Farm-Level and Consumption Responses to Improved Efficiency of Tanzania's Informal Dairy Value Chain

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ABSTRACT

The study uses a partial equilibrium model to determine the benefits that would accrue to smallholder dairy producers and consumers from improved efficiency of Tanzania's informal dairy value chain. Two sources of technical efficiency are analyzed, namely, cost efficiency and scale efficiency. Using aggregate time series data to simulate the model, the study finds that improvement in scale efficiency offers relatively large benefits to both producers and consumers. However, benefits from improvement in cost efficiency are relatively small and disproportionate. It is concluded that improving technical efficiency in general would lead to significant benefits for producers and consumers.

Key words: Tanzania's informal dairy value chain, smallholder farmers, partial equilibrium model

JEL Codes: Q11, Q13, Q18

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1. Introduction

Tanzania's dairy sector has in the last three decades been seen as one of the most important sectors in the country's efforts to alleviate poverty and food insecurity. Emphasis on the dairy sector as a vehicle for poverty reduction has been supported by Omamo et al. (2006); using a forward-looking multi-market model simulated up to 2015, they find milk to be the most important commodity in contributing to gross domestic product (GDP) and poverty reduction in east and central African countries including Tanzania. The Tanzanian dairy sector contributes roughly 30% to livestock GDP (NIRAS, 2010) and 1.53 % to overall GDP (Makoni et al. 2014).

Although milk supply has increased every year over the last ten years (National Bureau of Statistics 2010, 2014), it has not been able to match the ever increasing demand caused by growth in population and the economy at average rates of 3.3% and 7%, respectively (International Livestock Research Institute 2011). Under current circumstances, the mismatch between demand and supply is expected to continue into the foreseeable future. Projections by the International Livestock Research Institute (2011) indicate that given modest growths of 2% and 2.6% in GDP and population, respectively, and an income elasticity of 0.8, demand for milk would grow by more than 60% by 2020. At constant cattle productivity and observed herd growth rates, milk production is expected to increase by 41%, hence an annual milk deficit of 673 million litres, equivalent to 26% of quantity demanded. It is estimated that offsetting this deficit will require 4.5% growth in cattle productivity.

Considering that about 70% of total milk production comes from smallholder farmers[1], (Ministry of Livestock Development 2006), improving productivity of their cattle will be crucial

[1] Smallholder dairy farmers are defined as those owning between one to five cows (Njombe et al. 2012).

to alleviating the anticipated milk deficit. The livestock policy of 1983 shifted the government's focus from supporting the development of large-scale dairy farms to supporting smallholder dairy farmers (Kurwijila and Boki 2003), and the national livestock policy of 2006 has maintained emphasis on smallholder farmers, and this is partly because of the considerable potential of smallholder dairying to reduce poverty (Ministry of Livestock and Fisheries Development 2010). If smallholder dairy farmers were technically efficient, cattle productivity growth would be achieved through exploiting scale economies and/or technical change. However, smallholders are seldom able to easily increase the scale of their enterprises, and evidence indicates that they are inefficient producers. Kaliba (2004) finds milk yields of smallholder farmers in central Tanzania to be on average 30% below their production frontier. Using a normalized profit function, Omore et al. (2009) find profits of milk producers, hawkers and retailers to be 26%, 24% and 18% below their profit frontiers. Also, the authors are able to determine that remoteness of farmers and hawkers from major urban centres is a key contributor to their inefficiency. Swai and Karimuribo (2011) affirm the negative effect of remote location of dairy farmers on cattle productivity. Since the sources of inefficiency among smallholders are known to a certain extent, it follows then that one of the key issues in developing and promoting dairy industry policy is to understand the distributional implications of improving efficiency of the value chain in which majority of smallholder farmers operate. For instance, Holloway et al. (2000) caution that despite the expected growth in production and consumption of dairy products in sub-Saharan Africa, the additional income and employment accruing from this growth may not benefit resource-poor livestock farmers.

The purpose of this paper is to determine changes in milk supply, prices, and consumption that would result from increased efficiency of the informal dairy value chain[2]. The analysis is conducted for the informal rather than the formal value chain because majority of smallholder dairy farmers operate in the former, and it is through this value chain that about 97% of the milk produced in the country is marketed (MAFAP 2013). In particular, it would be instructive to know the extent to which efficiency gains would increase annual per capita milk consumption from the current 45 litres (Tanzania Dairy Board 2014) to the 200 litres recommended by the Food and Agriculture Organization (FAO). This analysis is critical because of the pro-poor dimension that has been embraced by the government and other stakeholders in developing the dairy sector.

A basic partial equilibrium model of Tanzania's informal dairy value chain is used to simulate production, price and consumption impacts from different scenarios depicting different sources and levels of improvement in the efficiency of the value chain. The model is simulated over a fourteen year period, which is long enough for the markets to adjust to each scenario. Results generally indicate that there would be marked improvement in producer and consumer welfare if the efficiency of the informal dairy value chain is improved.

2. Conceptual Framework

Efficiency in the production, processing and marketing of commodities has received a great deal of attention in the academic literature because of its welfare implications. In the realm of research for development where the concept of value chains has become a popular approach to achieving development and poverty reduction goals, realizing value chain efficiency is

[2] The informal value chain is one in which milk is produced and consumed in its liquid form without undergoing any form of processing.

imperative (Kaplinsky 2000). Efficiency can be decomposed into operational efficiency and pricing efficiency (Kohls 1956; Warrack 1972). Defined from the output perspective, operational (technical) efficiency is the quantity of output produced and/or marketed per unit of input relative to the maximum potential output from the input, while from the input perspective, it is the quantity of input for a unit of output relative to the minimum potential input (Coelli et al. 2005). Pricing efficiency is synonymous with allocative or exchange efficiency (Warrack). It is the degree to which inputs are allocated to their most valued use or the degree to which prices reflect all available information in the market. Maximum pricing efficiency may be relative if marginal rates of technical substitution are equal to input price ratios, implying that output is produced at minimum cost, and absolute if marginal value product for each input is equal to the input's price, implying cost minimization and production of optimal output quantity (Atkinson and Halvorsen 1980). Pricing efficiency may be measured across space, time and form (Vercammen and Schmitz 2001; Fackler and Goodwin 2001).

Generally, bad weather and farming practices (Førsund, Lovell and Schmidt 1980), remoteness from markets and lack of access to credit may cause inefficiency by constraining farmers' ability to optimally exploit existing inputs (Bagamba, Ruben and Rufino 2007). Therefore conceptually, an improvement in efficiency of the informal dairy value chain is expected to increase factor productivity, hence milk output. The subsequent chain of events is illustrated by the stylized schematic shown in figure 1. Initial equilibrium quantity and farm and retail prices are Q^0, P_f^0 and P_r^0. Assuming the usual regularity conditions, and if improvement in productivity causes the same reduction in average costs for both marginal and infra-marginal farmers, a parallel rightward shift in the farm supply curve (S_f^0 to S_f^1) ensues (Lindner and Jarret 1978). Moreover, assuming a parallel shift enables us to dispense with making assumptions about functional form as linear demand and supply functions would suffice (Kristjanson et al. 1999; Alston et al. 2004). The resulting shift in retail supply (S_r^0 to S_r^1) leads to new equilibrium quantity Q^1 and prices P_f^1 and P_r^1. Distributional impacts can then be determined by calculating, using geometry, changes in producer and consumer surplus, whose magnitudes will depend on the various elasticities of supply and demand.

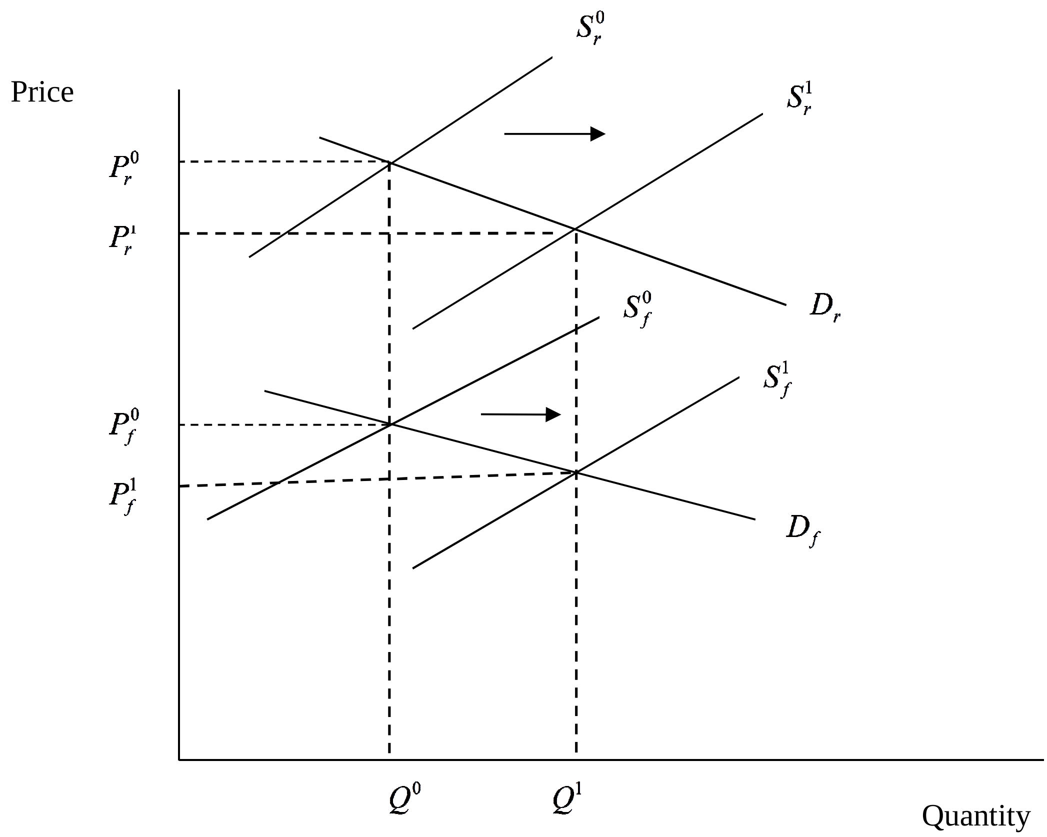

Figure 1: Effects of an improvement in efficiency on milk producers and consumers

3. Empirical Model and Data

For the most part, the informal dairy value chain comprises of farmers, milk traders (hawkers and retailers), and consumers. Farmers sell their milk directly to consumers in their neighborhood and/or to milk traders that sell to consumers in village trading centres, peri-urban and urban areas. Therefore we use a small multi-market partial equilibrium model that encapsulates and links demand and supply behavior at and between the farm and retail levels of the value chain. Because of the unavailability of aggregate data on many of the variables that would be needed to adequately estimate the relevant behavioral equations, we eschew an econometric partial equilibrium model. Instead, we implement a synthetic model; one that uses existing parameters to reproduce baseline values of endogenous variables. We assume perfect competition in factor and output markets at the two market levels, which implies that the markets are price efficient. Also, we assume autarky given the country's insignificant trade in fluid milk.

The model consists of seven linear structural equations solving for seven endogenous variables. It has three considerably parsimonious behavioral equations, as well as two accounting and two market clearing identities that are used to close it. Farm supply response for milk is a dynamic equation with the lagged dependent variable capturing producers' adaptive expectations:

$$S_t^f = \beta_0 + \beta_1 P_t^f + \beta_2 P_{c,t} + \beta_3 H_t + \beta_4 S_{t-1}^f \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In a given time period t, farm supply of milk, S_t^f, is a function of the real farm price of milk, P_t^f, real cow price, $P_{c,t}$, herd size, H_t, and a lagged dependent variable with β_4 being the coefficient of adjustment that can be obtained from the short- and long-run price elasticities of supply. Milk traders' derived demand for milk is basically an unconditional input demand function that can be derived from their profit function. It can be expressed as:

$$D_t^f = \alpha_0 + \alpha_1 P_t^f + \alpha_2 P_t^r \text{ .... } (2)$$

where P_t^r is the real retail price of milk. The farm market clearing identity is such that:

$$D_t^f = S_t^f \text{ .... } (3)$$

Retail supply of milk, S_t^r, is also a derived function but one that can be expressed as an identity that shows retail supply to be a proportion of the quantity of milk demanded from the farm. That is,

$$S_t^r = \kappa \cdot D_t^f \text{ .... } (4)$$

There are prices embedded in identity (4), and the proportionality constant, κ, accounts for losses due to spillage as well as milk rejected by retailers because of spoilage caused by adulteration and high bacterial count. Per capita retail demand, PCD_t, is a function of the real retail price of milk and real per capita income, Y_t:

$$PCD_t = \delta_0 + \delta_1 P_t^r + \delta_2 Y_t \text{ .... } (5)$$

Other variables thought to influence demand such as prices of substitutes and socioeconomic factors are assumed constant and hence captured by the intercept. An accounting identity is used to aggregate per capita demand for milk to market demand, D_t^r:

$$D_t^r = PCD_t \cdot POPN_t \text{ .... } (6)$$

where the mnemonic $POPN_t$ denotes size of the population. We then have the following retail market clearing condition:

$$D_t^r = S_t^r \text{ .... } (7)$$

Analyzing the impacts of efficiency is undertaken against a historical baseline. The model is calibrated to annual data for the period 2000 to 2014, but the presence of a lagged independent variable in the farm supply equation means that the year 2000 is dropped from the simulations. Calibration is done by calculating, for all behavioral equations, linear slope coefficients from elasticities using the elasticity formula, and then each year's intercept. Intercepts are calculated as the dependent variable less the sum of the product of the slope coefficients and the respective independent variables. By calculating intercepts for each year, we ensure that the model is perfectly calibrated. That is, it exactly reproduces the baseline data.

Baseline data on milk production, milk retail prices, real GDP at market prices, population, and herd size and herd growth rate were obtained from the National Bureau of Statistics (NBS). Farm supply of milk to the informal value chain was calculated as total production less the three percent of it that goes to the formal value chain. A proportionality constant of 0.9 was used to calculate an estimate of retail supply quantity[3]. Milk producer prices were calculated using the consumer price index provided by FAO starting with a producer price of $ 0.4 (USD)[4] per litre in 2000 (International Livestock Research Institute 2011). Data on cow prices for live animals were available only for 2014 from the Livestock Information Network Knowledge System (LINKS). The 2014 price per live weight was calculated by dividing the average price for a Grade 2 (forward store condition) animal by 219 kg, the average weight of a cow at the Pugu livestock auction in Dar es Salaam (Muthee 1996). The entire series was then constructed using the producer price index provided by FAO. Summary statistics of the model's variables for the period 2000 to 2014 are presented in table 1 and the elasticities used to calibrate the model are

[3] According to Lore, Omore and Staal (2005), post-harvest losses at farm level are estimated to be 6.5% of quantity produced, while at the retail level, of the total quantity procured, about 0.7% is lost as a result of spillage and 0.62% is lost to spoilage. We assume maximum total losses of about 10% along the entire value chain.
[4] This is equivalent to TSh 320.36 at the 2000 average exchange rate of 1 USD = 800.904 (Bank of Tanzania 2014).

provided in table 2. The coefficient of adjustment in equation (1) is calculated from the short-run (SR) and long-run (LR) price elasticities of farm supply as $\beta_4 = (LR - SR)/LR$.

Table 1: Variable definitions and summary statistics, 2000 - 2014

Label	Definition	Unit	Mean	Std. dev
S_t^f	Farm supply of milk[a]	Litres	1,383,879,999	384,972,934.30
D_t^f	Farm demand for milk[a]	Litres	1,383,879,999	384,972,934.30
P_t^f	Farm price of milk[b]	TSh/litre	359.93	25.25
P_t^r	Retail price of milk[a]	TSh/litre	775	378.26
$P_{c,t}$	Price of cows[c,b]	TSh/lwt	1,064.35	216.52
H_t	Herd size[a]	Head	21,348,425.24	3,997,470.28
S_t^r	Retail supply of milk[a]	Litres	1,245,491,999	346,475,640.90
D_t^r	Retail demand for milk[a]	Litres	1,245,491,999	346,475,640.90
PCD_t	Per capita demand for milk[a]	Litres	31.61	5.36
Y_t	Per capita income[a]	TSh	360,745.78	62,063.03
$POPN_t$	Population[a]		38,693,555	4,662,883
CPI_t	Consumer price index[b]		137.05	30.97
PPI_t	Producer price index[b]		131.63	26.78

TSh refers to Tanzania Shillings and lwt refers to live weight.
Sources:
[a] National Bureau of Statistics
[b] FAO Data Base
[c] LINKS Data Base

Table 2: Elasticities and their sources

Elasticity	Estimate	Source
Consumer demand for milk w.r.t. retail price	-0.65	Chongela, Nandala and Korabandi (2014)
Consumer demand for milk w.r.t. income	0.70	Chongela, Nandala and Korabandi (2014)
Retailer demand for milk w.r.t. farm price	-3.56	Estimated
Retailer demand for milk w.r.t. retail price	0.56	Estimated[d] ; $R^2 = 0.86$
Farm supply of milk w.r.t. farm price	0.60 [SR]	Rodriguez (1987)
Farm supply of milk w.r.t. farm price	1.00 [LR]	Kristjanson et al. (1999)
Farm supply of milk w.r.t. cow price	-0.46	Estimated[d] ; $R^2 = 0.30$
Farm supply of milk w.r.t. herd size	1.54	Estimated[d] ; $R^2 = 0.95$
	Other	
Price transmission	5.50	Estimated

[d] *Estimated using a simple bivariate regression*

Retailers' derived demand elasticity with respect to farm price is the product of the elasticity of price transmission and price elasticity of consumer demand (Marsh 1991; Wohlgenant 2001). In estimating the elasticity of price transmission, symmetric and linear price transmission is assumed, and the following log-linear specification implies a constant relative rather than constant absolute margin (Meyer and von Cramon-Taubadel 2004):

$$\ln P_t^r = \mu_0 + \mu_1 \ln P_t^f + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

We obtain a derived demand elasticity that is greater (in absolute terms) than the farm price elasticity of farm supply, implying that a reduction in farm price is likely to increase traders' demand for milk more than it would reduce farm supply. This is highly plausible because of the multiple functions of cattle among smallholder livestock keepers.

4. Model Simulation and Assumptions

To determine the impact of improvement in the efficiency of Tanzania's informal dairy value chain, we consider two components of technical efficiency, namely, cost efficiency and scale efficiency. Cost efficiency concerns the level of input and transaction costs associated with cost minimizing input levels relative to the cost of observed input levels. Holloway et al. (2000) note that the (high) cost of animals and high transaction costs are major barriers to smallholder participation in dairy production in sub-Saharan Africa. Assuming downward sloping input demand functions, cost efficiency can be improved by lowering the price of inputs. In this analysis, we simulate the impact of lower input prices by a hypothesized 10% reduction in cow prices.

Scale efficiency is the degree to which value chain agents are operating at optimal scale. Assuming that smallholder dairy farmers and small milk retailers are operating in the increasing returns to scale (IRS) part of their production functions, improving scale efficiency can be achieved by increasing the size of their operations[5], while maintaining the same mix of inputs. In a multiple-input production technology, improving scale efficiency requires increasing the levels of one or more inputs. In this study, we consider an increase in herd size, recognizing that the government of Tanzania is specifically targeting increasing the inventory of improved dairy cattle. Indigenous cattle make up 96.2% of the total herd and the remaining 3.8% is improved beef and dairy breeds (National Bureau of Statistics and Office of Chief Government Statistician of Zanzibar 2012). From 2010 to 2013, the government's target was to increase the number of improved dairy cattle by about 63% from 605,000 to 985,000 (Ministry of Livestock and Fisheries Development 2010), which would result in an improved dairy herd that is 3.5% of the current total herd. Given the average annual total herd growth rate of 4%, we simulate a 10% increase in herd size. In addition, the impact of other factors that may increase scale efficiency but are not included in the farm supply equation is simulated by increasing the intercept of the farm supply equation by 10%. These factors may include grazing land, labour, fodder production, and weather.

The impacts of simultaneous improvement in both cost and scale efficiency are determined by simulating the above scenarios concurrently. This is because most interventions in smallholder value chains have tended to target more than one component of value chain efficiency, and as such, it would be illuminating to understand the impact of improvement in technical efficiency in general. Also, this analysis enables us to weigh the relative importance of the different sources of efficiency. Assuming an indirect utility function of the Gorman polar form, change in consumer surplus (CS) is calculated for each scenario as a measure of the

[5] For a large enterprise, scale efficiency can be increased by reducing the size of the enterprise only if it is operating in the decreasing returns to scale (DRS) part of its production function.

welfare change for consumers. For producers, however, we calculate changes in revenue as a rough measure of change in their welfare.

5. Results

The average impacts of improvements in efficiency are presented in tables 3 and 4 as absolute and percentage changes in endogenous variables from their base[6]. That is, in each scenario, impacts are determined by comparing values of the endogenous variables after the simulation with the simulated values for the base period. Table 3 shows the results of three independent simulations of a reduction in cow price, increase in herd size, and increase in the intercept of the milk supply response equation. Increase in herd size yields the largest impacts, closely followed by changes in factors other than herd size and cow price. Reduction in cow price has considerably small impacts on the smallholder dairy value chain. Figures 1, 2 and 3 show baseline milk supply, real retail and farm prices juxtaposed to their simulated values.

Table 3: Impacts of independent changes in cow price, herd size, and other factors

	Cow price (scenario 1)		Herd size (scenario 2)		Other factors (scenario 3)	
	Unit Δ	% Δ	Unit Δ	% Δ	Unit Δ	% Δ
Farm supply (l)	54,453,642.86	4.05	200,703,571.43	13.06	188,235,357.14	12.39
Farm price (TSh/l)	-0.06	2.15	-0.18	-7.08	-0.17	-6.70
Retail supply (l)	49,007,357.14	4.05	180,631,857.14	13.06	169,410,785.71	12.39
Retail price (TSh/l)	-0.35	-7.14	-1.23	-21.99	-1.16	-21.02
PC demand (l/yr)	1.26	4.05	4.40	13.06	4.15	12.39

Holding other factors constant, a 10% increase in herd size would, on average, increase farm supply of milk by 13.06%, which is equivalent to an increase of over 200 million litres of milk annually. This would cause a reduction in both the real farm and retail prices of milk by about 7% and 22%, respectively, leading to an increase in annual per capita (PC) consumption of about 4.4 litres (13.06%). If the increase in scale is to be undertaken by smallholders that keep

[6] Equilibrium conditions used in the model mean that changes in farm supply are equal to changes in traders' demand for milk.

improved dairy breeds, increasing milk production to the simulated quantity would require an increase in the herd size of improved cattle of about 109,137 cows[7].

Reduction in cow price by 10% leads to a 4.05% increase in farm supply and the subsequent changes in other endogenous variables across the two markets are less than 10%. The smallholder dairy value chain appears not to be very responsive to cow prices probably because the limited participation of smallholders in input markets has meant that their main source of replacement cattle is their own herds. Moreover, milk production by smallholders is just one of the several objectives for keeping cattle, and it is not clear to what extent it is undertaken for profit maximization. For instance, whereas Mlay (1985) omits the cost of cattle from his profitability analysis of smallholder dairying, Mlote et al. (2013) account for it in their profitability analysis of small-scale cattle fattening. Significant responses could be obtained by simulating the impact of a change in the cost of artificial insemination (AI) and veterinary services since these services are used by smallholders keeping either indigenous or improved dairy breeds. Unfortunately, time series data on the cost of these services are unavailable.

[7] Given that improved cows produce about 6 litres per day during the wet season over which they are milked for 179 days and 5 litres per day in the dry season for a period of 153 milking days (National Bureau of Statistics and Office of Chief Government Statistician of Zanzibar, 2012), their productivity is about 1,839 litres per year per cow.

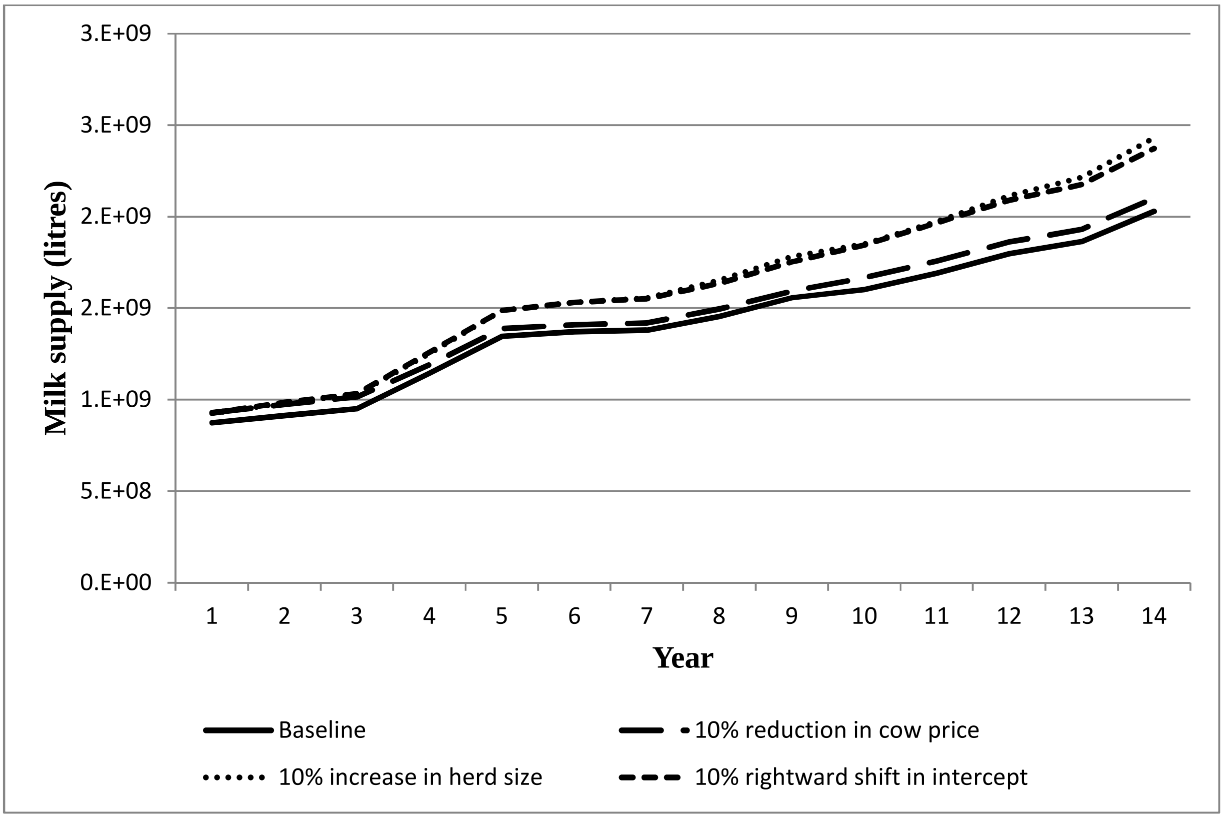

Figure 1: Baseline and simulated milk supply

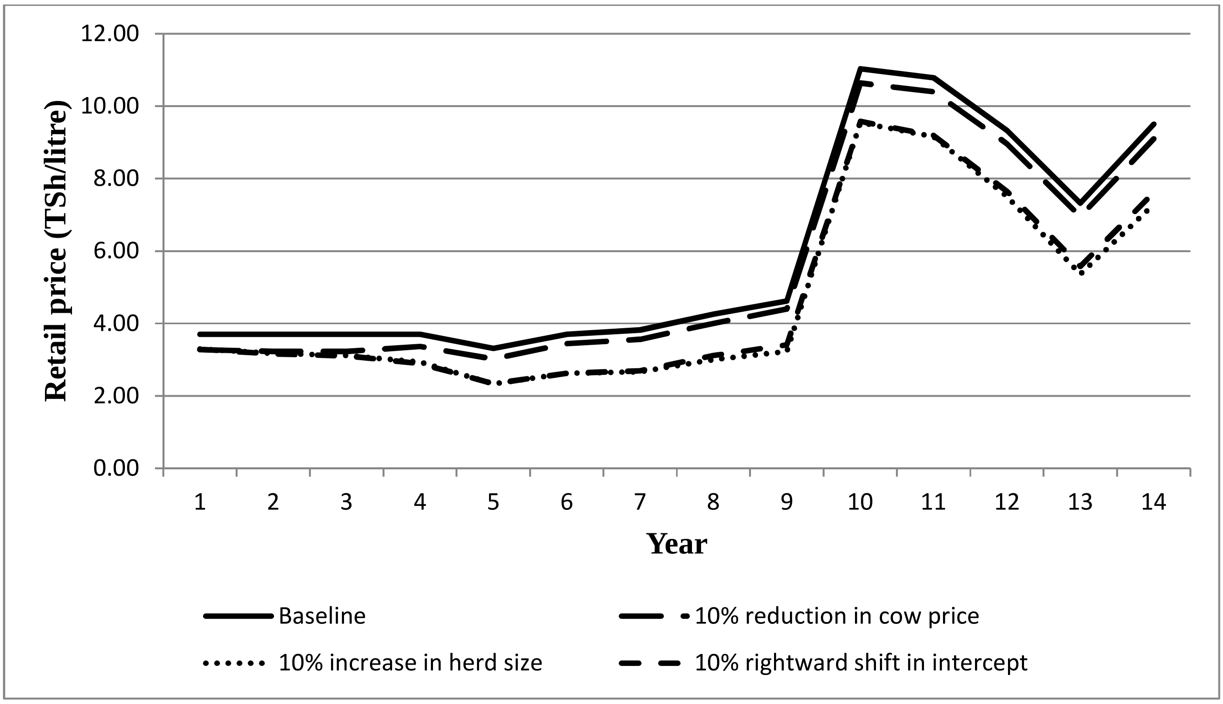

Figure 2: Baseline and simulated real retail price of milk

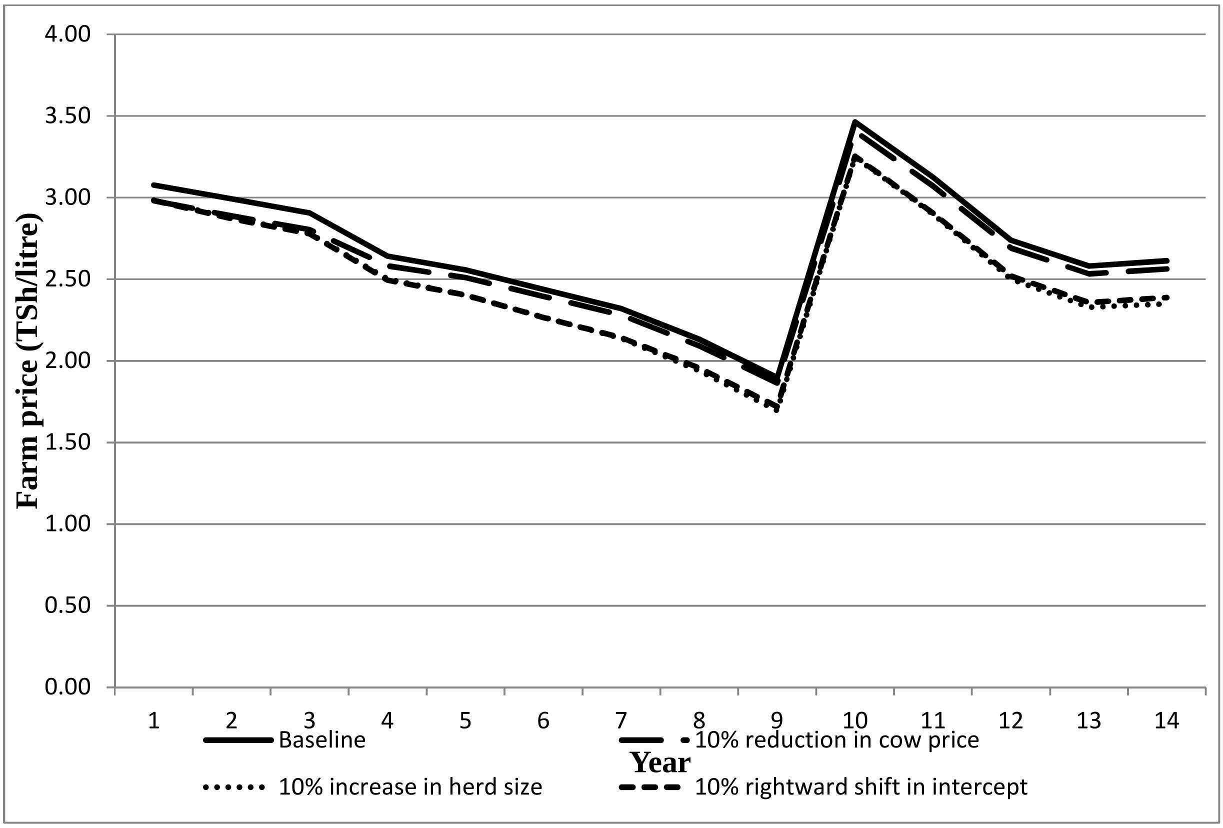

Figure 3: Baseline and simulated real farm price of milk

Table 4: Impacts of changes in all factors by 10% (scenario 4)

	Unit Δ	% Δ
Farm supply (l)	443,392,500	29.51
Farm price (TSh/l)	-0.42	-15.94
Retail supply (l)	399,054,000	29.51
Retail price (TSh/l)	-2.74	-50.15
PC demand (l/yr)	9.81	29.51

Results of the combined simulation in which each of the three exogenous factors is adjusted by 10% (table 4) indicate an increase in the retail supply of milk of about 400 million litres annually following a 30% increase in farm supply. The resulting 50% reduction in retail price increases per capita demand for milk by 30%, equivalent to an increase in per capita milk consumption of about 10 litres annually. Although it remains to be known to what extent the simulated increase in technical efficiency (of about 32%) would contribute to productivity growth, it appears that the resulting increase in milk production would go a long way in mitigating the annual milk deficit of 673 million litres predicted by the International Livestock Research Institute (2011).

To evaluate, at the farm level, the relative importance of each source of efficiency, we calculate the change in farm supply of milk for each individual source of efficiency as a percentage of the total increase in the farm supply of milk obtained from the combined simulation. We find that increase in herd size would contribute 45.27% to the increase in milk supply, while reduction in cow price would contribute 12.28%. Other factors would account for 42.45%. Considering the lack of information on the exact nature and magnitude of the other factors that may be pertinent to improving efficiency of the informal dairy value chain, it may well be worthwhile to appreciate the impact of a reduction in cow prices. After all, the combined impact of cow prices and herd size would be over 55%.

Next, we calculate changes in consumer surplus and producer revenues[8] that would accrue to each scenario. The results are summarized in table 5. On average, we obtain, in real terms, an increase of TSh 12 and TSh 42 per capita per year in consumer surplus from a 10% reduction in cow price and 10% increase in herd size, respectively. As expected, the largest increase in consumer surplus of about TSh 102 is obtained in scenario 4. Producer revenues would increase in real terms by TSh 68 million per year in scenario 1, TSh 211 million in scenario 2 and TSh 364 million[9] in scenario 4. These results provide unequivocal evidence of the substantial impact that improvement in the efficiency of Tanzania's informal dairy value chain would have on milk producers and consumers.

[8] Karagiannis and Furtan (2002) show that when supply is inelastic, regardless of the type of supply shift, there will be a loss in producer surplus if the sum of the absolute supply and demand elasticities is less than one.
[9] At the current exchange rate of 1 USD = TSh 1,679.97, this is equivalent to $216,758.54.

Table 5: Average changes in consumer surplus (CS) and producer revenue

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Change in CS	11.55	42.44	39.85	101.94
Change in revenue	68,361,114.29	211,093,992.86	202,582,428.57	364,147,842.86

Consumer surplus is measured in TSh per capita per year, while producer revenues are in TSh per year.

Generally, increasing herd size of smallholders would increase their returns to scale and size. This would be even more significant for smallholders who keep cattle breeds that yield relatively large quantities of milk. Therefore in a sense, the results of this study are particularly supportive of the government's policy that seeks to increase the inventory of dairy cattle breeds in the country. But they also highlight a point of caution: to the extent that a reduction in cow price and changes in other factors (such as reduction in transaction costs, improvement in dairy cattle husbandry and increased access to extension and other dairy business services) are crucial to improving the productivity of cattle, it will be imperative for the government and other industry stakeholders to support their realization if dairy cattle breeds are to achieve their genetic potential. This point is supported by the simulations in scenarios 3 and 4, from which we obtain relatively large impacts.

The findings in scenario 4 of proportionate gains in annual per capita consumption of milk and consumer surplus are particularly instructive in the context of the debate as to whether milk consumption in Tanzania should be promoted through either supply-side or demand-side strategies. In table 2, we see that consumer demand for milk is almost as relatively inelastic with respect to income as it is with respect to price. Moreover, to the best of our knowledge, there is no empirical evidence of the impact on the consumption of milk of programs such as the school milk feeding program (SMFP) that was started in 2002, the annual national milk promotion week, and the recently launched 'drink milk campaign'. There is hardly any advertising of milk in Tanzania probably because of its homogeneous nature. But even if there was, advertising would not necessarily generate additional consumer surplus (Goddard, Griffith and Quilkey 1992). Our findings suggest that addressing supply-side bottlenecks may be a viable strategy to significantly increasing per capita consumption of milk in Tanzania.

6. Summary and Conclusions

A lot of effort is being put into developing the smallholder informal dairy value chain in Tanzania based on its perceived potential to alleviate poverty and food insecurity. But the paucity of macro-level research on the dairy industry has meant little information is available for setting realistic targets for growing the value chain given existing resource and structural constraints. This paper contributes to filling this gap by examining *ex ante* the likely impacts of improving the efficiency of the informal dairy value chain, an aspect of the industry that is believed to be critical to enhancing its competitiveness and achieving the country's poverty reduction goals. To this end, the paper employs a simple partial equilibrium model to determine changes in milk supply, prices, demand, and producer and consumer welfare that would result from improvement in different sources of efficiency.

It has been found that improving scale efficiency would lead to greater gains in producer and consumer welfare than improving cost efficiency. Indeed, while the gains from the former are proportionate, those from the latter are disproportionate. Gains from improvement in efficiency in general are found to be fairly sizeable. But a caveat on our results is in order: prices of other inputs may capture cost efficiency better than cow prices. Also, this type of analysis is sensitive to the elasticities used in calibrating the model. Yet for some variables, elasticities specific to the Tanzanian context are unavailable. Therefore it may be helpful in future to re-run the simulations when more precise estimates of elasticities become available.

Two key policy implications emerge from the analysis. First, there is need to continue to focus on improving the genetic potential of cattle for dairy production. The government recognizes that its six livestock multiplication units (LMUs) and nine ranches of the National Ranching Company (NARCO) have not expanded the dairy herd at the desired rate. But even more important is that whereas the government estimates the demand for dairy heifers to be about 58,944 per annum (Ministry of Livestock and Fisheries Development, 2010), our analysis shows that this number is only slightly more than half of the number required to generate significant benefits for producers and consumers. Second, value chain interventions that lower the cost of inputs used by smallholder dairy farmers would complement gains from economies of scale. Such interventions may include collective action by smallholders in procuring inputs and improvement in rural infrastructure.

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