Risk and Uncertainty in Milk Production by Smallholders in Tanzania: Implications for Inclusiveness and Investment

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Abstract

The study evaluates the impact of risk on enterprises of smallholder male, female and young milk producers in Tanzania's formal and informal dairy value chains. It also examines the effect of uncertainty on the decision to invest in milk production in both value chains. Results indicate that youths in the informal value chain face the greatest level of risk followed by men in the formal value chain, and then men in the informal value chain. Women in both value chains and youths in the formal value chain face relatively low risk. Overall, milk production in the informal chain is found to be substantially riskier than production in the formal chain. Optimal investment triggers are found to be much larger than the conventional triggers and are sensitive to volatility of returns. The results' policy and practical implications for inclusive dairy industry development in Tanzania are highlighted.

Keywords: risk and uncertainty, milk production, inclusiveness, investment, Tanzania

JEL Code: Q12, Q14

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1. Introduction

Antle (1983) aptly labels risk as 'the farmer's perennial problem' (pp. 1099). Risk refers to random events whose probabilities of occurrence can be quantified. A concept that is closely related to risk and one that also bedevils the farmer is uncertainty. It too refers to random events but whose probabilities of occurrence cannot be quantified. Therefore in simple terms, both risk and uncertainty refer to randomness, with uncertainty being a necessary but not sufficient condition for risk (Gough, 1988). When randomness enters a farmer's objective function through, for instance, input prices, output prices, and technology, it renders the farmer incapable of behaving optimally (Antle, 1983). This is because optimality conditions that hold in a deterministic world might not necessarily hold with random variables in the objective function, and this could lead to sub-optimal production and investment decisions. Risk is especially challenging for the resource-constrained or risk-averse farmer that is either excluded from the financial market or operates in an environment devoid of one. This means that insurance against risk is not so much of an option for such a farmer.

Hella *et al.* (2001) and Baker *et al*. (2015) document the existence of risk and uncertainty in livestock production in Tanzania. Cattle are considered the most economically and socially important type of livestock. Risk and uncertainty are major concerns particularly for the dairy industry, which is seen as having relatively great potential to reduce poverty, improve nutrition and foster inclusive development. This is because milk production at the household level is for the most part a female preserve (Ministry of Livestock and Fisheries Development, 2016), and 30% of livestock's contribution to agricultural gross domestic product is from dairying. To ensure that risk and uncertainty do not impede the industry from realizing its potential, there is need to identify and quantify the various sources of risk and apply appropriate risk management strategies and investment models that account for uncertainty in the economic environment. An example of where public investment has complimented private investment in mitigating risk is the index-based livestock insurance scheme that insures Kenyan pastoralists against losses due to adverse drought conditions.

This study has two objectives: the first objective is to analyze the impact of risk on milk production, and the second one is to determine the effect of uncertainty in the economic environment and irreversibility of investment on investment behavior. The two objectives are related in the sense that the first objective provides parameters relevant to achieving the second objective. Specifically, the study seeks to identify the various sources of risk faced by milk producers, quantify their impact, and generate a single measure of risk in milk production. The study then uses the consolidated risk measure to estimate a risk-adjusted discount rate and hence the optimal investment trigger if producers are to account for uncertainty and irreversibility of investment in their investment decisions.

There are three important considerations in this study. First, to the extent that the government of Tanzania views the dairy industry as being crucial to poverty alleviation and improving food and nutrition security, the analytical approach is intended to provide evidence relevant to inclusive value chain development. Inclusive value chain development is an approach to value chain development that not only focusses on the inclusion of smallholder farmers in value chains, but also recognizes the vulnerability of different categories of smallholder farmers. In Tanzania, the vulnerable are mainly women and the youths (United Republic of Tanzania, 2003). Therefore the study undertakes a disaggregated analysis of the risks that men, women, and the youths face in milk production. Second, the study recognizes the two types of value chains that exist in the Tanzanian dairy industry; the formal value chain where milk is processed and often packaged before selling it to the final consumer, and the informal value chain where milk is sold to the final consumer in its raw form. Producers in the formal value chain sell their milk either directly to milk collection centres or to traders who in turn supply the milk to the collection centres. The centres are operated by individual agents, producer groups, cooperatives, or processing companies. Price discovery mechanisms and relationships between agents are different in the two value chains, and so are the prices and their fluctuations. For instance, although milk prices in the formal value chain are relatively low, they tend to be more stable than prices in the informal chain. This implies different levels of output price risk exposure for milk producers in the two value chains. Therefore for each of the three producer categories, the analysis is undertaken for the two value chains. Third, the study recognizes seasonality in milk production as a permanent feature of the industry in Tanzania. But seasonality per se is not a source of risk. Rather, it is its effects on regularity of feed supply and hence unpredictable fluctuation in some production and price variables within each season that causes risk. In simulating the impact of risk, the study therefore accounts for fluctuations in some of the risk variables during the dry and wet seasons.

The rest of the paper is organized as follows: the next section discusses the different sources of risk in milk production and marketing in Tanzania. This is followed by analytical methods including data for examining risk and incorporating uncertainty and irreversibility of investment in the investment decision. Results are presented in section four and section five summarizes and concludes the paper.

2. Sources of risk in milk production

Generally, farm enterprises face two broad types of risks, namely, business risk and financial risk, also known as leverage risk (Unterschultz, 2000). Business risk is risk that arises directly from production and marketing activities of an enterprise and can therefore be sub-divided into production risk and market (price) risk. Financial risk stems from an enterprise's association with the financial market and it refers to the level of indebtedness of the enterprise. Unterschultz (2000) notes that the two broad types of risks are related in that an increase in business risk could lead to greater indebtedness of the enterprise. Covarrubias *et al*. (2012) and Twine *et al*. (2015) have found the incidence of debt to be considerably low among cattle keepers in Tanzania and therefore this study disregards financial risk.

Milk producers face both production risk and price risk. Production risk is fluctuation in output and is usually caused by variation in weather conditions, hence variation in availability of water and feed, and variation in animal health status due to diseases. Hella *et al*. (2001) attribute the highly risky nature of livestock production in the semi-arid region of Dodoma to the large variation in the amount of rainfall. Changes in herd health due to disease can be severe and result in death loss. Swai *et al*. (2010) estimate dairy cattle mortality rates to be 8.5 and 14.2 per 100 cattle years at risk[1] for Tanga and Iringa regions, respectively, and are mainly due to East Coast fever, a tick-borne disease. Ultimately, production risk manifests itself in fluctuations in daily milk yield or milk yield per lactation period, quality of milk produced and herd size. Quality of milk produced and sold also depends on milking and milk handling practices, which could be

[1] This is an epidemiological measure of risk of mortality and is different from the measure used in this empirical analysis.

considered an internal source of risk. Milking and milk handling practices could be dictated by attitudes and cultural norms, but are also likely to vary depending on the cost of inputs used to avoid contamination before, during and after milking.

Price risk is fluctuation in output and input prices, with fluctuation in output prices being mostly seasonal. Even though producers are aware of seasonality, the real source of risk is the unpredictable fluctuation in seasonal patterns such as the variation in the onset and duration of different seasons, which may in turn change the variance of prices. Input price risk is associated with the cost of the animal, the cost of labour, animal health services and feed. Compound feeds are in the form of maize bran, cotton seed cake and sunflower seed cake, and their prices closely follow prices of the respective raw materials. Heavy dependence on maize for concentrate feed is a serious concern for the industry because of the large fluctuation in maize prices (Geerts, 2014).

3. Methods

3.1 Study area and data

The study was undertaken in August 2016 in Lushoto district, located in the northern part of Tanga region. Seventy five percent of the district is covered by the Western Usambara Mountains. The topography allows for only intensive dairy cattle feeding, and farmers in the district have historically benefited from most of Tanzania's smallholder dairy development projects. As a result, farmers keep improved dairy breeds.

Data on variables related to milk production and marketing cash flows were obtained from representative milk producers in three gender categories: men, women and the youths[2]. For each gender category, two representative producers were considered: one producer sells milk into the formal value chain and the other sells into the informal value chain. Therefore data were collected from a total of six producers. The primary criteria for defining a representative milk producer for each gender category were that the producer undertakes commercial milk production and owns the dairy enterprise. In this regard, internal risk due to inability to make decisions regarding the enterprise does not arise. In addition, producers were selected based on their willingness and

[2] The Tanzanian government defines youths as persons from the age of 15 years up to 35 years (Ministry of Labour, Employment and Youth Development, 2007). Following this definition, the study analyzes the dairy enterprise of a male youth as there are hardly any female youths in the study area that own dairy enterprises.

ability to provide accurate and substantial enterprise data. Each selected producer provided data (table 1, with the exception of death loss) on their best performing cow that was lactating or had finished lactating in the last one year. Clearly, the data are typical of a low-input low-output production system.

3.2 Examining risk

Following Twine *et al*. (2016), the impact of risk is examined using a Monte Carlo cash flow model of milk production by a single cow for one lactation period (300 days). The potential cash flow for each producer in any given month is calculated as:

$$CF = PQ - CH - WX - \sum OC - OHC - DL \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

where CF is cash flow in \$ (USD), P is price per litre of milk (\$), Q is quantity of milk sold in litres, CH is cost of in-calf heifer[3] (\$), W is price of feed per kilogram (\$), X is quantity of feed, OC are other operating costs (\$), OHC are overhead costs (\$), and DL is death loss[4] (\$). Production risk is incorporated in the producer's cash flow model using death loss, fluctuations in daily milk yield, and amount of purchased concentrate feed given to the cow. Price risk is captured through fluctuations in the price of feed and price of milk. The cash flow model in equation (1) is simulated using Monte Carlo simulation in which triangular distributions are specified for average daily milk yield, death loss, feed quantities, feed prices and milk prices. Values of parameters of the triangular distributions were obtained from the producers. In essence, the variables P, Q, W, X and DL are made stochastic, implying a stochastic rather than deterministic cash flow model. Cash flows are obtained after 10,000 iterations.

Cash flow at risk (CFaR) is used to quantify the effect of risk on cash flows in the dry (Jan and Feb; Jun to Sep) and wet (Mar to May; Oct to Dec) seasons. CFaR of the enterprise is defined at a given confidence level, c, as the probability that the future cash flow value, cf, is less than or equal to a given cash flow value CF^* and is at most $(1 - c)$. As specified in Jorion (2001),

[3] It is assumed that the animal is purchased with a loan and loan repayment is half of monthly revenues. This is the practice by Covenant Bank, which offers dairy cattle loans to smallholder farmers.
[4] Death loss is not necessarily a cash outflow but because it represents loss in cash inflows in the event of death of the animal, it enables accounting for production risk due to death. Mortality rates are used to calculate the amount of milk lost that would have been sold.

$P(cf \leq CF^*) = 1 - c = m$ ……………………… (2)

It is either the probability, m, for a given CF^*or the CF^* at a given probability, m. In order to obtain a combined measure of risk from the different sources of risk, we use cash flows to calculate the monthly volatility of returns from milk production, σ_m. This is the standard deviation of the average monthly return on investment. Following Copeland and Antikarov (2001) and Hull (2005), the annual volatility, σ_a, is then calculated as:

$\sigma_a = \sigma_m \cdot \sqrt{12}$……………………… (3)

Table 1. Data on parameters used in the cash flow models

Parameter	FI	FF	MI	MF	YI	YF
ADY - wet season (litres/day)	4	6	4	12.5	6	10
ADY - dry season (litres/day)	3	2.5	2.75	4.5	6	9
% of ADY sold - wet season	75	83.3	50	84	67	80
% of ADY sold - dry season	66.7	80	54.5	67	67	78
Av. price of milk - wet season ($/litre)	0.35	0.23	0.55	0.23	0.23	0.23
Av. price of milk - dry season ($/litre)	0.35	0.23	0.55	0.23	0.35	0.23
Av. quantity of feed - wet season (Kg/day)	1.5	0	1.43	2	1.3	0
Av. quantity of feed - dry season (Kg/day)	1.5	0	1.43	1	0.4	0
Av. price of feed - wet season ($/Kg)	0.09	NA	0.12	0.20	0.15	NA
Av. price of feed - dry season ($/Kg)	0.09	NA	0.12	0.16	0.31	NA
Av. cost of medicines ($/day)	0	0	0	0.008	0	0
Annual death loss (%)	9.2	9.2	9.2	9.2	9.2	9.2

Source: Milk producers, except for death loss, which is obtained from an earlier sample survey of milk producers in the study area.

ADY denotes average daily yield, while FI, FF, MI, MF, YI, and YF denote producer categories and the value chains they operate in as follows: female informal, female formal, male informal, male formal, youth informal and youth formal, respectively.

3.3 Examining investment in milk production

The decision to invest in milk production can be analyzed using traditional capital budgeting methods such as net present value, adjusted present value, internal rate of return, modified internal rate of return, accounting rate of return, payback period, and cost-benefit analysis. However, these methods do not account for uncertainty in the economic environment and irreversibility of investment decisions. There is considerable uncertainty in smallholder milk production in Tanzania, which is exacerbated by the fact that investments in milk production are generally sunk costs and hence irreversible. Irreversibility means that once an investment has been made, it cannot be easily reversed; milk production technology is industry-specific, and even if it were not, it would fetch less than its original value on a secondary market. Given uncertainty and irreversibility, waiting to invest until more information becomes available to the decision maker might be of value. Therefore in the face of uncertainty and irreversibility, the decision is not only about whether or not to invest but when to invest.

This study employs the real options approach to capital budgeting. Following Dixit (1992), consider a smallholder farmer that intends to invest in milk production. Let I denote the sunk cost that they would incur, and V the flow of net operating revenues per unit time that lasts in perpetuity. Uncertainty means that future milk revenues are not exactly known, but in each time period, it is assumed that V follows a geometric Brownian motion[5]. The farmer aims to maximize the expected (average) present value of profits, and therefore future revenues are to be discounted at a positive discount rate, ρ, equal to the opportunity cost of riskless capital. The Marshallian criterion for the decision to either invest now and get $V/\rho - I$ or not investing at all and thus get 0 is that investment should occur (or that the option should be exercised) if $V/\rho > I$. The farmer will be indifferent between investing now and not investing at all if

$$M = \rho I \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

[5] This is a continuous-time stochastic process (also known as a Wiener process or standard Brownian motion) that is exponentiated to ensure that it is always positive. That is, V can trend upward and downward in equal proportions and the distribution of its logarithm is approximately normal (i.e., lognormal).

where M is the Marshallian investment trigger – the borderline level of the current revenue flow. Traditional investment analysis would recommend investing when current flow of revenue exceeds M. At M, waiting is better than either investing immediately or not investing at all, and will remain better for initial values of V slightly greater that M. When current revenue exceeds a certain level, H, investment then becomes optimal. We refer to H as the critical or trigger level of current revenue flows. It is larger than M and it shows that the farmer benefits from waiting for some time before investing. The optimal investment decision can be illustrated graphically (figure 1) when H is exogenously given, and when it is endogenously determined by the farmer. Both the value of investing immediately ($V/\rho - I$) and the value of the option to wait are denoted by P, and are plotted against revenues, V. If the project is undertaken yet $V = 0$, then the farmer loses I. As revenues increase, so does the value of investing immediately as shown by the straight line i_1i_2. The point at which the line i_1i_2 crosses the horizontal axis is the Marshallian trigger, M. The optimal investment decision when H is exogenously given occurs where the value of the option to wait as given by the convex curve w_1w_2 intersects i_1i_2. The value of the option to wait is the segment w_1h. Beyond this point, the option to wait has no value. If the investment trigger H is to be optimally determined by the farmer, it has to be increased above the value it had when it was exogenously given. This requires shifting the graph of the value of waiting until it is tangent to the line i_1i_2 as illustrated by the dotted curve. This is called the smooth pasting condition. It is a condition where the slope of the value of waiting is equal to the slope of the value of investing.

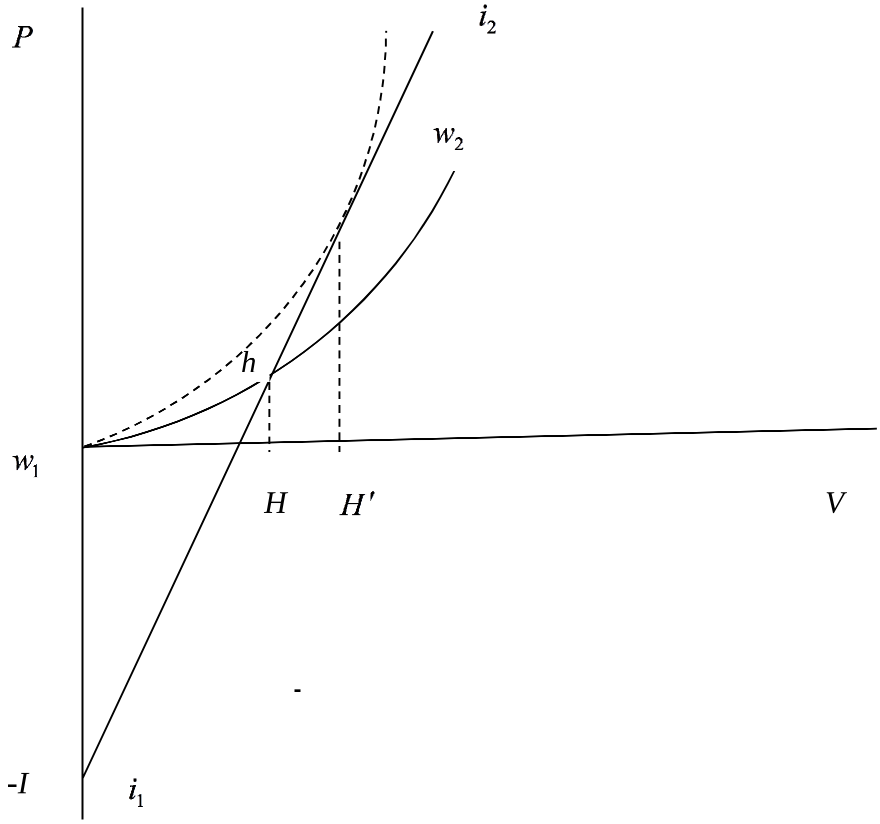

Figure 1: Optimal investment decision

Source: Dixit (1992)

After some calculus and algebra, the optimal investment trigger chosen by the farmer is given as:

$H = (\beta/(\beta - 1))\rho I$ …………………… (5)

where

$\beta = 0.5(1 + \sqrt{(1 + (8\rho/\sigma_a))}$ ………….. (6)

The optimal investment trigger can be expressed in a manner similar to the Marshallian trigger in equation (4) as: $H = \rho^r I$

where

$\rho^r = (\beta/(\beta - 1))\rho$ …………….……….. (7)

is the discount rate adjusted for the value of waiting. It is also known as the hurdle rate.

A discount rate of 0.135, which was the Government of Tanzania risk-free interest rate on treasury bonds issued on December 7, 2016 (Bank of Tanzania, 2016) is applied to the model. Other data used to implement the model are obtained from the cash flow model. We examine the sensitivity of the hurdle rate and optimal investment trigger to changes in volatility and discount rate.

4. Results and discussion

Impact of risk on cash flows

Average cash flows and their standard deviations are calculated for each month and are noncumulative across months (table 2). Positive cash flows are obtained for all producers in each month except for youths in the informal value chain who obtain negative cash flows in the wet seasons. This is because they tend to increase the amount of concentrate feed in the wet seasons, yet unlike the other categories of producers, they receive a lower price for their milk in the wet seasons. The rationale for giving cows more concentrates in the wet seasons is that apparently, animals drink less water in the wet seasons and therefore more concentrates are needed to induce the animals to drink more water. This does not seem to be economically feasible.

Cash flows in the formal value chain are higher than those in the informal chain except for male milk producers in the dry seasons. Overall, youths in the formal value chain have the largest cash flows in both seasons, and whereas female formal value chain producers have slightly higher cash flows than their male counterparts in the dry seasons, the latter have considerably larger cash flows than the former in the wet seasons. In the informal value chain, youths have significantly higher cash flows than male and female producers in the dry season, but have negative cash flows in the wet season. Cash flows for male and female informal chain producers are comparable. Therefore regarding liquidity, the key finding that could be of concern is that youths in the informal chain do not feasibly produce milk during the wet seasons. However, their cash flows in the dry seasons seem to be large enough to offset the negative cash flows in the wet seasons.

Table 2 here

Next is a quantification of the impact of risk on the cash flows of milk producers. This is done by calculating the 20% CFaR values and the probability of obtaining net cash flows that are less than their seasonal averages (table 3). CFaR values at 20% are a realistic measure that indicates likely losses to the enterprise for one in five chances. At the 20% level, losses are observed only for youths in the informal value chain during the wet seasons; there is one chance in five that a loss of $4.37 or more will occur. The probabilities of cash flows falling below their seasonal averages do not vary much across the different producer categories and seasons. For instance, in the informal value chain, the probability of youths' cash flows being less than their seasonal average is about 45% for both seasons and is nearly the same for male producers in both seasons and for female producers in the wet seasons. In the dry season, the probability increases to about 51% for women. In the formal value chain, the probabilities are slightly higher but quite invariant across seasons; about 51% for youths and female producers, and 56% for male producers. The probability of cash flows falling below their seasonal average suggests insignificant seasonal variation in risk for each producer category and among producer categories in each value chain. In fact an examination of the risk variables with the largest effect on cash flows reveals that for four of the six producer categories, the same risk variable has the largest impact on cash flows in both seasons (table 4).

Table 3. CFaR values by gender, value chain and season

	CF at 20%		**Prob CF < seasonal average**	
	Dry season ($)	Wet season ($)	Dry season	Wet season
FI	5.03	7.55	50.5%	44.5%
FF	5.66	14.15	50.5%	50.5%
MI	5.57	6.40	44.2%	44.6%
MF	4.61	20.06	55.7%	55.3%
YI	13.20	-4.37	44.9%	44.6%
YF	19.81	22.64	50.5%	50.5%

Holding other factors constant, fluctuation in quantity of concentrate feed given to the animal accounts for the largest variation in cash flows of youths in the informal value chain (table 4). Availability of concentrate feed varies seasonally because most of it is locally produced from maize. Supplies are low during the wet season when the maize crop is still in farmers' fields and they are high in the dry season after harvest. However, young milk producers opt to feed animals with more concentrates in the wet season, a practice that can be avoided. As such, they expose themselves to greater risk. This is a typical case of external risk being compounded by a producer's internal risk factors, which in this case is the producer's husbandry practices.

For youths in the formal value chain, death loss is the greatest risk factor. Likewise, death loss is the greatest risk factor for women in the formal value chain, and for those in the informal value chain, it features prominently in the dry seasons. The finding that death loss is a major risk for women and the youths can be explained by the finding of Swai *et al*. (2010); cattle mortality is lower among farmers that receive training in animal husbandry than among those that do not. Data collected by the authors from a recent survey in the study area shows that a smaller proportion of women and the youths have received training on dairy husbandry than men.

Fluctuation in average daily yield is important for men and women in the informal chain. Msangi *et al*. (2005) find variation in milk yield to be a function of body condition at calving, which is in turn a function of use of hired labour. Although none of the producer categories used hired labour, it is reasonable to expect labour to be a constraint for older farmers who are likely to be involved in off-farm livelihood activities and/or are less energetic than the youths. Fluctuation in feed prices and quantity are important for men in the formal chain. Interestingly, fluctuation in milk prices is not a major source of risk for any of the producer categories. Overall, these results point to the need to tailor risk mitigation measures to individual categories of producers to reflect the specific sources of important risks they face.

Table 4. Risk variables with the largest effect on cash flows

	Wet season	**Dry season**
FI	ADY (6.80 – 9.23)	Death loss (5.02 – 5.09)
FF	Death loss (14.12 – 14.24)	Death loss (5.65 – 5.70)
MI	ADY (5.19 – 9.10)	ADY (5.35 – 6.06)
MF	Feed price (19.75 – 21.01)	Feed quantity (4.26 – 5.83)
YI	Feed quantity (-8.17 – 4.40)	Feed quantity (12.08 – 16.89)
YF	Death loss (22.60 – 22.79)	Death loss (19.77 – 19.94)

Figures in parenthesis are ranges of cash flows in USD

In order to obtain a better comprehension of the magnitude of risk faced by the different gender categories, a consolidated measure of risk that accounts for all the risks faced by each category of producers is calculated (table 5). The measure is based on returns to milk production and is calculated on an annual basis. Youths in the informal value chain are found to face the highest annual volatility of returns to milk production of 35.14% compared to only 1.60% obtained for their counterparts in the formal value chain. Men in the formal value chain experience the second highest level of volatility of 10.02% followed by men in the informal value chain (7.90%). Contrary to what was expected a priori, female milk producers in either value chain face relatively low levels of risk. This could be attributed to women generally having more experience in milk production than men and youths as mentioned earlier.

Table 5: Annual volatility of returns to milk production

	Formal value chain (%)	Informal value chain (%)
Youths	1.60	35.15
Men	10.02	7.90
Women	1.60	4.03
Combined	**4.41**	**15.69**

We now depart from gender disaggregation in order to focus on the value chains as a whole and compute values of parameters necessary for evaluating the effect of uncertainty on investment. Combining all producer categories in each value chain, we find greater risk in the informal value chain than in the formal one, with annual volatilities of 15.69% and 4.41%, respectively. That milk production in the formal value chain is significantly less risky than production in the informal chain is to be expected. Since the mid-1970s when the Government of Tanzania started supporting commercialization of smallholder dairying, emphasis has been on the formal value chain[6]. In the study area in particular, farmers operating in the formal value chain are relatively well-linked to input and output markets and extension services, and have benefited from donor-supported dairy development programs courtesy of their membership in primary dairy cooperatives. Several of these cooperatives constitute the Tanga Dairies Cooperative Union, a secondary cooperative that

[6] However, Quaedackers *et al*. (2009) contend that government support for the development of the formal value chain has been less than sufficient.

owns Tanga Fresh Ltd., the largest dairy processor in the country. Through the company's projects such as the Modern Dairy Services Network, producers have gained access to risk mitigating services and technologies including information, better dairy breeds, milk collection centers, and credit.

The preceding analysis has provided values of parameters (table 6), except the risk-free discount rate, that are relevant to analyzing the effect of uncertainty and irreversibility on the decision to invest in milk production. The cost of investing in the formal value chain is about a half of the cost of investing in the informal value chain. This is because of the relative ease with which a prospective formal value chain producer is able to access the necessary support from the organizational infrastructure that already exists in the value chain. Moreover, the country's milk processing capacity utilization is only 26% of total installed capacity mainly because of supply-side constraints. As such, milk processors are supportive of smallholder farmers willing to enter the formal value chain.

Table 6. Data on parameters used in the real options model

	Formal value chain	Informal value chain
Volatility of returns (%)	4.41	15.69
Risk-free discount rate	0.135	0.135
Beta	1.06	1.02
Investment cost ($/litre)	0.13	0.27

However, the analysis undertaken thus far raises a fundamental question: if milk production in the formal value chain is relatively less risky and investing in the value chain is less costly than investing in the informal value chain, why does the majority of smallholder farmers operate in the informal value chain, supplying 97% of the milk consumed in the country? The answer to this question can best be provided by an analysis of producers' risk preferences. Such an analysis, however, is beyond the scope of this study. But disregarding risk preferences, a probable answer lies in the importance that farmers attach to high milk prices given the low-input low-output nature of smallholder milk production. Milk prices received by producers in the informal value chain are higher than (sometimes twice as high as) prices in the formal value chain. And indeed, Rao *et al*. (2016) have found that most smallholder milk producers prefer marketing arrangements that offer the highest milk price possible to those that do not, even though the latter might have other economically beneficial attributes.

Effect of uncertainty on the investment decision

The real options model yields hurdle rates that are substantially larger than the conventional discount rate (table 7). The resulting optimal investment triggers of $0.33 and $2.15 per litre of milk for the formal and informal value chains, respectively, are much larger than the Marshallian investment triggers. Therefore owing to the uncertainty that currently exists in the dairy industry, the option to wait to invest in milk production is of value. For the formal value chain, the current price of milk of $0.23 per litre (table 1) has to increase by $0.10 before waiting to invest ceases to be optimal. This, however, is much less than the increase in price that is needed to make investment in the informal value chain optimal. The current farm gate price of milk in the informal value chain, averaged across the three producer categories, is $0.38 per litre. It would have to increase nearly six-fold to make investing in the informal value chain optimal.

Notice that if a prospective milk producer is to disregard uncertainty and go by the Marshallian criterion, they should invest immediately since current farm gate prices in both value chains are way greater than the Marshallian triggers. But anecdotal evidence indicates farmers are reluctant to adhere to the Marshallian criterion. This study was undertaken in Tanga region where the authors were involved in implementing a research-for-development project that supported greater investment in milk production. In the course of project implementation, farmers consistently argued that the milk prices they receive are low and discourage further investment in milk production. These results suggest that the farmers are right and are perhaps aware of the risks and uncertainty they face.

Table 7. Hurdle rates, optimal and Marshallian investment triggers

	Formal value chain	Informal value chain
Hurdle rate	2.47	8.11
Optimal investment trigger ($/litre)	0.33	2.15
Marshallian investment trigger ($/litre)	0.02	0.04

Sensitivity analysis

Sensitivity of the hurdle rate and optimal investment trigger are examined by increasing and decreasing the discount rate and volatility of returns each by 10%. Generally, the hurdle rate and optimal investment trigger are not sensitive to changes in the risk-free discount rate (table 8). For instance, a 10% increase in the discount rate, holding other factors constant, does not increase the optimal trigger for the formal value chain, and only does so by a mere 0.5% for the informal value chain. However, the two parameters do respond to changes in volatility by nearly the same degree; for instance, a 10% increase in volatility, holding other factors constant, causes a 9.1% and 9.8% increase in the optimal investment trigger for the formal and informal value chains, respectively. Similarly, reduction in volatility by 10% lead to almost proportional reduction in optimal investment triggers.

Table 8. Hurdle rates and optimal triggers for different discount rates and volatility levels

	Formal value chain	Informal value chain
Discount rate		
0.149	\$0.33 (2.50)	\$2.16 (8.14)
0.122	\$0.32 (2.44)	\$2.15 (8.09)
Volatility (formal value chain)		
4.85%	\$0.36 (2.69)	
3.97%	\$0.30 (2.25)	
Volatility (informal value chain)		
17.26%		\$2.36 (8.90)
14.12%		\$1.95 (7.33)

Figures in parentheses are hurdle rates

5. Summary and concluding remarks

The study has found that youths in the informal dairy value chain face the greatest level of risk followed by men in the formal value chain, and then men in the informal value chain. Women in both value chains as well as youths in the formal value chain face considerably low levels of risk. Overall, milk production in the informal value chain is found to be substantially more risky with an annual volatility of returns of 15.69% than production in the formal chain whose annual volatility is only 4.41%. Regarding the effect of uncertainty on the decision to invest in milk production, the study finds optimal investment triggers of \$0.33 per litre of milk for the formal value chain and $2.15 for the informal value chains. These triggers are much larger than the Marshallian investment triggers and are sensitive to volatility levels but not to the risk-free discount rate.

The study's findings have policy and practical implications for inclusive dairy industry development. Promoting dairy development requires government policy to recognize that risk and uncertainty negatively impact milk production. Moreover, impacts vary by gender of producers and type of value chain they operate in. Therefore assuming that smallholder farmers are risk averse, practical considerations for risk mitigation include: strengthening the capacity of youths in the informal value chain to undertake proper animal husbandry practices, use of body condition scoring as a herd management tool for men in the informal value chain, and strengthening linkages between input suppliers and men in the formal value chain through, for instance, the use of input supply contracts. Also, lenders should take into consideration the different levels of risk exposure when determining risk premiums and interest rates.

To encourage investment in milk production, public investments should aim to reduce uncertainty in the informal value chain. However, this is not easy. From a strategic management perspective, it would be imperative for existing and potential milk producers to exercise flexibility in decision making so as to adapt to the uncertain environment. But flexibility requires market information and knowledge of the implications of alternative production decisions. Therefore smallholder milk producers should be supported to strengthen their linkages with other value chain agents to enhance their access to market information and to build capacity in enterprise management.

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Table 2. Cash flows of dairy enterprises by gender and type of value chain

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FI												
CF ($)	5.05	5.05	8.24	8.24	8.24	5.05	5.05	5.05	5.05	8.24	8.24	8.24
	(0.02)	(0.02)	(0.75)	(0.75)	(0.75)	(0.02)	(0.02)	(0.02)	(0.02)	(0.75)	(0.75)	(0.75)
FF												
CF ($)	5.67	5.67	14.18	14.18	14.18	5.67	5.67	5.67	5.67	14.18	14.18	14.18
	(0.01)	(0.01)	(0.03)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.03)	(0.03)
MI												
CF ($)	5.78	5.78	7.52	7.52	7.52	5.78	5.78	5.78	5.78	7.52	7.52	7.52
	(0.22)	(0.22)	(1.22)	(1.22)	(1.22)	(0.22)	(0.22)	(0.22)	(0.22)	(1.22)	(1.22)	(1.22)
MF												
CF ($)	4.89	4.89	20.26	20.26	20.26	4.89	4.89	4.89	4.89	20.26	20.26	20.26
	(0.49)	(0.49)	(0.40)	(0.40)	(0.40)	(0.49)	(0.49)	(0.49)	(0.49)	(0.40)	(0.40)	(0.40)
YI												
CF ($)	15.03	15.03	-0.63	-0.63	-0.63	15.03	15.03	15.03	15.03	-0.63	-0.63	-0.63
	(2.20)	(2.20)	(4.25)	(4.25)	(4.25)	(2.20)	(2.20)	(2.20)	(2.20)	(4.25)	(4.25)	(4.25)
YF												
CF ($)	19.85	19.85	22.69	22.69	22.69	19.85	19.85	19.85	19.85	22.69	22.69	22.69
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)

Figures in parentheses are standard deviations