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ANIMAL HUSBANDRY & VETERINARY SCIENCE | RESEARCH ARTICLE

Determinants of sustainable innovation performance by smallholder dairy farmers in Malawi

Sylvia Chindime^{1*}, Paul Kibwika¹ and Mizeck Chagunda²

Abstract: The smallholder dairy farmer's performance and ability to improve productivity for increased incomes, is driven by their level of innovativeness. Knowledge on the nature, degree and frequency of innovations provide opportunities for supporting the competitive advantages of smallholder dairy farmers to sustainably break away from the poverty cycle. Little attention has been given to measuring the performance and drivers of innovation for improvement of smallholder dairy-farming in Malawi. Without understanding innovation, it is difficult to make policies and provide targeted, impactful support to smallholder farmers. This study is based on a cross sectional survey of 193 smallholder farmers in Lilongwe and Blantyre milk shed areas of Malawi. Innovation indices were computed to measure the innovation performance and further analysed to determine the drivers and barriers of innovations. Four categories of innovations namely; feeding, breeding, market, and animal health innovations are presented. The innovation index for the smallholder farmers was less than half (0.37) which is relatively lower in comparison to developed industries. The key driver was access to credit along with training, access to information and networking. For efficient and sustainable management of innovations, clear policies should be put in place to ensure formal structures for supporting continuity

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PUBLIC INTEREST STATEMENT

About 85% of milk production in Malawi is produced by smallholder farmers. For smallholder farmers to benefit more from their dairy enterprises amidst challenges of changing and unpredictable climate and international milk chains, they are now required to be more innovative in their practices to increase productivity and remain competitive. This paper explores the determinants for smallholder dairy farmers in Malawi to continuously innovate in part to effectively address the challenges of income and food security. This study suggests that for smallholder dairy farmers to remain innovative and competitive, they would have to strengthen their social networking to facilitate access to relevant inputs, production knowledge and market information including quality requirements. For this to happen, policies must be in place to support collective action for smallholder farmers through milk bulking groups, infrastructure for distribution and access to quality inputs, and regulation of market actors for fair trade.

of innovations through enhancements in social networking among the farmers and cost effective mechanisms for accessing quality inputs.

Subjects: Environment & Agriculture; Food Science & Technology; Development Studies, Environment, Social Work, Urban Studies; Social Sciences; Development Studies

Keywords: innovation index; regression, innovation domains, drivers and barriers, smallholder dairy

1. Introduction

The declining dairy productivity in most sub-Saharan countries due to climate variability (Gerosa & Skoet, 2012) is constraining achievement of food security in the region (Guaitero, Avermaete, Rugeles, & Ariza, 2013). Innovations can accelerate dairy productivity while simultaneously responding to global challenges such as poverty, food insecurity and low income (Future, 2011; Laple, Renwick, & Thorne, 2015; Meynard et al., 2016). If, for example, improvement in breeding practices through artificial insemination (Tebug, 2012) is combined with improved feeds and feeding practices such as use of dairy mash and zero grazing, production and productivity of milk would increase and lead into long term positive impacts on livestock productivity growth and poverty reduction (CIE, 2011). Creative combinations of technologies and practices that address contemporary challenges are the innovations that will enhance the resilience of small holder farmers against the hash effects of climate variability.

Agricultural Innovation System (AIS) thinking provides a framework for understanding the complexity of innovations in farming systems. Scholars such as (Klerkx et al., 2014) explain that innovations entail alignment of tangible product or well defined set of practices and technologies (referred as hardware), new modes of thinking and corresponding practices and learning processes (referred as software), and new institutions and social-organisational arrangements (referred as orgware). Appropriate innovations need to be situated in systematic learning and knowledge exchange processes, and accompanied by organisation of smallholder farmers to take advantage of economies of scale. The overall Government's intention in supporting innovations, for the case of sub-Saharan Africa is to empower the smallholder dairy farmers to benefit more from the dairy value chain by increasing their competitiveness.

There is on-going effort in developing countries towards raising smallholder dairy farmers' productivity with recent calls to invest in innovations and expand market based interventions for sustainable intensification (Banda et al., 2011). While smallholder dairy farmers are increasingly getting exposed to elements of innovations, such as improved feeding practices, improved breeding practices and dairy management processes, the challenge is how to consolidate the performance of these innovations and other critical elements such as market access, value addition and organisational capacity for the innovations to benefit the farmers. Several studies (Chagunda et al., 2010; Chindime, 2008; Phiri, 2007) have used the rate of technological uptake by the smallholder dairy farmers as a proxy for innovations in improving the productivity at farm level, but this is only part of innovation and this creates incomplete understanding. Mofakkarul Islam, Renwick, Lamprinopoulou, and Klerkx (2013) extends the trajectory of innovations beyond the creation of technologies to creation of knowledge that encompass the factors affecting demand for and use of knowledge in novel and useful ways. A robust and comprehensive quantifiable analysis is needed to understand the performance of innovations of smallholder dairy farmers with a view of identifying the bottlenecks for sustaining such innovations. Using the case of Malawi, this study seeks to identify the determinants of sustainable innovations among smallholder dairy farmers taking into consideration the significance of the dairy sector to rural livelihoods with regard to food, income and nutritional security (GoM, 2013).

This paper establishes the degree of innovation performance and drivers of those innovations in Malawi's smallholder dairy farming. Innovations are the key driver for sustainable smallholder

dairying hence measurement of the performance of such innovations is crucial to guide investments at farm, sector and national levels.

2. Methodology

2.1. Design

The study design is according to Ariza, Rugeles, Saavedra, and Guaitero (2012) and Läßle et al. (2015) who suggested building blocks for innovations performance for agricultural firms. The building blocks for innovation in this case are stages of innovations along the dairy value chain. To generate data on these, a cross-sectional survey was conducted in two milk shed areas of Malawi namely; Lilongwe and Blantyre. The study focused on tracing available *elements of* innovations in form of hardware, software, and orgware that were being promoted by dairy development programmes and Malawi Government within the milksheds.

Multistage sampling technique was used to select respondents. The first stage involved purposive selection of four Milk Bulking Groups (MBGs) considering; (1) their breadth of engagement in dairy development programmes; (2) time of establishment and long term experience in dairying (3) outstanding commonalities in terms of maturity stage advancement to registered cooperatives. The second stage involved obtaining a comprehensive list of farmers who deliver and sell milk at the selected MBGs. From this list, simple random sampling was carried out and a total of 193 smallholder farmers were selected for the study.

Primary data was gathered by semi-structured interviews and participatory observation. Participatory observation were done at farmer level with a purpose of determining actual usage of innovations, how trainings and workshops were organised and conducted in promotion of innovations, and organisation of demonstrations plots. For this study secondary data included; reports, minutes, newsletters which were used to establish how the innovations have been useful in smallholder dairy farming. Data on innovations was guided by Oslo Manual (OECD, n.d.) on innovation indicators. It provides guidelines for collecting and interpreting innovations data in a comparable manner. The innovations assessed cut across the dairy value chain and include: feeding, breeding, marketing and animal health. Depending on the nature of the innovation, these were further categorized as hardware (technologies and tangible products); software (knowledge, processes, trainings and learning); and orgware (social organisation, integrated service arrangements, advocacy and promotions and marketing). The social demographic characteristics of the smallholder farmers such as assets owned, age, sex, education levels, access to land, and livestock owned were also captured.

3. Analysis

Data collected was analyzed in three successive steps namely; (1) development of an innovation inventory matrix to summarize the features of innovations; (2) computation of an innovation index to provide an indication of the degree of innovation among the smallholder farmers; and (3) a regression model to isolate the determinants of innovations. Each of these steps is explained in detail as below.

3.1. Step 1: developing innovation matrix

An innovation matrix was used as an instrument to organize innovation data in a systemic and synthetic way. Innovation Matrix provided a deeper understanding of the nature, characteristics and features of observed innovations (N_1 , N_2 and N_3) and were identified as hardware, software and orgware (see Ariza et al., 2012). The overall innovation (N_0) is the sum of the respective innovations.

Thus, N_0 = total number of innovations; N_1 = Innovation 1; N_2 = innovation 2; N_3 = innovation 3.

3.2. Step 2: computation of innovation index (II)

Having computed the innovation matrix and defined categories, these were used to input into an Innovation Index. Innovation Index (II) is a single number that combines information about innovations level and frequency observed by individual smallholder dairy farmer. It was computed to obtain the degree of innovation of every smallholder farmer. The innovations considered were of four types.

where innovation 1 = market innovations (H, S, O); innovation 2 = feeding innovations (H, S, O); innovation 3 = breeding innovations (H, S, O); innovation 4 = animal health innovations (H, S, O).

Therefore Innovation Index (II) is computed by

$$II = \sum_j^n 1_j f_j^k$$

where II is an innovation index; $j = j$ th innovation in the Innovation Matrix; $n =$ the total number of innovations in smallholder dairy farming; $1_j =$ an indicator function that points where there are innovations or no innovation; $f_j =$ the relative frequency/how regular the j th innovation are practiced by the smallholder farmers; $k =$ is the power of the sub innovation category of the innovations practiced.

The frequency is measured in the interval (0, 1). The minimum value of Innovation Index is 0, for a firm with no innovations. The maximum value of innovation index is 1 if in extreme cases where all possible innovations are implemented by firm.

H = Hardware, S = Software, O = Orgware.

3.3. Step 3: model specification for estimating

An econometric model, Ordinary Least Square estimations was used to test the effect of coordination and articulation of variables along with other explanatory variables on the continuous variable the Innovation Index (II). The model specifications are as below;

$$II = F(X_1, X_2, X_3, X_4, X_5, X_6, \dots X_n) + \epsilon$$

where II = innovation index; $X_n \dots X_n =$ factors; $X_1 =$ market prices; $X_2 =$ social networking; $X_3 =$ access to credit; $X_4 =$ access to production inputs; $X_5 =$ age; $X_6 =$ farming experience; $X_7 =$ cost of production inputs; $\epsilon =$ error.

Linear form presents the model as:

$$(Y) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \dots \beta_n X_n + \epsilon$$

where $\beta_0, \beta_1 \dots \beta_n$ are estimated coefficients. ϵ is estimated error.

The IBM SPSS statistics package version 20 was used to obtain descriptive statistics, means, and frequencies on socio economic characteristics of the smallholder dairy farmers.

4. Results

The demographic characteristics of the sampled smallholder dairy farmers involved in the survey are presented in Table 1. The majority of the farmers were in between 30 and 60 years old, a category that Oladeebo and Oladeebo (2008) considers able to make choices in farming based on sound decisions including use of innovations. The sample was 52 and 48% males and females respectively. Education is an important factor especially in access and use of information and technologies (also see Akzar, Permani, & Wendy Umberger, 2016). Only 16% of the farmers had acquired education beyond primary level while 79.4% had only primary level education. The importance level the

Table 1. Socio economic characteristics of the surveyed smallholder farmers

Variable	Percentage (n = 193)
<i>Age (years old)</i>	
Less 20	2.6
20–29	31
30–59	57.7
Over 60	8.8
<i>Education</i>	
No schooling	4.6
Primary school leaving certificate education	79.4
Junior certificate education	10.3
Malawi school leaving certificate education	5.7
<i>Gender</i>	
Males	52
Females	48
<i>Ranking dairy enterprise by smallholder farmers</i>	
Very important	53.5
Important	42.8
Not important	3.6

Source: Authors own data analysis.

smallholder farmers attaches to dairy as compared to other enterprises in contributing to their livelihood change was determined through ranking. About 54% of the farmers ranked the dairy farming enterprise as very important.

5. Domains of innovations matrix for smallholder dairy

Under the Ministry of Agriculture, Irrigation and Water Development, the domains of the innovations are the packages of innovations promoted in the milkshed areas by the Department of Animal Health and Industry in collaboration with other non-state actors in the last five decades. Table 2 describes a typology of innovations and the proportions of farmers undertaking those innovations. For each innovation, the constituent elements categorized as hardware, software and orgware are identified and their respective characteristic activities outlined.

5.1. Market innovations

The MBGs were established to organise the smallholder farmers for collective marketing of their milk especially to the processors. Through this, farmers get better prices due to collective bargaining and it is a mechanism for collective responsibility to guarantee quality of milk supplied to the buyer (processor). Over 94% of the farmers participated in this arrangement indicating the relevance and value of collective action. For the buyers, it is convenient as they obtain substantial volumes of milk of the desired quality in designated places, which saves costs. Aside from marketing milk, milk bulking centres serve multiple functions including being an output and input market place (animal drugs, feeds, and artificial insemination services) and access point for information and knowledge (extension services). The processor pays to a group bank account and individual farmers are accordingly paid depending on the volumes supplied. With this guaranteed income, the farmers can also access inputs on credit and payment is deducted from their incomes over an agreed time period. The bulking centres are also a platform for farmer interaction with service providers, networking, and learning.

Table 2. Typology and innovation matrix of smallholder farmers along the dairy value chain

Innovation along the dairy value chain	Elements of innovations	Innovations	Percentage of farmers involved in the innovation (multiple responses n = 193)
Market innovations	Hardware	• Installation of equipment for monitoring milk hygiene	10%
		• Maintenance of milk cooling tank and engine	10%
	Orgware	• Membership to Milk Sales to Milk Bulking Group that offer integrated services such as AI feeds, drugs and extension services	28%
		• Agreements with processors an input supplier	5%
	Software	• Recruitment of Skilled staff to monitor quality of milk	6%
		• Integrating procedures and code of conduct to ensure quality management of the Milk and standards	35%
Feeding innovations	Hardware	• Use of improved fodder varieties	2.2%
		• Use of feed processing technologies (Silage, Hay)	7%
		• Acquisition of supplements Molasses, Dairy mash and Mineral premix)	9%
		• Zero grazing feeding management practice	12%
		• Rules and regulations for conducting training and dissemination of information on improved feeding by the Extension workers and Milk Bulking group leaders	7%
	Software	• Conducting field demonstrations and farmer to farmer visits for improved feeding	10%
		• Awareness and advocacy campaigns for improved feeds (leaflets, brochures)	5%
		• Provision of Semen straws of Artificial Insemination	10%
Breeding innovations	Hardware	• Provision of liquid nitrogen and necessary equipment	10%
		• Credit arrangement for smallholder farmer access to AI	10%
	Orgware	• Group trainings on heat detection and monitoring breeding symptom animals	7%
		• Promoting AI Service for improved breeds through trainings and information sheets	7.2%

(Continued)

Table 2. (Continued)

Innovation along the dairy value chain	Elements of innovations	Innovations	Percentage of farmers involved in the innovation (multiple responses n = 193)
Animal health innovations	Hardware	• Acquisition of vaccination	5%
		• Acquisition de-wormers	5%
		• Acquisition dipping	5%
		• Acquisition mastitis treatments	5%
	Orgware	• Integrating drug revolving fund suing credit payment system after monthly milk sales	18.4%
	Software	• Promoting farmers decision in use of veterinary drugs	1.6%
• Improving drug service delivery		1%	
Total number of innovation as collected from the study		27	

5.2. Feeding innovations

Dairy feeds and feeding practices greatly influence dairy production and productivity. Members of the MBGs are privileged to have exposure and access to various types of feeds as promoted by different service providers who target the groups. The common innovative feeding systems among the smallholder dairy farmers combines forages, concentrates (supplementary feeds) and Zero grazing feeding practices. Some farmers use improved forages grass like *Rhodes* and *Napier* and maize stalks as supplements to concentrates. Extension workers and other advisory services providers target the MBGs for demonstration of the feeding practices including production of fodder. The demonstration plots serve as nurseries for multiplication and dissemination of fodder seed. Supplementary feeds such as dairy mash, mineral premixes, mineral blocks, and molasses to boost production and enhance milk quality are made available to the farmers through MBGs. The feed supplier provides bulk consignments of these supplementary feeds based on consolidated demand of the MBG. Farmers can acquire the feeds and payment is deducted from their milk sales at the end of month.

5.3. Dairy breeding innovations

The potential productivity per animal is determined by the breed. There has been a concerted effort by government and NGOs to upgrade the dairy breeds through Artificial Insemination (AI) techniques. The MBGs are supported to access quality semen, inseminators and facilities for storage of semen such as liquid nitrogen. Training and information related to breeding of animals is also provided. These services can be accessed on credit and payment is deducted from monthly milk sales for farmers in MBGs. However AI remains expensive to farmers because of repeated inseminations due to untimely reporting and ineffective insemination practices.

5.4. Dairy health related innovation

Dairy Animal health innovations support the smallholder dairy farmers through the provision and availability of treatments, drugs, good management practices, diseases prevention and control. The MBGs operate a drug revolving fund to ease access to veterinary drugs. The MBGs stock essential

Table 3. Innovation index of the smallholder dairy farmers

Mean smallholder dairy farmer innovation index	Minimum	Maximum	Standard deviation
0.3706	0.06	0.75	0.14976

Source: Data analysis.

drugs which are accessed by farmers on credit and paid for at the end of the month. Farmers are also provided with technical services for diagnosis and administration of drugs and treatment.

6. Smallholder dairy innovation performance

An innovation index was used to determine the innovation performance of the smallholder dairy farmers. Innovation index is measured through a weighted combination of adopted innovations such as software, hardware and orgware investments (Renwick, Läpple, O'Malley, & Thorne, 2014). Information on the Innovation Index of the smallholder dairy farmers which presents the level of smallholder farmer innovativeness is presented in Table 3. The overall mean Innovation index for smallholder dairy farmers in Malawi was found to be 0.3706. This is lower in comparison to developed industries in countries like Ireland (0.64). This could be attributed to the fact that agricultural innovation is advanced and is a separate industry which is given adequate attention. Ariza et al. (2012) indicates that the index ranges from 0 to 1 as the maximum value for highly innovative farmers. This indicates that the smallholder dairy farmers in Malawi have a performance of less than half of the maximum value of innovativeness. However, the sector is still progressing albeit slowly.

7. Determinants of innovations

Results of the econometric model were used to identify and interpret the determinants of innovation performance of the smallholder farmers. Innovation index is a dependent variable in the model. The explanatory variables consist of socio economic factors, social networking, and access to knowledge, credit, inputs and milk prices. The results of fitness test of the model indicated absence of multicollinearity, autocorrelation and heteroskedasticity among the variables. A summary of the model output is presented in Table 4. Variables that are significant at least from 1% up to 10% as a cut-off point and their respective p^2 are reported. Overall, the model was significant at 1% ($p = 0.000$). The adjusted R^2 value of 0.43 obtained indicates that about 50% of the observed variation in the innovation index level of the smallholder farmers could be attributed to the combined influence of the independent variables which were included in the regression equation.

Table 4. Linear regression analysis on determinants of innovations by smallholder dairy farmer

Variable	Coefficient	p-value
(Constant)	-0.291	0.531
Age of respondent	-0.011	0.386
Number of years of innovations usage	0.001	0.781
Social networking	0.090	0.000
Access to knowledge	0.097	0.013
Access to credit	0.142	0.073
Access to inputs	0.042	0.029
Milk price	-0.003	0.342

Notes: $R^2 = 0.50$; Adjusted $R^2 = 0.43$; SE = 0.06360 and $p \leq 0.001$.

8. Determinants of innovation performance of the smallholder dairy farmers

8.1. Social networking

Networking in this study refers to farmer to farmer regular contact including farm visits for the purposes of sharing ideas and new ways of doing things. Networking was measured as binary variable and was found to be highly significant at 1% level and has a positive impact on the innovation index. The unit increase in networking activities also increases innovation index by 9.0%. Those who participate in networking activities adopted 9% more innovative techniques out of the total that were surveyed. These results correspond with (Klerkx et al., 2014) who states that innovations takes place through social interaction and in the process individuals build, learn from each other and strategically adapt to new tools and techniques to suit their particular circumstances. Therefore, it is important to promote and strengthen effective networking by improving the farmers network sizes, connectedness and frequent interactions (Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2014) for more benefits in smallholder farming innovation performance.

8.2. Access to knowledge

The results show that access to knowledge was highly significant at 5% and had a positive effect on the innovation index in the smallholder dairy farming. Studies have documented that knowledge is paramount and is the heart of innovation (Kibwika, 2006; Läßle et al., 2015). Among the available avenues for knowledge development and access are advisory services from the extension workers which have been encouraging the farmers to participate and influence innovation adoption. Farmer demonstration plots have also provided a platform for peer learning among the smallholder dairy farmers. Additionally, there are periodic meetings by the management of the MBGs.

8.3. Access to inputs

Farm inputs are among the main factors of agricultural production. Access to input was highly significant at 5% had positive impact on the innovation index. Unit increase in accessibility of inputs such as dairy mash, artificial insemination services, and veterinary drugs, among others, increased the innovation index by 4.2%. The farmers who accessed the necessary inputs for the dairy farming adopted 4.2% more innovative techniques out of the total that were surveyed. The farmers' main avenue for accessing inputs is through the Milk Bulking groups which facilitates availability of the technologies. However, the farmers pointed out the need to increase the level of quality of the inputs and strengthening their contractual arrangements with the suppliers to ensure the delivery of standard products.

8.4. Access to credit

Access to credit eases financial constraints among the smallholder farmers (Said & Hassan, n.d.). Access to credit had a positive and significant impact on innovation performance. As expected, the results show that unit increase in access to credit significantly raises the innovation index by 14.2%. The farmers with larger net of borrowing had a high innovation index. The access to credit were mainly in-kind credit whereby they obtain inputs and make repayment at the end of the month. The results are consistent with (Ndunda & Mungatana, 2013) who also found that increased access to credit has a positive relationship with innovation behavior of farmers. With increased access to credit, farmers are able to purchase the essential farming tools.

8.5. Age

The results show no evidence that age of the household had an effect on the innovation index. The results corresponds with (Läßle et al., 2015; Ndunda & Mungatana, 2013) that indicated that age had a negative effect and not significant in innovation performance of the farmers. Therefore, although it can be inferred that older farmers are less likely to innovate effectively, the results in this study were statistically insignificant and does not have much influence on willingness to innovate.

8.6. Milk price

The results shows evidence that the price of milk offered by the processors negatively affected the innovation performance among the smallholder dairy farmers. The higher the milk prices at Milk Bulking groups the less innovative the smallholder dairy farmer become. This is probably due to the fact that as the demand for milk increases, the farmers are assured of ready market for their product irrespective of the quality and are less likely to innovate.

9. Conclusion

This study set out to find out the determinants of the smallholder dairy farmers innovation performance in Malawi suing Lilongwe and Blantyre milk sheds. Four categories of innovations were observed namely, market, feed, breeding, animal health innovations. The combined weighted impact of the multiple innovations resulted in a smallholder dairy measurable index of performance of 0.37. This shows that the performance of the smallholder dairying needs to be supported to become more innovative.

The determinants of smallholder dairy innovations which had a positive impact on innovation index are social networking, access to knowledge, access to inputs, and access to credit. The increase in age and milk price negatively impacted innovations.

In light of the government's aim to attain self-sufficiency of milk and milk products, some of the policy recommendations derived from the study include:

- Networking promotes innovations: it is important to build on these relations by providing professional development activities for social networking to increase the network size, connectedness and more frequent interactions among the farmers. The shared marketing facilities were shown to be important and can be used as a hub for greater networking, sharing information on innovations and to address access and finance for inputs as well as enrolling farmers for training.
- Government should expand extension services to support initiatives aimed at improving access to inputs, knowledge and credit. The mechanisms in which these are taking place should, however, be reviewed and monitored. For instance, smallholder holder farmers acknowledged the availability of inputs though the quality of these inputs in questionable.

The smallholder dairy sector in Malawi needs to become more innovative if it is to improve productivity and remain relevant both in achieving Government's self-sufficiency goals and in improving rural nutrition and livelihoods.

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Competing Interest

The authors declare no competing interest.

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