering milk and this could explain why it was considered that the time taken to input market was lessened.

Table 4 gives the means, standard deviation and F-statistics of the continuous variables across the business models while Table 5 gives the means between counties.

Table 4 Descriptive statistics of farmers and farm characteristics by dairy business models

Variables	Business models	Mean	Std. Dev.	F statistics
Age (Years)	Direct procuring	46.18	14.36	3.13**
	Producer organisation driven	42.09	12.30	
	Milk processor driven	48.4 1	12.47	
	Overall	45.34	13.68	
Farm size (Ha)	Direct procuring	2.97	4.49	2.46*
	Producer organisation driven	1.91	1.51	
	Milk processor driven	2.01	1.60	
	Overall	2.54	3.59	
Area allocated to dairy (Ha)	Direct procuring	1.61	2.42	2.07
	Producer organisation driven	1.09	0.91	
	Milk processor driven	1.12	1.03	
	Overall	1.39	1.96	
Area under cultivated fodder (Ha)	Direct procuring	0.52	0.71	2.84*
	Producer organisation driven	0.34	0.29	
	Milk processor driven	0.37	0.33	
	Overall	0.45	1.58	
Market distance (walking minutes)	Direct procuring	49.50	62.29	4.69**
	Producer organisation driven	32.91	18.19	
	Milk processor driven	26.03	14.13	
	Overall	41.60	49.58	
Veterinary cost (KES.)	Direct procuring	4351.72	1963.18	4.93***
	Producer organisation driven	4007.86	1834.04	
	Milk processor driven	5483.74	3803.20	
	Overall	4411.73	2307.20	
Milk price (KES per litre)	Direct procuring	31.14	4.81	2.67**
	Producer organisation driven	29.92	1.50	
	Milk processor driven	30.20	1.88	
	Overall	30.67	3.85	
Milk output (litres /animal /year)	Direct procuring	2442.98	878.46	2.49*
	Producer organisation driven	2262.37	625.43	
	Milk processor driven	2630.07	856.57	
	Overall	2418.18	817.36	

*Significant levels at ***99%, **95%, and *90%.*

Veterinary costs, important for good health of the dairy cows, was highest for farmers linked to milk processor driven model (KES 5,483) compared to producer organisation (KES 4,007) or direct procuring (KES 4,451) models. This difference was statistically significant ($p<0.01$). Under the producer organisation model, dairy inputs are acquired in bulk thus farmers benefit from quantity discount which translates into lower input prices. Moreover, the arrangement under producer organisation driven model is not for profit making. This, however, is different from the milk processor driven model where private inputs and service providers are contracted by the milk processor and paid later from the farmers' milk proceeds. It was noted that the milk processor delayed in making payments to the contracted inputs and service providers. In response, the contracted inputs providers offered higher inputs prices as a cost of time, thus the higher average veterinary cost.

The average price of milk was KES 30.67 per litre. This was higher in Nandi (KES 31.23) compared to Nyandarua (KES 30.11). Farmers linked to direct procuring model received the highest price offer (KES. 31.14) compared to KES 29.92 and 30.20 for producer organisation and milk processor driven models respectively. The difference in price offered was significant ($p<0.05$). Farmers linked to direct procuring model unlike those in producer organisation and milk processor driven models, access a variety of output market like middlemen and institution who offer higher prices as found by Wambugu *et al*. (2011).

Table 5 Descriptive statistics of farmers and farm characteristics by county

	Nyandarua		Nandi		
	Mean	SE	Mean	SE	t
Age of dairy decision maker	47.54	1.34	43.14	1.08	2.55**
Dairy experience	13.38	1.06	11.86	0.87	1.11
Total Farm size (Ha)	2.94	0.41	2.14	0.19	1.75*
Market distance	40.2	2.79	43.01	5.69	-0.44
Average veterinary cost (KES)	4419.00	212.21	4404.00	204.64	0.05
Average milk price (KES)	30.11	0.16	31.23	0.46	-2.3**
Land allocated to dairy	1.62	0.22	1.18	0.11	1.78*
Land under fodder (Ha)	0.61	0.06	0.31	0.03	4.17***
Dairy land as a % of total farm	0.58	0.02	0.59	0.03	-0.3

Significant levels at ***99%, **95%, and *90%.

4.2 Dairy management practices

The dairy management practices adopted by farmers across the business models are presented in Table 6. These were based on feeds, breeding services and dairy record keeping.

Table 6 Distribution of the sample households by dairy management practices

Management practices	Level	Pooled n=246	Direct procuring n=143	Producer organisation n=69	Processor driven n=34	chi2(2)
Use of AI	Yes	171	108	38	25	
	No	75	35	31	9	9.49***
Own feeds formulation	Yes	16	12	4	0	
	No	230	131	65	34	3.26
Fodder production	Yes	222	134	57	31	
	No	24	9	12	3	6.55**
Fodder type	Grasses	227	127	67	33	
	Leguminous	19	16	2	1	5.75*
Fodder preservation	Yes	61	32	20	9	
	No	185	111	49	25	1.14
Record keeping	Yes	125	72	38	15	
	No	121	71	31	19	1.12

Significant levels at ***99%, **95% and *90%

The use of artificial insemination (AI) was adopted by over two thirds (69.51%) of the sampled farmers and the remainder (30.49%) used natural service. Use of AI was higher ($p<0.01$) among farmers linked to direct procuring (75.52%) and to milk processor driven (73.53%) than those linked to producer organisation driven (55.07%). Farmers pay for AI services and the cost might have been beyond the reach of some farmers. McDermott *et al.* (2010) observed that AI services were characterised by high delivery charges and low conception rates and this is likely to discourage some farmers who opt to use bull services.

Majority of the sampled farmers (90.24%) grew fodder for their livestock, majority of who were in Nyandarua (97.56%). Producer organisation model had fewer farmers growing fodder (82.61%) compared to farmers linked to the direct procuring model (93.71%) and milk processor driven models (91.18%). This might have been as a result of less acreage of land among farmers linked to producer organisation model (1.91ha) in comparison to farmers linked to direct procuring (2.97 ha) and milk processor driven model (2.01 ha), (Table 4), who were able to allocate more area to fodder crops.

Fodder grown was classified into two; grasses and legumes. Majority of farmers (92.28%) grew grasses, that is, boma-rhodes, oats and nappier grass, but few (7.72%) grew leguminous fodder (desmodium, lucern and vetch). Among the sampled farmers, none of the farmers in Nandi grew legume fodder compared to 15.45% in Nyandarua. Lack of technical knowledge and unavailability of seeds has been found to contribute to the low uptake of leguminous fodder production (Vernooij, 2016). More farmers linked to the direct procuring model grew leguminous fodder (11.19%) compared to producer organisation (2.90%) or milk processor driven models (2.94%). The cost of legume fodder seeds is high, going up to KES 3,000/kg of lucern for quarter acre, in the local agro-shops. Since farmers under direct procuring had larger acreage of land, they were likely to be better off hence could afford the seed. Fodder legumes have high level of proteins and thus enhance milk production. High quality fodder enables farmers to reduce the cost of supplementation.

Fodder preservation was practiced by less than a quarter of the sampled farmers (24.8%). Fodder was either preserved wet in form of silage or dry in form of hay. Majority of the farmers who preserved fodder were linked to the producer organisation driven model

(28.99%) while direct procuring model had the least farmers (22.38%). Properly preserved high quality forages can help reduce the costs associated with feeding concentrates and supplements. Farmers linked to the producer organisation driven model had the least acreage of land allocated to fodder cultivation (0.34 Ha versus 0.37Ha or 0.52 Ha) (Table 4) hence the need to preserve feeds.

Farmers practicing own feeds formulation were the minority (6.50%) compared to those who bought ready rations (93.50%) such as dairy meal. None of the sampled farmers linked to milk processor driven model formulated own feeds, compared to direct procuring (8.39%) or producer organisation driven model (5.80%). Feed ingredients are expensive and may not be readily available. Besides, technical knowhow on feed mixing may be a challenge to majority of farmers.

Among the sampled farmers about half (50.81%) maintained dairy records and there was no difference across the three business models. Well maintained dairy records can be an important management tool as it enables farmers to make informed decisions like culling uneconomical cows. However, most farmers only maintained records for quantity of milk sold to verify with the payment received at the end of the month as found by Nyekanyeka (2011). Farmers cannot then make informed decisions regarding the management of the dairy enterprises.

4.3 Factors influencing the choice of dairy business model

Prior to employing multinomial logit model (MNL), independent variables were tested for multicollinearity. When the variables are correlated, the standard errors are inflated and the confidence intervals tend to be wider leading to acceptance of the null hypothesis more easily. A lower VIF is preferred as a VIF of 10 indicates the variables are highly collinear, Gujarati (2004). The multicollinearity test gave a mean variance inflation factor (VIF) of 1.30 indicating multicollinearity was not a problem.

The MNL results (Table 7) show the independent variable and the multinomial coefficients for producer organisation driven and milk processor driven models relative to direct procuring model. From the results, farm characteristics and institutional factors with significant influence on farmers' choice of a dairy business model can be isolated.

Input market access

The relative risk ratio of a farmer being in producer organization model or milk processor model was 0.99 and 0.98 respectively. Therefore as the distance to in input market (measured in terms of walking time) increased, the likelihood of farmers being in processor model relative to direct procuring was reduced. This implied that the direct procuring model was preferred to milk processor driven model and producer organization model as the distance covered increased. To counter this, producer organization driven model supply some of the inputs during milk collection. Distance influences the transaction costs incurred and farmers choose the option where they incur less. This observation relates to that of Nkwasibwe (2014) that the longer distance a farmer had to cover the less likely they would be involved in formal channels, thus choosing what is readily available despite the added benefit of a formal channel.

Table 7 Multinomial regression results for dairy business models on farm and farmer characteristics

Variables	Producer			Processor		
	rrr	SE	P	rrr	SE	P
Age of dairy decision maker	0.99	0.01	0.47	1.05	0.02	0.02
Gender of dairy decision maker	1.08	0.45	0.85	1.38	0.82	0.58
Education level[1] (*reference category: no formal education*)						
Primary	6.59	7.62	0.10	2.30	2.08	0.36
Secondary	3.63	4.24	0.27	0.97	0.93	0.97
Tertiary	1.41	1.81	0.79	0.91	1.01	0.94
Primary occupation	1.10	0.50	0.83	0.88	0.52	0.83
Land (Ha)	0.86	0.13	0.32	0.83	0.19	0.40
Dairy herd	1.14	0.13	0.26	0.95	0.21	0.81
Distance to input market	0.99	0.01	0.03	0.98	0.01	0.05
Milk price	0.84	0.06	0.01	0.83	0.07	0.03
County	4.07	1.59	0.00	10.61	6.07	0.00
Access to credit	2.14	0.89	0.07	5.12	2.83	0.00
Access to extension	2.40	1.02	0.04	1.05	0.55	0.93
Constant	3.20	8.10	0.65	0.16	0.51	0.56
Log likelihood -190.20	P value	0.00				
Pseudo R^2 0.18						

Significant levels at ***99%, **95% and *90%

[1] is education dummy where base category is no formal education. Direct procuring is the reference dairy business model. RRR(relative risk ratio) is the probability of choosing a business model $_i$ divided by the probability of choosing the reference business model

Milk price

An increase in milk prices reduced the likelihood of a dairy farmer to supply his milk to producer organization model relative to direct procuring model by a factor of 0.83. Similarly, the likelihood of farmers supplying milk to milk processor relative to direct procuring reduced by a factor of 0.84. This implied that farmers were more likely to choose the business model offering the highest price all factors held constant. In contrast to producer organization and milk processor model, farmers linked to direct procuring model have no contractual arrangement on supply of a particular market. Thus, the shift from one buyer to another, offering better prices is easy. Also as established by Wambugu *et al* (2011), final consumers offer higher prices as compared to cooperatives due to the longer marketing chain involved.

County

Comparing farmers from the two counties under the study, the relative risk ratio of farmers in Nandi being in a producer model relative to direct procuring was 4.07. This implies farmers in Nandi County relative to farmers in Nyandarua, were more likely to be in producer model relative to direct procuring model. Also the likelihood of farmers being in processor model relative to direct procuring model was 10.61, implying farmers in Nandi relative to Nyandarua, were more likely to choose milk processor compared to direct procuring. Kenya Agricultural value chain market research study in Nandi, conducted by ASDSP (2016) indicated that 65% of milk was sold to cooling plants while only 15% and 20% was sold to traders and hotels respectively.

Extension services

The relative risk ratio of farmers being in producer organisation model relative to direct procuring was 2.40, implying access to extension services increased the likelihood of farmers being linked to producer organization model compared to direct procuring. Extension services are important in transfer of dairy knowledge and skills to farmers. Due to the high transaction cost of accessing extension as an individual, producer organization model is more cost effective as farmers are trained as a group and this was likely to have attracted more farmers.

Credit access

The need to obtain credit increased the likelihood of farmers being in milk processor driven or producer organisation driven models compared to being in direct procuring model. As farmers commercialize their dairy enterprises, their need for finances is more for investment in improved fodder, better structures, quality concentrates and minerals. Therefore, farmers are more likely to choose business models that enhance access to credit to strengthen management practices and improve enterprise performance. This concurred with findings of Mburu *et al. (*2007) who found that farmers were likely to choose producer model if it could facilitate access to credit.

In summary, milk price offered and distance covered to the input market influenced the choice of direct procuring relative to producer organization or milk processor model. On the other hand, access to credit and extension services influenced the choice of producer organization or milk processor model relative to direct procuring model. Also farmers in Nandi relative to those in Nyandarua were more likely to be in producer organisation or milk processor model relative to direct procuring.

4.4 Influence of dairy business models on economic performance

This section describes the performance of dairy enterprises across the dairy business models. Section 4.4.1 describes the performance of farms across the business models while section 4.4.2 describes performance per litre of milk produced across the business models.

4.4.1 Gross margin of the dairy enterprises

Gross margin was used as a proxy for economic performance. The dairy enterprise revenue, gross production value (GPV) consisted of value of milk output plus the productive stock value (PSV) which was computed as the increment in stock value. The variable cost consisted of; cost fodder produced on farm, cost of purchased fodder, cost of concentrates, cost of veterinary services and cost of labour which included both family and hired labour. Table 8 presents the farm revenues, variable costs and gross margin estimates across the dairy business models.

The gross production value for farms linked to milk processor driven model was 3% to 17% higher than farms linked to direct procuring model and producer organisation driven models respectively. This is likely to be as a result of higher adoption of artificial insemination (AI) by farmers linked to milk processor driven model (73.53%), (Table 6). AI enables farmers to improve the genetic potential of their dairy herd in terms of milk productivity. It was also observed that farms linked to milk processor driven model incurred the highest cost in purchased fodder, KES. 7,900.00 compared to producer organisation model (KES. 2561.60/) or direct procuring (KES.3101.40/). This was meant to supplement what was produced on the farm, given that smallholder dairy enterprises are characterised by shortage and low quality fodder especially in dry season as was observed by Mutinda *et al.* (2015). Consistent supply of feeds is essential in maintaining dairy production throughout the season.

The total veterinary cost (cost of treatment, vaccination, deworming, dipping and breeding) was 8% to 21% higher among farmers linked to milk processor driven model compared to direct procuring and producer organisation driven model respectively. Fodder production cost was 7.8% to 25% higher among farmers linked to direct procuring model than milk processor driven model and producer organisation model. This could be attributed to the larger acreage of land under fodder among farmers linked to direct procuring (0.52Ha versus 0.34 or 0.37 acres), (Table 4).

Of the total variable costs, cost of feeds was the highest (45%) followed by labour cost (42%) while veterinary cost was the least (12%). This agrees with the findings of Yielmaz *et al.* (2016) who observed that labour cost was the second most important cost after feeds. Feed cost is the highest cost in dairy production especially in intensive production systems. It is the key determinant of the enterprise profitability as it accounts for 50% to 70% of the total cost of milk production (ROK, 2006). The total variable cost and the revenues per farm were significantly lower among farmers linked to producer organisation driven model who as well attained relatively lower gross margins.

Table 8 Farm's average gross margin (KES) estimates by dairy business model

Variable	Pooled	Direct procuring	Producer organization	Milk processor driven
Milk production value	167,556.33	174,447.97	148,639.26	176,961.40
Production stock value	33,064.64	34,041.96	28,839.13	37,529.42
GPV	**200,620.97**	**208,489.93**	**177,478.39**	**214,490.82**
Total veterinary cost	14,472.72	14,886.50	12,758.84	16,210.59
Concentrate cost	29,679.27	29,678.95	30,402.46	28,212.94
Purchased fodder cost	3,613.21	3,101.40	2,561.60	7,900.00
Fodder production cost	19,439.47	21,150.77	15,857.68	19,510.88
Labour cost	50,120.30	51,897.44	47,201.28	48,569.77
Total Variable cost	**117,324.97**	**120,715.06**	**108,781.86**	**120,404.18**
Gross Margin	83,296.00	87,774.87	68,696.53	94,086.64

Comparison of the three business models for annual gross margins earned revealed that the dairy enterprises were profitable in line with the report of (Staal *et al*., 2003). The profitability was 7% to 27% higher in farms linked to milk processor driven model than in direct procuring and producer organisation driven models. This profitability difference was as a result of higher productivity per animal already observed in these farms and higher milk prices (KES 31.14) in farms linked to direct procuring model compared to KES 29.92 in farms linked to producer organisation driven model (Table 4). Most farmers linked to direct procuring model (36%), (Table 3) sold their milk to middlemen and institutions that offered higher prices. This concurs with the findings of Wambugu *et al.* (2011) who found brokers and institutions offered farmers higher milk prices compared to cooperatives. The lower price offered by cooperatives was associated with the longer marketing chain they are involved in.

4.4.2 Gross margin per litre of milk

The gross production value per litre of milk produced was higher among farmers linked to direct procuring model and processor driven model (KES. 35.43 and 35.56 respectively) compared to to producer organisation driven model (KES.33.69). Among the variable costs, farms linked to producer organisation driven model had the least veterinary cost per litre of milk produced probably because of bulk purchase of inputs by producer organisations.

The fodder production cost was also the lowest as a result of less land acreage but this was complemented by higher concentrate cost given the need to supplement the available fodder. As a result, farmers linked to producer organisation driven model incurred the least variable cost, KES.23.30 compared to KES. 25.41 and KES. 25.71 in processor driven and direct procuring models respectively. Thus gross margin per litre of milk produced was highest (Table 9) among farmers linked to producer organisation driven model (KES. 10.39) relative to processor driven model (KES. 10.02) and direct procuring model (KES. 9.85). This is in contrast to the findings of gross margin per farm (Table 8), where farmers linked to producer organisation model had the lowest gross margin per farm. This would imply higher cost was incurred by farmers linked to direct procuring and milk processor models than producer organisation model that had less effect on production. Labour cost per litre of milk was higher among farmers linked to direct procuring by KES 2.02 and milk processor model by KES 1.44 (Table 9) and this is likely to have caused the shift. In previous study, Staal *et al.* (2003) observed that farmers offered lower milk price had a higher gross margin as a result of lower production cost.

Table 9 Gross margin per litre of milk across the dairy business model

Variable	Pooled	Dairy business model		
		Direct procuring	Producer organisation	Milk processor driven
Gross production value (KES)	**35.02**	**35.56**	**33.69**	**35.43**
Veterinary cost	2.88	2.92	2.57	3.31
Concentrate cost	5.82	5.63	6.44	5.38
Purchased fodder cost	0.83	0.74	0.76	1.31
Fodder production cost	3.93	4.23	3.36	3.80
Labour cost	11.54	12.19	10.17	11.61
Variable cost (KES)	**25.00**	**25.71**	**23.30**	**25.41**
Gross margin (KES./Litre of milk)	10.02	9.85	10.39	10.02

Though descriptive statistics showed higher gross margin per litre in farms linked to producer organisation driven model, a Kruskal-wallis test showed no significant difference in the gross margin attained across the business models (X^2 = 0.26 (2df), p = 0.87) implying dairy business models had no significant influence on economic performance of smallholder dairy enterprises.

4.5 Estimation of stochastic production frontier

The independent variables used in the efficiency model were tested for the presence of heteroscedasticity which is often common in cross sectional data (Mawa *et al*., 2014). A regression analysis of the dependent and independent variables in stochastic production frontier was carried out and tested for heteroscedasticity. The Breusch-Pagan test showed no significant heteroscedasticity (X^2 = 1.51, p > 0.22).

A skewness test was also carried out. In a stochastic production frontier model with the composed error $\varepsilon_i = vi - ui, ui \geq 0$ and vi distributed symmetrically around zero, the residuals from the corresponding ordinary least squares (OLS) estimation are negatively skewed (Kumbhakar *et al*., 2016). The results of the skewness test showed the data was skewed to the left (skewness -0.55) and was significant (p < 0.01). The stochastic production frontier was therefore employed in a single step approach where both the efficient and inefficient model were estimated in a single analysis. The exogenous factors included in the model were farmer characteristics (age, gender, education level and primary occupation) institutional factors (access to credit and access to extension) and dairy management practices (type of fodder grown, dairy record keeping and use of artificial insemination).

The maximum likelihood estimates presented in Table 10 exhibit positive coefficients for all the resources as expected, except for labour which was negative. Since the resources are in natural log form, the coefficients denote the elasticity. Feed costs was significant in both the pooled data and direct procuring model ($p<0.01$). The elasticity of output to feeds in the pooled data was 0.17 and this was the highest among all the resources. However, the direct procuring model had the highest elasticity, 0.20 compared to 0.08 or 0.15 for producer organisation driven and milk processor driven models respectively. This implied increase in feeds had a greater effect on milk output among farms linked to direct procuring model. Farmers linked to this business model were observed to have largest area allocated to dairy (1.61 Ha versus 1.09 or 1.12 Ha), highest proportion of farmers growing leguminous fodder (11.19% versus 2.90% or 2.94%) and the highest level of concentrate use, 475 kg per cow per year compared to 432 kg or 434 kg in producer and processor driven model respectively. Though feed is a major input in dairy production, smallholders often feed their animals with inadequate quality and quantity or feed imbalanced diet that is insufficient for animals to express their genetic potential. Nassiuma and Nyoike (2014) argued that high feed supply and utilization in dairy production has a positive impact on the performance of dairy cattle and this is reflected in the increased milk production.

Land coefficient was positive for all the business models and significant in pooled data and direct procuring model ($p<0.01$) as well as for processor driven model ($p<0.1$). The results showed an increase in area allocated to dairy increased output by 8% for the overall sample. Among the farmers linked to the direct procuring and processor driven models, the effect of acreage on output was higher (8% to 12%) compared to the producer organisation driven model (1%). This was in accordance to the acreage allocated to dairy where farmers linked to producer organisation driven model had the least acreage, 1.09 Ha versus 1.61 Ha among farmers linked to direct procuring (Table 4). Smallholder dairy production systems range from stall-fed cut-and-carry systems to free grazing (Wambugu *et al.*, 2011) in which land is a major resource for pasture and fodder production. Farmers respond to the declining farm size in dairy production by increasing reliance on purchased feeds, both concentrates and forage (Muriuki, 2003).

The average veterinary cost comprising treatment, vaccination, control and AI services had positive impact on milk output. The results showed one percent increase in the veterinary cost currently used would increase milk output by 8%. Disease challenges and animal genetics are top constraints in dairy production and it is therefore important for farmers to implement regular herd health programme to control disease introduction into and spread within the farm. However, biosecurity measures are weak in smallholder farms, which impacts on the production efficiency.

Labour coefficient was negative against the expectation in all dairy models and was significant in the pooled data and direct procuring model ($p<0.01$) as well as in producer organisation driven model ($p<0.1$). The estimated elasticity of milk output to labour was -0.16 implying an increase in a man- day reduced milk output by 16%. This might have been as a result of long distance to water points that consumes energy that would have been used for lactation. Low level of mechanization in smallholder dairy enterprises was also likely to contribute to the negative elasticity since the smallholder dairy enterprises are labour intensive. This meant that much of the time consumed on dairy activities manually had no impact on output, an observation which is consistent with that of Tangka *et al*. (1999) that most of smallholder dairy farms in Kenya have greater labour input per unit of milk produced.

In the inefficiency model factors relating to farm and farmer characteristics and institutional factors were analysed. Farm characteristic consisted of dairy management practices. In this model, a positive coefficient implies that the factor increases inefficiency while a negative coefficient implies the factor reduces inefficiency (Mawa *et al*., 2014).

Overall, age had a negative coefficient and this was also the case for producer organisation driven and milk processor driven models, which indicated older farmers were more efficient compared to younger farmers. This could have been as a result of the experience gained over time, in line with observations of Musemwa *et al.* (2013); Otieno *et al.* (2012) that efficiency among smallholder farmers increased with age. However, this was significant only for farmers under milk processor driven model ($p<0.05$) and could be attributed to the fact that farmers linked to this model were relatively older and more experienced than those in direct procuring and producer organisation driven models.

Education level of the dairy decision maker reduced inefficiency and this significantly increased with the level of education attained in the overall sample. However, among farmers linked to the direct procuring model, only the secondary level of education had significant influence ($p<0.05$) while primary level of education was significant ($p<0.01$) among farmers linked to milk processor driven model. This indicated the need for at least basic level of education among dairy farmers if they are to benefit from extension and instructions given on the inputs packages. These findings concur with those of Ng'ang'a *et al.* (2010); Majiwa *et al.* (2012); Kibiego *et al*. (2015) who also found that the level of schooling reduced inefficiency in dairy production. This is expected since with a given level of education, a farmer is able to comprehend information, adoption of new technology is enhanced and this improves productivity.

Farmers' primary occupation (farming) was found to influence efficiency positively in the overall sample. This however had varying effect on efficiency across the business models. Among the farmers linked to producer organisation driven model, farming as the primary occupation reduced inefficiency significantly ($p<0.05$). However, among farmers linked to milk processor driven model, farming as the primary occupation increased inefficiency ($p<0.05$). This could have been attributed to the fact that dairy was the main source of income for most farmers linked to producer organisation driven model (79.71%) compared to farmers linked to processor driven model (58.82%) who were more likely to devote their time to other enterprises. This was in contrast to the findings of Hussein (2011) who found that farmers engaged in other non-farm activities were more efficient than farmers who concentrated in farming.

With higher number of years in dairy farming, it was expected that farmers would improve their performance and thus increase efficiency. However, the results showed dairy experience increased inefficiency significantly ($p<0.05$) among farmers linked to processor driven model.

This was contrary to the findings of Ng'ang'a *et al.* (2010) who found that experience reduced inefficiency in dairy production. This could be explained from the fact that dairy was a major income source to the least proportion of farmers in processor driven model (58.82%) compared to those in producer organisation driven (79.71%) and direct procuring models (65.73%) implying more attention was given to other enterprises giving higher returns at the expense of dairy.

Against the expectation, institutional factors analysed (access to extension and credit) were not significant though they had an overall negative coefficient, implying their access reduced inefficiency. Most farmers (52%) accessed extension yearly (Table 3) and this might not have been sufficient to gather necessary information on dairy management. The frequency of extension access was not significantly different across the models hence the insignificant influence on efficiency across the models. Access to extension services support acquisition of knowledge and improved production technologies as found by Kibaara (2005); Nyekanyeka (2011).

Among the dairy management practices analysed, production of leguminous fodder as well as record keeping reduced inefficiency but were not significant contrary to the expectation. This could imply the information recorded was not sufficient to make informed enterprise decisions. Nyekanyeka (2011) found dairy records kept by farmers were mainly on quantity of marketed milk to enable the reconciliation with milk proceeds at the end of the month. Animal records on production, calving and calving interval and disease history would be of much importance in dairy enterprise decisions.

The use of artificial insemination (AI) significantly reduced inefficiency ($p<0.05$). AI technology can bring about rapid genetic improvement in cattle (Boettcher and Perera 2007). The effectiveness of AI technology has been found to reduce calving interval. Consequently, milk production per day of calving interval is increased thereby improving efficiency. A study by (Perez, 2016) found AI to be a major determinant of efficiency among dairy farms in Uruguay. Thus adequate feeding on quality fodder is essential for the particular breed to achieve its full potential. Dairy management practices thus have a positive influence on efficiency as also found in other studies (Cabrera *et al*., 2010; Ayele and Muriithi, 2012)

Table 10 Results of maximum likelihood estimates of stochastic production frontier

Business model	Overall		Direct procuring		Producer organisation		Milk processor driven	
Variable	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error	Coefficient	Std error
Ln Feeds	0.17***	0 .03	0.20***	0.05	0.08	0.07	0.15	0.14
Ln Land	0.08***	0 .02	0.08***	0.02	0.01	0.04	0.12*	0.07
Ln Veterinary	0.08*	0 .04	0.03	0.06	0.04	0.08	0.09	0.15
Ln Labour	-0.16***	0 .04	-0.15***	0.05	-0.14**	0.06	-0.13	0.12
_cons	6.26***	0 .37	6.28***	0.52	7.40***	0.71	6.30***	1.16
lnsig2v	-3.31***	0 .35	-2.84***	0.21	-4.04***	0.90	-4.06***	0.69
Inefficiency model								
Age	-0.005	0.01	0.03	0.02	-0.02	0.02	-0.17**	0.07
Gender	0.144	0.30	0.07	0.56	0.28	0.62	1.04	1.39
Education level								
Primary	-1.04**	0.40	-1.00	0.65	-1.00	1.24	-2.76*	1.60
Secondary	-1.31***	0.45	-1.60**	0.81	-2.21	1.37	-2.36	1.79
Tertiary	-1.58***	0.53	-2.43	1.69	-2.39	1.64	-1.23	2.23
Primary Occupation	-0.53	0.35	-1.14	0.78	-1.24**	0.65	4.20**	2.02
Dairy experience	0.02	0.01	-0.04	0.03	0.03	0.03	0.22**	0.10
Extension acess	0.09	0.27	-0.79	0.66	0.92	0.55	-1.70	1.84
Credit access	-0.30	0.32	0.34	0.79	-0.63	0.57	-1.15	1.13
Fodder type	-1.62	1.10	-3.20	6.11	-3.84	5.06	4.30	3.82
Record keeping	-0.13	0.26	-0.38	0.59	0.32	0.55	1.21	1.42
AI	-0.58**	0.30	-1.45**	0.67	-0.21	0.52	0.53	1.37
Sigma_v	0.19	0.03	0.24	0.03	0.13	0.06	0.13	0.05
Log likelihood		-42.3		-22.39			4.72	
P		0.00		0			0.04	
N		246		143			34	
Chi		61.03		41.57			9.57	

*Significant levels at ***99%, **95%, and *90%*

4.5.1 Technical efficiency across the dairy business models

On estimation of the production frontier, the technical efficiency (TE) scores were predicted. Table 11 shows distribution by level of the attained efficiency score while Table 12 shows the efficiency scores for farms under each business model. Majority (72%) attained a mean TE above 0.70 and only a few (6.1%) attained a TE score of less or equal to 0.5.

Table 11 Distribution of TE scores across dairy business models

TE	Overall		Direct procuring		Producer organisation		Milk processor	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
0.31 - 0.40	5	2.03	2	1.40	2	2.90	1	2.94
0.41 - 0.50	10	4.07	7	4.90	1	1.45	2	5.88
0.51 - 0.60	17	6.91	11	7.69	6	8.70	0	0.00
0.61 - 0.70	35	14.23	19	13.29	11	15.94	5	14.71
0.71 - 0.80	64	26.02	37	25.87	21	30.43	6	17.65
0.81 - 0.90	91	36.99	48	33.57	25	36.23	18	52.94
> 0.90	24	9.76	19	13.29	3	4.35	2	5.88

Table 12 Technical efficiency estimates across dairy business models

Dairy business model	Sample (n)	Mean	SD	Min	Max
Pooled data	246	0.77	0.13	0.32	0.94
Direct procuring	143	0.77	0.13	0.31	0.94
Producer organisation driven	69	0.75	0.12	0.37	0.92
Milk processor driven	34	0.78	0.13	0.35	0.93
Technical efficiency between counties:					
Nyandarua	123	0.77			
Nandi	123	0.76			

The most inefficient farmer achieved a TE score of 0.31 while the least inefficient achieved a score of 0.94. Majority (36.99%) of farmers across the three business models attained a TE score of 0.81 to 0.90. The milk processor' driven model, however, had the highest proportion (52.94%) compared to producer organization (36.23%) or direct procuring (33.57%).

Majority of the "most efficient" farmers (13.29%) were linked to the direct procuring model compared to producer organization model (4.35%) or milk processor driven model (5.88%). Farmers linked to the milk processor driven model, nevertheless, attained the highest mean efficiency (78%) followed by direct procuring models (77%) and producer organization' driven (75%) respectively. The mean technical efficiency of smallholder farmers was 0.77. This implies that 23% of potential output was lost due to technical inefficiency. These findings are comparable to the technical efficiency estimates of 75% to 85% in smallholder farms within the Kenya highlands (Majiwa *et al.*, 2012; Kimenchu *et al*., 2014). This indicates there is potential for increasing dairy output among smallholder dairy farmers by 23% within the current level of input use

Technical Efficiency is positively influenced by education level and use of AI (Table 10). Majority of farmers practicing AI (75.52%) were from direct procuring model followed by milk processor model (73.53%). However, direct procuring model also had the largest range of TE scores (0.31% - 0.94%) as compared to milk processor (0.35% - 0.93%) and producer organization' driven model (0.37% - 0.92 %) (Table 12). This lowers the average score relative to that of milk processor driven model. The milk processor driven model which also had a relatively high percentage of farmers practicing AI, relatively larger acreage under fodder and relatively lesser range of TE scores, thus, attained the highest mean TE (78%).

A Kruskal Wallis test carried out to determine whether TE was significantly different for the three dairy business model, showed no statistically significant difference in TE across the business models, χ^2 (2) = 2.84, p=0.24.

CHAPTER FIVE

CONCLUSION AND POLICY IMPLICATIONS

5.1 Conclusions

1. Farm characteristics of the dairy decision maker and institutional factors influenced the farmers' choice of a dairy business model. With increase in input market distance and milk prices, farmers were more likely to choose direct procuring model relative to producer organisation or milk processor model. On the other hand, the need for credit and extension services increased the likelihood of choosing either producer organisation driven model or milk processor driven model relative to direct procuring.
2. Analysis of gross margin, a proxy for economic performance showed smallholder dairy enterprises in Nyandarua and Nandi had positive returns. The economic performance across the dairy business models did not statistically differ implying dairy business models had no significant influence on economic performance of smallholder dairy enterprises. Feeds and labour were found to be the major costs in dairy production.
3. Technical efficiency attained by farms linked to the three business models did not differ statistically. Increase in provision of feeds, land allocated to pasture and fodder and use of veterinary services had a positive effect on milk output while increase in labour hours had a negative effect on output. Farmer characteristics with significant influence on efficiency were age, education level and primary occupation of the dairy decision maker. Contrary to expectation, access to extension and credit had no significant influence on efficiency. Use of artificial insemination (AI), a management practice, significantly influenced efficiency.

5.2 Policy implications

To inform interventions for improving the economic welfare of smallholder dairy farmers in Nyandarua and Nandi Counties, some relevant policy implications are identified:

1. Consistent supply of adequate quantity and quality feed will enable smallholder farmers improve on the productivity of their dairy herd. Training farmers on own farm production of fodder and preservation would be an important pathway in addressing consistency of feed supply at lower cost.

2. The county governments should promote mechanization appropriate to smallholder dairy farmers. This would increase effectiveness of labour and consequently reduce labour cost.
3. Enhancing the use of artificial insemination to acquire higher yielding breeds can increase productivity.
4. Large credit institutions can support dairy farmers indirectly through their producer organisations to obtain credit at flexible terms. However, there is need to train farmers on prioritising of dairy needs so that the credit obtained is used to improve dairy productivity.

5.2 Suggestion for further research

Further research could consider effectiveness of extension services offered by the different agents in improving technical efficiency of dairy farmers.

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APPENDICES:

Appendix 1: Questionnaire

Date: ……………… Enumerator: ………… Questionnaire No... ……….
County ………………… Location ……………………
Respondent name ……………………………………… Household head=1 { } Spouse=0 { } Gender: M=1 { } F=0 { }
Age: …………….
1a) Who is the main decision maker on dairy cattle management: SELF=1 { } Spouse=0 { } other family member=2 { }

If not **SELF**, *(fill the table below for the main decision maker* ***If SELF,*** *ask only the questions not answered in the previous question)*

b. General information on main decision maker

Gender	Age (*years)*	Education	Primary Occupation	Dairy experience

Key: ***Gender****, 1=male, 0=Female,* ***Education,*** *1=No formal, 2=Primary, 3= secondary, 4= Tertiary,* ***Primary Occupation****, 1=Farming, 2=Off-farm (informal), 3=Off-farm (formal),* ***Other occupation,*** *(specify)…..*

1c) Does the household own and use these amenities?
Radio { } Electricity supply { } Mobile phone { } {1 = YES 2 = NO]

1d) What is your source of water for the dairy cattle? Piped water supply { } River { } Dam { } Roof catchment { }

2. Farm and farm enterprises

a) List the farm agricultural enterprises and the acres of land allocated

Land owned (acres)	**Rented in**	**Rented out**	**Acreage under**			
			Natural pasture	Cultivated fodder	Food crops	Commercial crops
	KES/ acre:					

b) Rank your income sources in order of importance (1 being the best)

Income source	Dairy	Crops	Off farm informal	Off farm formal
Rank				
			Specify;	Specify;

3. a) Livestock reared:

Livestock	Stock Jan 2015	Value/ unit	Birth	Purc-hased	Valu e/unit	Valu e/unit	Sold	Valu e/unit	Stock at Dec 2015	Val ue/u nit	Curre-nt stock
Calves											
Weaned heifers& bulls											
Steers											
Bulls (breeding age)											
Heifers											
Milking cows											

b) Production

Cow	Breed	Calving interval (days)	Lactation length (months)	Milk yield per day (litres			Months production is		
				Low	High	normal	Low	High	normal
1									
2									
3									
4									
5									

4a.Milk utilisation

i) On average, what quantity of milk does the household consume per day? …………. Kg

ii) On average, what quantity of milk do you feed calves, that is:

From birth to the start of weaning …………..Kg/day for ………….. Weeks

From weaning: ……….. Kg/day for ……………Weeks

4b. Marketing

i) Where do you sell your milk and what price?

Buyer	Highest price	No. month	Lowest price	No. Months	Normal price	No. months

***Codes; Buyer**: 1= Cooperative, 2 = Processor, 3= Institution, 4=Middlemen 5= neighbour*

ii) What quantity of milk did you sell in 2015?

2015	Buyer type	Highest quantity	No. of months	Lowest quantity	No. of months	Normal quantity	No. of months	Total
Qty (kg)								

What is your opinion on the price offered? { } Satisfactory { } Low { } High
How has the milk price offered affected you dairy farming? ....
………………………………………………………………………………………………
…………………………………………….

5. Dairy inputs

a) Source of inputs

ai)

i) How do you source your inputs and services?

		Tick the input/ services received						Why do you choose this source of inputs and/or services? ***code 1***
Code	Model	Concentrates & minerals	Animal health	AI	Extension	Credit	Other (specify) ……….	
1	Purchase directly from private service providers							
2	Cooperative owned agrovets through check off system							
3	Private Service providers contracted by processor							

Code 1

1 = Variety of product and/or services offered 2 = Offer lower price 3 = Offer goods on credit
4 = Less distance to the source 5 = Quality inputs and services 6= Inputs delivered to me during milk collection 7= other (specify)….

Which would you say is your main model for sourcing of inputs/services { } Model 1 { } Model 2 { } Model 3

iv) How long does it take to your input centre ………………. min
v) How much do you pay to the input centre? KES…….. /trip

b) Veterinary costs

i) How much did you spend in **t**reatment of the dairy cattle? KES ………………

ii) How many cows were served (AI/ Bull service)? .... Charges per service ……………..

iii) How often do you deworm? 1=monthly, 2 = three months 3= six months

iv) How much do you spend per deworming? KES …………

v) How often do you dip/spray? 1=Weekly, 2= fortnight, 3= monthly, 4 = three months

vi) How much do you spend per dipping/Spray? KES ………….

Ci) Feeds Cost (purchased)

Particulars	Freq:1=weekly, 2=fortnight, 3=monthly 4=(Specify).	Qty per purchase	Total qty/year	Unit cost	Total cost	Usage/ cow	Frequency of feeding
Fodder							
Silage							
Hay							
Concentrates							
Minerals							
Others(specify) …..							

Cii) Feed produced on farm

Particulars	Fodder No.	Acreage	No. of seasons planted/yr	Harvesting freq:1=weekly, 2= fortnight, 3=monthly, 4=(Specify).	Total qty/year	Frequency of feeding
Fodder; Nappier						
- Oats						
-						
-						
-						
Silage						
Hay						
Minerals						
Others(specify)						

d) Fodder production cost for the year 2015

Annual cost of fodder production								
Inputs;								
Particular	**Quantity (kg)**			**Unit cost**			**Total cost**	
Seed								
Planting fertilizer(eg DAP)								
Top dressing fertilizer(eg CAN, Urea)								
Labour;								
	Frequency			**Time taken (hours)**			**Unit cost**	
	Fodder1	2	3	Fodder1	2	3		
Planting								
Weeding								
Top dressing								
Harvesting								
Transport								
Baling								
Silaging								

Code; Frequency:1=daily,2=weekly, 3=fortnight, 4=monthly, 5= (Specify).

What is the local daily wage rate for farm labour? KES...................
Have you employed a 'shamba boy' {Yes} {No}. If yes, what is the salary per month? KES……………..
In your opinion, what proportion of time does he spend on dairy activities and on crops? *(Compute the proportion in percentage)*
Dairy activities………… % Crops ……………..%

e.) How long do you take to carry out the following dairy activities?

Activity	Time (minutes)	Frequency ***Code 1=daily, 2=weekly, 3= monthly***
1. Feeding		
2. Watering(time to watering point)		
3. Milking		
4. Cleaning milking equipments		
5. Cleaning shed		
6. Sourcing inputs		
7. Delivery to market		
8. Others (specify)		

6. Investment in dairy assets

Do you own the following dairy assets and equipment?

Assset/equipment	**Yes=1 No=0**	**Approximate Value**
Milking equipment		
Spraying Knapsack		
Chaff cutter		
Baler		
Zerograzing unit		
Others: specify		

7. Income *(For the year 2015)*

No	Particular	Quantity produced	Average annual Income (KES)
1.	Milk		
2.	Increment in herd value		
3.	Bull service		
4	Fodder/pasture		
5			
6			
7			

8. Institutional factors

a) Extension

i) In the last one year, have you received extension services? {YES} {NO}

If YES,

No	Activity	Source (two main) *Code 3*		Frequency *Code 4*		How satisfactory *Code 5*
1	Artificial Insemination (AI)					
2	Feeding; TMR					
3	Fodder production					
4	Fodder preservation (hay/silage)					
5	Record keeping					
6	Zero grazing					
7	Input market information					
8	Output market information					

*Key: **Code 3**:Government extension=1, Processor=2, Cooperative=3, Media (TV, radio,Internet)=4, Phone=5, Others: (specify)…….=6. **Code 4**: weekly=1, Fortnightly=2, Monthly=3 Quarterly=4, Yearly=5 **Code 5:** Satisfied=1, Fair satisfied=2, Not satisfied=3*

ii) Do you pay for extension servives? {Yes} {No} If yes, how much do you pay year? KES -----

b) Credit

i) In the last one year have you received credit for dairy {YES} {NO} **If yes,**

ii) What was the source of the credit?

{ } Commercial bank { } Microfinance/sacco { } Cooperative { } Relative { } others (specify)………….

iv) What was the interest charged? { %}

vi) In your opinion, how would you gauge the interest rate charged

{ } Very high { } High { } Fair { } Low

If No,

vii) Why didn't you receive?

{ } Did not apply for { } No credit institutions in the area { } High interest rate { } No suitable collateral { } others (specify)……………………….

Remarks

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………

Appendix 2 Summary of analysis and outputs

A. Skewness test for SPF

	Percentiles	Smallest		
1%	-.8283747	-1.00283		
5%	-.5849084	-.8471954		
10%	-.4359173	-.8283747	Obs	246
25%	-.1900726	-.7788906	Sum of Wgt.	246
50%	.033715		Mean	1.12e-09
		Largest	Std. Dev	.3087767
75%	.2148006	.5333493		
90%	.4083703	.5441688	Variance	.0953431
95%	.4806949	.5532098	**Skewness**	**-.544107**
99%	.5441688	.5606483	Kurtosis	3.106838

B. Test for heteroskedasticity

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of LnY

chi2(1) = 1.51

Prob > chi2 = 0.2197

C. Test for multicollinearity

Variable	VIF	1/VIF
HZD	1.21	0.82588
LandH	1.21	0.829799
Mktdist	1.03	0.97398
Avprice	1.01	0.987866
Mean VIF	1.11	

D. Kruskal-Wallis equality-of-populations rank test

Dairy business model	Obs	Rank Sum
Direct procuring	143	18012.00
Milk processor driven	34	4612.00
Producer organization	69	7757.00

chi-squared = 2.834 with 2 d.f.

probability = 0.2424

chi-squared with ties = 2.836 with 2 d.f.

probability = 0.2421