Analysis of milk production, butter marketing and household use of inputs in rural Ethiopia

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Abstract:

This paper uses two triple-hurdle models to analyse the determinants of Ethiopian rural households' decisions in (1) milk production, butter marketing and volume of butter sales; and (2) milk production, purchased input use and intensity of purchased input use. Results are based on data collected from 5000 households and 497 rural communities in the highlands of Ethiopia. Availability of feed stands out as an important factor influencing household decision to engage in milk production, indicating the dire need to develop feed resources to promote dairy production in rural Ethiopia. Milk production in rural Ethiopia seems to have an interesting and complex gender dimension. While female-headed households are less likely to be engaged in milk production, perhaps because of resource limitations, they are more likely to manage their dairy farms intensively. Marketing costs matter in dairy production and marketing in rural Ethiopia, suggesting for the need to develop market infrastructures for both dairy outputs and inputs. Our results further show that participation in butter markets as sellers or the amount of butter sales do not respond to price signals, suggesting the need to understand the behavioural aspect of dairy marketing decision in rural Ethiopia.

Acknowledgement:

JEL Codes: D01, D01

#959

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Key words: milk production, butter marketing, dairy input use, triple hurdle model, Ethiopia,

1. Introduction

Smallholder dairying holds significant potential benefit for the rural population as a source of income (Kidoido and Korir 2015), nutrients (FAO 2013), and employment opportunities (Kaitibie et al. 2010). The sector also provides opportunities to improve the livelihood options of women (Quisumbing 2013; Johnson et al. 2015) since in most developing countries milking, processing and marketing of milk and milk products are the responsibility of women. For example, a study in Uganda showed that women contributed about 70% of the labour for dairy production (Makoni et al. 2013).

Dairy plays an important role in the Ethiopian agricultural sector and the national economy (Tegegne et. al. 2013). It is a source of livelihoods for the majority of the rural population both in terms of income and employment. Recent estimates indicate that there are about 55 million cattle, with 55.4% female animals, and about 12 million cows in reasonably favourable environments for dairy production (Tegegne et al. 2013; CSA 2014; CSA 2016). The CSA survey further indicates that 2.8 billion litres of milk was produced in 2012/2013, with 42.3% used for household consumption.

Despite its potential, the Ethiopian dairy sector is characterized by a large gap between actual and potential contributions to national economy and the welfare of rural people (Yilma et al. 2011). This emanates from a number of interrelated issues including limited availability and low usage of improved dairy breeds and inputs (Duncan et al. 2013; Kumar et al. 2013; Makoni et al. 2013), low awareness of improved dairy management practices (Mekonnen et al. 2010) and weak market linkages (Duncan et al. 2013; Makoni et al. 2013). National estimate shows that average milk yield per cow per day for indigenous breeds stands at about 1.37 litres (Adane et al. 2015b). About 98.7% of the dairy cows in Ethiopia are local breeds which partly explains the low productivity of the sector.

Several studies have been conducted on dairy production and marketing in Ethiopia. To our knowledge, almost all of these studies focus on fluid milk marketing (Ahmed et al. 2004; Francesconi et al. 2010; Holloway et al. 2008; Kumar et al. 2013; Yigrem et al. 2008). However, the great majority of rural households involved in dairy production do not sell fluid milk. More than 75% of milk producers in rural Ethiopia sell butter (Gebremedhin et al. 2014). Tegegne et al. (2013) also argue that attention needs to be given to Ethiopian rural households' behaviour in butter production and marketing. Input use for dairy production has also received inadequate research attention.

The aim of this paper, therefore, is to analyse the determinants of Ethiopian rural households' decisions in milk production, input use and butter marketing, to better inform policy and practice to develop the Ethiopian rural dairy sector. The effects of transaction cost factors, household and farm characteristics, institutional and infrastructural services, and prices are analysed. Two triple hurdle models are used. The first triple hurdle model deals with household decisions to engage in milk production, butter marketing and volume of butter sold, while the second model deals with household decision to engage in milk production, input use and intensity of input use.

The paper is organized as follows. The next section presents the conceptual framework. Section three deals with our econometric modelling and estimation approach. Section four presents and discusses the econometric results. Section five concludes the paper and presents implications.

2. Conceptual framework

The underdeveloped nature of the Ethiopian dairy sector prompts several empirical questions related with feasibility, profitability, input supply and services, and market access conditions. Fuelled by rising demand due to population and income growth, urbanization and changing food habits, prices of milk and milk products in Ethiopia have been rising over the last two decades. However, supply never responded adequately to meet the rising demand.

The sluggish supply response cannot be explained based on price analysis only. A broader look at the various nodes in the dairy value chain is needed. This paper, therefore, tries to answer three important questions in the dairy value chain in rural Ethiopia: (1) What factors determine household decision to engage in milk production? (2) What factors constrain or promote household decisions to engage in butter marketing and the volume of butter sold? (3) What factors determine household decision to use modern dairy inputs and the intensity of use of those inputs?

Household and farm characteristics, transaction cost factors, community level variables, agro-ecological zones, and prices are hypothesized to influence household participation in milk production, butter marketing and the use of purchased dairy inputs. Hence, the triple-hurdle models are specified as functions of access to infrastructures, markets and services (tc), household characteristics (hc), farm characteristics (fc), asset endowment (ae), community level variables (cc), agro-ecological zones (az) and prices (p).

The following models are estimated.

milkprod = (tc, hc, fc, ae, cc, az, p) (1)

buttermrket = (tc, hc, fc, ae, cc, az, p) (2)

buttersuppl =(tc, hc, fc, ae, cc, az, p) (3)

inputmarkt = (tc, hc, fc, ae, cc, az, p) (4)

inputdemand = (tc, hc, fc, ae, cc, az, p) (5)

Where *milkprod* is a binary indicator of whether a household is involved in milk production, *buttermrkt* is a binary indicator of whether household is involved in selling butter, *buttersuppl* is the volume of butter sold, *inputmrkt* is a binary indicator of whether household used purchased inputs, and *inputdemand* is the monetary value of purchased inputs. Exclusion restrictions are possible, so not all explanatory variables may be included in each model (Burke et al. 2015).

The decision on volume of butter supply is preceded by two prior decisions of involvement in milk production, and the decision to engage in selling butter. Similarly, the household decision of how much purchased dairy input to use is also preceded by two prior decisions of involvement in milk production and the decision of whether to use purchased inputs. Hence, two triple-hurdle models are used to estimate the parameters of the determinants of these sequential decisions.

3. Empirical models and estimation

3.1 Empirical model

The triple-hurdle models are specified based on the hypotheses that milk production and participation in input (output) market are determined by household characteristics ((age of household head ($age_i, agesq_i$), sex of household head ($hhsex_i$), education of household head[1]

[1] Education of household head was classified into illiterate ($edu\_0_{i,}$), 1-4 years of schooling ($edu\_1_{i,}$), 5-8 years of schooling ($edu\_2_{i,}$), and above 8 years of schooling ($edu\_3_{i,}$). We used illiterate as a base of comparison in our regression models.

($edu_{i,}$), number of children of up to 5 years old ($childfive_i$)) and labour supply ($labsup_i$)); asset endowment (physical assets excluding small and large ruminants ($hasst_i$), and non-farm cash income ($cash_i$)); farm characteristics (land ($land_i$), lagged number of small ruminants ($lagnsr_i$), lagged number of crossbred cows ($lagncrcow_i$), amount of crop residue produced ($cropresdu_i$), total milk production ($totmilk_i$), total number of lactating cows ($nlactcow_i$) and proportion of crossbred lactating cows ($prcrslactcw_i$)); household access to infrastructure, services and markets (distance to town market ($disttwnm_i$), distance to district market ($distdsrtm_i$), distance to veterinary clinic ($distvc_i$), distance to livestock input market ($dislivinptc_i$), distance to DA post ($disdpost_i$), whether the household accessed credit ($crdt_i$), whether there is supplier of bran in the PA ($branseller_i$), whether there is supplier of compound feed in the PA ($cfeedseller_i$), and whether there is supplier of hay in the PA ($hayseller_i$)); community level variables (population density ($popdens_i$), availability of grazing land per tropical livestock unit (TLU) ($tglpltu_i$), wage rate for off-farm employment for both male ($wagemale_i$) and female ($wagefemale_i$)); agro-ecological zone of the community[2] ($azzone_i$)); shocks (occurrence of less than average rainfall ($rainshock_i$); and market prices ((lagged district price of small ruminants ($lagdsrpr_i$), lagged district price of butter ($lagdbuttpr_i$), relative price of maize with respect to butter ($pricemazbutr_i$) and relative price of teff with respect to butter ($priceteffbutr_i$)). We used zonal dummies[3] ($zone1_i$ through $zone9_i$) to control for any zone specific unobserved effects. Since specifications may vary by model and exclusion restrictions are possible, not all variables are included in each model.

The specifications of the two triple-hurdle models are given in equations 6 – 10. The specification for milk production ($milkprod_i$) equation is given by equation 6.

$$milkprod_i = f(age_i, agesq_i, hhsex_i, childfive_i, labsup_i, edu\_1_i, edu\_2_i, edu\_3_i, land_i, hasst_i, cash_i, lagnsr_i, lagncrcow_i, cropresdu_i, disttwnm_i, distdsrtm_i, disdpost_i, distvc_i, crdt_i, popdens_i, tglpltu_i, azzone\_d_i, azzone\_w_i, wagemale_i, wagefemale_i, lagdsrpr_i, lagdbuttpr_i, rainshock_i, zone1_i - zone9_i, u_{1i}) \quad (6)$$

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[2] We categorized the ten agro-ecological zones we used for sampling purposes into three broad agro-ecological zones: below 1500 masl ($azzone\_k_i$), above 1500 but below 2300 masl ($azzone\_w_i$), and above 2300 masl ($azzone\_d_i$). We used the lower altitude agro-ecology as a base of comparison in our regression models.

[3] We used Eastern Tigray as a base of comparison in our regression models.

The specification for butter market participation ($buttermrkt_i$) equation is given by equation 7. Amount of crop residue produced by the households ($cropresdu_i$), household access to grazing land ($tglpltu_i$), household access to veterinary clinic ($distvc_i$) and occurrence of negative rainfall shock ($rainshock_i$) are expected to affect household decision to participate in butter market through their effect on total amount of milk produced ($totmilk_i$). After controlling for total amount of milk produced by the household these variables become conceptually irrelevant for market participation decision and so are excluded from the model. Wage rate for off farm employment for male ($wagemale_i$) is also excluded from the market participation equation because conceptually it would be irrelevant once milk production decision is made.

$$buttermrkt_i = f(age_i, agesq_i, hhsex_i, chidfive_i, labsup_i, edu\_1_i, edu\_2_i, edu\_3_i, land_i, hasst_i, cash_i, lagnsr_i, lagncrcow_i, totmilk_i, disttwnm_i, distdsrtm_i, disdpost_i, crdt_i, popdens_i, azzone\_d_i, azzone\_w_i, wagefemale_i, lagdsrpr_i, lagdbuttpr_i, zone1_i - zone9_i, u_{2i}) \quad (7)$$

The specification for intensity of butter market participation ($buttersupply_i$) equation is given by equation 8. Distance to market town ($disttwnm_i$) is used as a proxy for fixed transaction cost and is hypothesized to affect the market participation decision but not the volume of sale. Thus, it is excluded from the intensity equation.

$$buttersupply_i = f(age_i, agesq_i, hhsex_i, childfive_i, labsup_i, edu\_1_i, edu\_2_i, edu\_3_i, land_i, hasst_i, cash_i, lagnsr_i, lagncrcow_i, totmilk_i, distdsrtm_i, disdpost_i, crdt_i, popdens_i, azzone\_d_i, azzone\_w_i, wagefemale_i, lagdsrpr_i, lagdbuttpr_i, zone1_i - zone9_i, u_{3i}) \quad (8)$$

The specification for input market participation ($inputmrkt_i$) model is given by equation 9. Similar to butter market participation model above, wage rate for off farm employment for male ($wagemale_i$) is also excluded from the input market participation equation since conceptually it would be irrelevant once milk production decision is made.

$$inputmrkt_i = f(age_i, agesq_i, hhsex_i, childfive_i, labsup_i, edu\_1_i, edu\_2_i, edu\_3_i, land_i, hasst_i, cash_i, lagnsr_i, nlactcow_i, prcrslactcw_i, cropresdu_i, disttwnm_i, distdsrtm_i, disdpost_i, dislivinptc_i, distvc_i, branseller_i, cfeedseller_i, hayseller_i, crdt_i, popdens_i, tglpltu_i, azzone\_d_i, azzone\_w_i, wagefemale_i, lagdsrpr_i, lagdbuttpr_i, pricemazbutr_i, pricemazbutr_i, rainshock_i, zone1_i - zone9_i, u_{4i}) \quad (9)$$

The specification for intensity of input market participation ($inputdemand_i$) equation is given by equation 10. Distance to livestock input centre ($dislivinptc_i$) and availability of dairy input sellers ($branseller_i$, $cfeeddseller_i$ and $hayseller_i$) are used as a proxy for fixed transaction cost and are hypothesized to affect only the market participation decision but not the volume of purchases. Thus, these variables are excluded from the intensity equation.

$$\begin{aligned} inputdemand_i = {} & f(age_i, agesq_i, hhsex_i, childfive_i, labsup_i, edu\_1_i, edu\_2_i, edu\_3_i, land_i, \\ & hasst_i, cash_i, lagnsr_i, nlactcow_i, prcrslactcw_i, cropresdu_i, disttwnm_i, \\ & distdsrtm_i, disdpost_i, distvc_i, crdt_i, popdens_i, tglpltu_i, azzone\_d_i, \\ & azzone\_w_i, wagefemale_i, lagdsrpr_i, lagdbuttpr_i, pricemazbutr_i, \\ & pricemazbutr_i, rainshock_i, zone1_i \text{ - } zone9_i, u_{5i}) \end{aligned} \quad (10)$$

3.2 Estimation

Input or output market participation decisions have traditionally been modelled as two-stage models, the first stage being decision on whether to participate in the market and the second stage on how much to participate (Bellemare and Barrett, 2006; Burke et al., 2015; Goetz, 1992). Such modelling approach leaves out household decision to engage in the production of the commodity in the first place. The two-step models are, therefore, appropriate only if all households in the study population are involved in the production of the commodity. In the context where significant number of households do not produce the commodity, as is the case for dairy production in our study area, policies to influence market participation among producers may result in non-producers joining the producer set, thus rendering generalizations of results from the two-step models to the whole population difficult (Burke et al., 2015). Hence to analyse the determinants of household decision in the production and marketing of butter, and in milk production and purchased input use, instead of the usual “two-step” modelling framework including that of Cragg's (1971) double-hurdle model, triple hurdle modelling approach as developed and elaborated by Burke et al. (2015) is used. We, therefore, estimated two triple-hurdle models.

Market participation and intensity of participation in dairy output or purchased input use can be thought of as three-stage decision problem where clearance from the previous stage is required for each successive stage. The first stage is production decision (i.e. whether to engage in dairy production or not), followed by market participation decision (i.e the decisions of dairy producers to participate in marketing the output or purchasing the input). Conditional on being a market participant producer, the third stage is the decision on intensity of participation (i.e. how much dairy output to sell or how much external input to purchase).

The three-stage decision problem has three possible outcomes. Not engaging in dairy production (D_i=0), engaging in dairy production but not participating in input (output) market (I_{1i}=0|D_i=1 (O_{1i}=0|D_i=1)) and for market participating producers, the intensity of participation ($I_{2i}(O_{2i})$). Let W be explanatory variables and β be the respective coefficients, then the probabilities for the three possible outcomes are.

- Pr(D_i=0) = 1-$\Phi(W_{1i}\beta_1)$
- Pr(I_{1i}=0|D_i=1) = $\Phi(W_{1i}\beta_1) - \Phi(W_{1i}\beta_1, W_{2i}\beta_2)$
- E($I_{2i}(O_{2i})$) =E(volume of purchase(sell)) =$\Phi(W_{1i}\beta_1)\Phi(W_{1i}\beta_1, W_{2i}\beta_2) * \exp(W_{3i}\beta_3 + \sigma_3^2/2)$

Combining these outcomes and their respective probabilities gives the following likelihood function

$$l_i(\theta)=1[D_i=0]\log[1-\Phi(W_{1i}\beta_1)]$$

$$+\ 1[D_i=1]\ 1[I_{1i}(O_{1i})=0]\{\log[\Phi(W_{1i}\beta_1)] - \log[\Phi(W_{1i}\beta_1, W_{2i}\beta_2)]\}$$

$$+1[D_i=1]1[I_{1i}(O_{1i})=1]\left\{\begin{matrix}\log[\Phi(W_{1i}\beta_1)] + \log[\Phi(W_{1i}\beta_1, W_{2i}\beta_2)] \\ +\ \log(\phi\left[\frac{\log(I_{2i}(O_{2i})) - W_{3i}\beta_3}{\sigma_3}\right]) - \log\sigma_3 - \log(I_{2i}(O_{2i}))\end{matrix}\right\}$$

Where, $\emptyset(.)$ is the standard normal density function, $\Phi(.)$ is standard normal cumulative distribution function, β_1 are the parameters on W_1 in the first stage, β_2 are the second stage parameters on W_2, and β_3 are the third stage parameters on W_3. Finally, σ_3 is error variance parameter.

The models can be estimated simultaneously via maximum likelihood method or separately using Heckman's (1979) method. However simultaneously estimating the model would allow us to easily calculate the predictive margins and partial effects of explanatory variables. Stata 14 is used to estimate the model coefficients and parameters.

We used wage rate for off-farm employment, which measures alternative use of households' labour time, to identify the butter market participation equation, because alternative use of time only affects the decision of whether to engage in dairy production, and becomes conceptually irrelevant after the production decision is made. Distance to market town is used to identify the equation for volume of butter sold since distance to market measures fixed transaction costs which should not affect volume of sales.

Similarly, wage rate for off-farm employment was used to identify the input market participation equation for the same reason given above. Distance to livestock input supply centres and availability of input suppliers in the village are used to identify the equation for amount of purchased input use, since these variables measure fixed transaction costs (Goetz, 1992).

4. Econometric analysis

4.1 Data and description of variables

Results are based on analysis of data from a survey of 5000 households and 497 rural *kebeles*[4] (PAs) in the 4 highland regions of Ethiopia (Tigray, Amhara, Oromia, and Southern Nations, Nationalities and Peoples (SNNP)). For sampling purposes, the study districts were stratified into 10 agro-ecologies, and farm households were selected randomly based on proportional to size sampling technique.

Tables 1 and 2 present descriptive statistics of continuous and categorical variables used in the regression models. About 32% of sample households participated in milk/butter production, of which 53% participated in butter market and 48% purchased some type of dairy inputs. About 81% of the households are male-headed. The mean age of the household heads is about 46 years and on average, a household has about 3 working age family members. The average household's total land size is small at 1.41 ha and the variation is relatively small across households as is evident in the small standard deviation of 1.37. On average, a household has to travel for 108.76 minutes to reach nearest town market, 165.04 minutes to reach district town, 70.763 minutes to reach nearest livestock input market and 90.67 minutes to reach the nearest veterinary clinic. Moreover, only about 20% obtained credit during the previous production season. About 20% of respondents reported that there was cereal bran supplier in their PA and lesser proportion (13%) reported the presence of compound feed supplier. Hay sellers seems to be abundant with 80% of respondents reporting that there was a hay seller in their area.

[4] A *KebeleI* is the lowest administrative unit in Ethiopia and comprises of 4-5 villages.

Table 1: Definitions and summary statistics of the continuous variables used in the analysis

Explanatory Variables	Percentile			Mean	Std. Dev.
	25	50	75		
Household characteristics					
Age of household head (year)	36	45	53	45.51	12.55
Number of adult household members (no.)	2	3	4	3.14	1.5
Number of children less or equal to 5 years (no.)	0	1	1	0.8	0.88
Household wealth (1000 Birr[5])	0.94	2.87	8.28	17.43	55.49
Household non-farm income (1000 Birr)	0	1.44	4.23	3.55	7.41
Farm characteristics					
Land owned (ha.)	0.5	1	1.75	1.41	1.37
Lagged number of small ruminants	0	1	6	4.14	6.66
Lagged number of cross breed cows	0	0	0	0.08	0.45
Annual crop residue produced (in kg)	0	0	0	264.03	1638.52
Total milk produced during the year (in liter)	122.5	210.3	375	332.61	440.03
Total number of lactating cows (no.)	1	1	2	1.42	0.77
Proportion of cross breed lactating cows	0	0	0	0.06	0.23
Access to infrastructure, service and markets					
Distance to town market (walking minutes)	50	90	150	108.76	88.44
Distance to District town (walking minutes)	80	150	240	165.04	114.38
Distance to DA post (walking minutes)	10	20	40	30.55	29.9
Distance to the nearest livestock input provider (walking minutes)	20	60	90	70.75	77.14
Distance to the nearest veterinary clinic (walking minutes)	30	60	120	94.91	90.67
Community characteristics					
Population density (persons/ha.)	1.6	2.25	3.54	3.13	3.02

[5] During the survey period 1 USD = 19 Ethiopian Birr.

Grazing land (ha/tlu)	0.02	0.04	0.08	0.07	0.12
Wage rate for female for off-farm employment (Birr/hour)	0	0	47	23.36	27.54
Wage rate for male for off-farm employment (Birr/hour)	45	57	75	59.43	22.57
Prices					
Lagged district butter prices (birr/kg)	77.21	100	122.5	105.54	32.71
Lagged district sheep prices (birr/head)	600	700	760	714.33	168.12
Relative market price of Maize to butter	0.04	0.05	0.06	0.06	0.02
Relative market price of Teff to butter	0.1	0.12	0.14	0.12	0.02

Table 2: Definitions and summary statistics of the binary variables used in the analysis

Variables	Mean	Std. Dev.
Household characteristics		
Male headed household (yes=1)	0.81	0.4
No education (yes=1)	0.58	0.49
1 to 4 years (yes=1)	0.18	0.38
5 to 8 years (yes=1)	0.19	0.39
More than 8 years (yes=1)	0.05	0.22
Agro ecological zones		
Agro ecological zone 1(=1 if altitude is > 2300 m)	0.26	0.44
Agro ecological zone 2 (=1 if altitude is 1,500-2,300 m)	0.66	0.47
Agro ecological zone 3 (=1 if altitude is <1500m)	0.08	0.27
Access to credit and market		
Credit use (=1 if the farmer took credit)	0.18	0.39
Bran sellers are available in the PA	0.2	0.4
Compound feed seller are available in the PA	0.13	0.34
Hay seller are available in the PA	0.8	0.4
Shock		
Negative rainfall shock (yes=1)	0.32	0.47
Dependent variables		
Household participation in milk production	0.32	0.47
Household participates in butter market	0.53	0.5

Household intensity of butter marketing	6.11	7.16
Household use of purchased dairy inputs	0.48	0.5
Household intensity of purchased input use	821.80	2437.93

4.2. Econometric results

Engagement in milk production

In our data almost all milk producers (94%) also produce butter. Thus, the first-stage probit model estimates milk/butter production decision, the second stage estimates butter market participation decision and the third stage estimates the volume of butter sales decision.

Our model assumes a non-zero correlation among the three error terms. To test the assumption a restricted model is estimated by setting the correlation among the error term to zero, and likelihood ratio (LR) test is used to for testing. The likelihood ratio test suggests that the unrestricted model is preferred to the restricted χ^2 (3) = 129.33, p = 0.000. In addition, the LR test of the hypothesis that all regression coefficients are jointly equal to zero is highly rejected.

Wage rate for off-farm employment for male used to identify the butter market participation equation was shown to be statistically significant in stage 1 (milk/butter production decision) (p =0.062), but was both conceptually and empirically irrelevant in stage two (butter market participation) (p = 0.358). Likewise, distance to market town (as a measure of fixed transaction costs) used to identify the third stage equation of volume of butter sold was statistically significant in stage 2 (p = 0.052), but was insignificant in stage 3 (p = 0.897).

Table 3 presents the maximum likelihood estimates of the three-stage dairy production and butter market participation decision models. The probit model for engagement in milk production gives intuitive results. Male-headed households have 30.8% greater likelihood of engaging in dairy production than female-headed households (Table 3).

Table 3: Triple hurdle model estimates of Milk/butter production and butter market participation decisions in rural Ethiopia

	Stage 1:	Stage 2:	Stage 3:
VARIABLES	Production	Butter Market	Sales Volume

		Participation	
	Probit	Probit	Log normal
Household characteristics			
Age of household head (year)	-0.001	0.005	0.014
	(0.914)	(0.763)	(0.497)
Age of household head squared	0.000	-0.000	-0.000
	(0.915)	(0.889)	(0.376)
Male headed household (yes=1)	0.281***	-0.329***	0.300**
	(0.000)	(0.000)	(0.015)
Number of adult household members (no.)	0.051***	-0.059***	0.062**
	(0.001)	(0.005)	(0.026)
Number of children less or equal to 5 years (no.)	0.055**	-0.054	0.061
	(0.028)	(0.117)	(0.176)
1 to 4 years (yes=1)	-0.012	0.130	-0.233**
	(0.826)	(0.104)	(0.022)
5 to 8 years (yes=1)	0.150***	-0.084	0.011
	(0.008)	(0.281)	(0.910)
More than 8 years (yes=1)	-0.023	-0.198	0.099
	(0.818)	(0.153)	(0.581)
Household wealth (1000 Birr)	0.000	-0.000	0.000
	(0.554)	(0.308)	(0.811)
Household non-farm income (1000 Birr)	-0.002	-0.010**	0.006
	(0.463)	(0.017)	(0.291)
Farm characteristics			
Land owned (ha.)	0.112***	-0.073***	0.098***
	(0.000)	(0.003)	(0.002)
Lagged number of small ruminants	0.024***	-0.008*	0.005
	(0.000)	(0.072)	(0.367)
Lagged number of cross breed cows	0.392***	-0.149***	0.080
	(0.000)	(0.009)	(0.286)
Annual crop residue produced (in kg)	0.000**		
	(0.033)		
Total milk produced during the year (in		0.001***	0.001***

liter)		(0.000)	(0.000)
Access to infrastructure, services and market			
Distance to town market (walking minutes)	-0.000	-0.000*	
	(0.451)	(0.051)	
Distance to District town (walking minutes)	-0.000	-0.000	0.001
	(0.627)	(0.479)	(0.136)
Distance to DA post (walking minutes)	0.001	-0.001	0.002*
	(0.201)	(0.303)	(0.099)
Credit use (=1 if the farmer took credit)	0.104**	0.017	0.057
	(0.045)	(0.812)	(0.537)
Distance to the nearest veterinary clinic (walking minutes)	0.000		
	(0.919)		
Community characteristics			
Population density (persons/ha.)	-0.019**	0.010	-0.004
	(0.041)	(0.386)	(0.819)
Grazing land (ha/tlu)	0.379**		
	(0.020)		
Wage rate for female for off-farm employment (Birr/hour)	0.001	-0.002	0.002
	(0.274)	(0.242)	(0.208)
Wage rate for male for off-farm employment (Birr/hour)	-0.002*		
	(0.062)		
Agro ecological zones			
Agro ecological zone 1(=1 if altitude is > 2300 m)	0.018	0.238	-0.294
	(0.886)	(0.171)	(0.190)
Agro ecological zone 2 (=1 if altitude is 1,500-2,300 m)	0.019	0.326*	-0.180
	(0.883)	(0.066)	(0.444)
Prices			
Lagged district butter prices (birr/kg)	0.004**	0.001	-0.002
	(0.046)	(0.817)	(0.496)
Lagged district sheep prices (birr/head)	-0.001	-0.000	-0.001
	(0.169)	(0.530)	(0.213)
Shock			

Negative rainfall shock (yes=1)	0.046		
	(0.310)		
Constant	-1.493***	0.717	1.527
	(0.002)	(0.315)	(0.104)
Observations	4,610	1527	810
Ancillary parameters			
σ		1.261*** (0.000)	
ρ_{12}		-0.964*** (0.000)	
ρ_{13}		0.440*** (0.000)	
ρ_{23}		-0.640*** (0.000)	
Log likelihood		-4504.927	
LR chi2(106) =		1187.40*** (0.000)	

P-values in parentheses. *** P<0.01, ** P<0.05, * P<0.1. †Eastern Tigray is the reference zone

An additional adult member of the household raises the probability of engaging in dairy production by 1.8 percentage point. Similarly, an increase of land size by one standard deviation increases the probability of engaging in dairy production by 6.2 percentage points. This is because labour is a critical factor of production for dairy, while cultivated land is an important source of animal feed.

An additional child of up to 5 years age increases the likelihood of engaging in dairy production by 1.9 percentage points. This is probably because existence of children in a household increases household's demand for milk to feed the children. Household heads who had completed upper primary level (grade 5–8) are likelier to engage in diary production than those with no formal education—43% as compared to 38%. However, completing lower primary school (grade 1–4) or having more than primary school education (above 8th grade) did not have statistically significant effect.

Lagged possession of small ruminants and crossbred dairy cows have positive and statistically significant relationship with the probability of being a milk producer. Likewise, the amount of crop residue produced and access to communal grazing land have statistically significant and positive effects on the probability of engaging in dairy production. This shows the importance of feed availability which is consistent with the practices in other African countries (Ngongoni et al. 2006; Moll et al. 2007).

The result also shows that participation in dairy/butter production is negatively affected by population density, perhaps because high population density is associated with resource scarcity and degradation which ultimately affects availability of animal feed (Hassen et al. 2010). On the other hand, male's wage rate for off-farm employment is inversely related to the probability of being dairy producers, reflecting the role of opportunity cost of labor in choosing livelihood options.

Household that accessed credit have 9.4% greater likelihood of being a dairy producer. Freeman et al. (1998) found similar result for Ethiopia and Kenya where access to credit leads to higher investment in crossbred animals with higher milk production potential. This suggests the importance of access to credit for dairy development in rural Ethiopia.

Engagement in milk production is positively associated with lagged butter price, consistent with the findings of Ahmed et al. (2004). This is probably because past output prices shape smallholders' price expectations, which ultimately affect farmer's production decisions. As expected households who are located in west Gojam, north Gonder, south Wollo and Sidama are more likely to be engaged in milk production relative to eastern Tigray, indicating the relatively higher potential for dairy development in these zones[6].

Butter market participation and volume of sale

Although less likely to be engaged in dairy production, female-headed households are more likely to participate in butter market than their male counterparts, conditional on being a milk producer. An average female-headed household is 15% more likely to participate in butter market than an otherwise comparable male-headed household. This is consistent with Burke et al. (2015) study where they found that female-headed dairy producing households are more

[6] Regression results for the zonal dummies are not reported in order to save space.

likely to be net sellers in rural Kenya. Given that a household is a seller, however, we find a positive and statistically significant relationship between male-headedness and quantity sold. All else equal, male-headedness increases the (conditional) quantity sold by 12% but decrease the unconditional[7] amount by 0.8%.

Market participation declines with the number of adult members and children of up to 5 years of age, indicating the effect of household consumption on milk sales. Burke et al. (2015) found similar result for children in milk producing households in rural Kenya.

Not surprisingly, the volume of milk produced significantly affect the probability of butter market participation as well as the volume of sales. This is in line with Negassa (2009) findings where low level of production was identified as one of the main reasons for not selling milk in the market. The results suggest that, keeping other things constant, an increase in annual milk production by 1000[8] liters on average increases the conditional probability of market participation by 25% and the unconditional probability by 9.7%. Similar increase in annual milk production also increases the conditional and unconditional expected volume of butter sales by 172.3% and 142.5%, respectively. The implication is that promoting productivity and production at household level is a potent policy option in promoting market orientation in dairy production in rural Ethiopia, consistent with pervious study by Holloway et al. (2000) who focused on the fluid milk market in Ethiopia.

Probability of market participation decreases with household non-farm income, land size and possession of small ruminants, ceteris paribus. This is probably because all three variables represent alternative sources of income to the households, and as such butter producers who have access to these other income sources have less incentive to participate in butter. However, only land size has a statistically significant and positive effect on the volume of sale, perhaps because of its effect on feed production.

Interestingly, lagged possession of cross breed dairy cows decreases the probability of participating in butter market for milk/butter producers. This finding is consistent with the

[7] The term unconditional is used here to indicate that the partial effect of a given explanatory variable is not conditional on any of the dependent variables (production and market participation) taking a specific value

[8] Debrah & Anteneh (1995) estimated that annual milk yield from cross breed cow in rural Ethiopia is about 1120-2500 liters

notion that a dairy producer who owns crossbred cows is more likely to sell fluid milk than butter (Tegegne et al., 2013).

As expected distance to market town has statistically significant and negative effect on the probability of market participation but not on the volume of sale for a given seller. Similar result has been found by Holloway et al. (2000b) and Holloway et al. (2004) for milk marketing in Ethiopian highlands as well as by Staal et al. (1997) in Ethiopia and Kenya. The probability of market participation is 3.8% lower for milk/butter producers located at two hours walking distance from market town (the 75th percentile) than those located at 40 minute walking distance (25th percentile). These findings suggest that investments in market infrastructure are important to promote participation in dairy markets.

Surprisingly, butter sellers do not respond to price signals. This is contrary to results found by Burke et al. (2015) for milk in rural Kenya. This could be because butter producers sell butter to meet household cash needs, not necessarily to maximize profit, which is not unusual consideration for livestock producers in rural Africa (Bellemare and Barrett, 2006). Moreover, volume of sales increases with distance to development agent (DA) office which proxies for access to extension services. This apparent paradox may be explained by the fact that dairy producers who are located far from DA offices are also more likely to be butter sellers rather than fluid milk sellers. However, this is a tentative explanation for unexpected result and needs further verification.

Purchased input use and demand in dairy production

The input demand model assumes a nonzero correlation among the three error terms corresponding to the three equations representing butter production, participation in dairy input market and intensity of participation. To test the assumption, a restricted model is estimated by setting the correlation among the error term to zero and likelihood ratio (LR) test is used for testing. The likelihood ratio test suggests that the unrestricted model is preferred to the restricted model χ^2 (3) = 54.92, P = 0.000.

Wage for off-farm employment for male used to identify the 2nd stage equation is statistically significant in stage one (P =0.062), but both conceptually and empirically irrelevant in stage two (P=0.3584). Likewise, we used distance to nearest livestock input supply center, and availability of shops for compound feed, hay and bran as exclusion restriction variables to identify the 3rd stage equation of value of purchased inputs. These variables are jointly statistically significant in stage 2 χ^2 (4) = 11.15, P = 0.0249, but are either insignificant (as in the case of distance to nearest livestock input supply center) (P= 0.4236) or conceptually irrelevant after the market participation decision is made (as in the case of availability of feed shops)[9].

The input demand model shares the same first stage equation with the butter market participation model. Thus, only the results for input market participation and level of participation conditional on being milk/butter producer are presented and discussed in this section. Estimation results for the triple hurdle model of smallholders' input market participation decision are presented in Table .

Table 4: Triple hurdle model estimates of dairy input market participation decision in Ethiopia

	Stage 2:	Stage 3:
	Dairy input Market Participation	Purchases Volume
VARIABLES	Probit	Log normal
Household characteristics		
Age of household head (year)	0.013	-0.006
	(0.558)	(0.848)
Age of household head squared	-0.000	0.000
	(0.401)	(0.872)
Male headed household (yes=1)	0.074	-0.580***
	(0.609)	(0.000)
Number of adult household members (no.)	0.061*	0.001
	(0.052)	(0.969)
Number of children less or equal to 5 years (no.)	0.089*	0.027
	(0.060)	(0.654)
1 to 4 years (yes=1)	0.063	0.003
	(0.559)	(0.980)
5 to 8 years (yes=1)	0.000	-0.199
	(0.997)	(0.134)

[9] We have not been able to test the significance of the availability of feed shops variables, as the third stage equation would not converge when these variables were included.

More than 8 years (yes=1)	0.275	0.345
	(0.124)	(0.110)
Household wealth (1000 Birr)	0.000	0.000
	(0.687)	(0.499)
Household non-farm income (1000 Birr)	0.016**	0.010
	(0.027)	(0.126)
Farm characteristics		
Land owned (ha.)	0.032	-0.117**
	(0.408)	(0.014)
Lagged number of small ruminants	0.026***	-0.014*
	(0.000)	(0.054)
Total number of lactating cows (no.)	0.126**	0.094
	(0.027)	(0.155)
Proportion of cross breed lactating cows	0.221	0.294
	(0.322)	(0.138)
Annual crop residue produced (in kg)	0.000	0.000
	(0.815)	(0.117)
Access to infrastructure, services and market		
Distance to town market (walking minutes)	-0.000	-0.000
	(0.946)	(0.664)
Distance to District town (walking minutes)	0.001***	-0.000
	(0.006)	(0.712)
Distance to DA post (walking minutes)	-0.001	-0.003*
	(0.667)	(0.050)
Distance to the nearest veterinary clinic (walking minutes)	-0.001	-0.001
	(0.127)	(0.383)
Distance to the nearest livestock input provider (walking minutes)	-0.001**	
	(0.036)	
Credit use (=1 if the farmer took credit)	0.056	-0.143
	(0.554)	(0.217)
Bran sellers are available in the PA	-0.200	
	(0.156)	
Compound feed seller are available in the PA	0.442**	

	(0.022)	
Hay seller are available in the PA	0.232*	
	(0.092)	
Community characteristics		
Population density (persons/ha.)	0.019	0.066***
	(0.299)	(0.003)
Grazing land (ha/tlu)	0.001	-0.957**
	(0.998)	(0.015)
Wage rate for female for off-farm employment (Birr/hour)	0.000	0.002
	(0.908)	(0.422)
Agro-ecological zones		
Agro ecological zone 1(=1 if altitude is > 2300 m)	-0.042	0.115
	(0.857)	(0.703)
Agro ecological zone 2 (=1 if altitude is 1,500-2,300 m)	0.472*	-0.090
	(0.054)	(0.778)
Prices		
Lagged district butter prices (birr/kg)	0.001	-0.003
	(0.863)	(0.596)
Lagged district sheep prices (birr/head)	-0.003***	-0.000
	(0.002)	(0.990)
Relative market price of Maize to butter	4.643	-13.508***
	(0.250)	(0.003)
Relative market price of Teff to butter	1.919	-0.392
	(0.515)	(0.908)
Shock		
Negative rainfall shock (yes=1)	0.004	0.017
	(0.967)	(0.881)
Constant	-0.319	9.840***
	(0.795)	(0.000)
Observations	1,489	734
Ancillary parameters		
σ	1.758***	
	(0.000)	

ρ_{12}	-0.191 (0.483)
ρ_{13}	-0.927*** (0.000)
ρ_{23}	0.133 (0.690)
Log likelihood	-4544.939
LR chi2(120)	1005.66*** (0.000)

P-values in parentheses. *** p<0.01, ** p<0.05, * p<0.1. † Eastern Tigray is the reference zone

Though sex of household did not matter for the probability of dairy input market participation, female-headed milk/butter producers use purchased dairy input more intensively than male-headed households. Holding other variables fixed, female-headedness is expected to increase the amount spent on dairy inputs by 9.2%. This could be partly because, female-headed households, ones involved in milk production, are more focused on dairy as source of income and manage their dairy farms more intensively. Similar findings are reported by Alene et al. (2008) and Winter-Nelson & Temu (2005) where female-headed households used fertilizer more intensively than male headed households in Kenya and Tanzania, respectively.

Conditional on being a dairy farmer, the probability of participating in input market increases with adult household members as well as children of up to 5 years of age partly due to the fact that demand for milk increase with household member especially with children. Non-farm income as well as ownership of small ruminant are positively associated the probability of participating in input market, perhaps because both are sources of cash income for the households raising households purchasing power. After the market participation decision is made, ownership of small ruminant and land size negatively affect the intensity of input market participation partly due to competition for resources.

Higher lagged price of small ruminants is associated with lower probability of participation in dairy input markets. Farmers keep small ruminant as a source of income and as such if households expect higher return from this alternative sub-sector they are more likely to divert resources from other activities. Similarly, higher relative price of maize, which is one of the major cereals grown by smallholder farmer in Ethiopia, decreases the amount of purchased inputs. As expected input market participation increases with total number of lactating cows, although unexpectedly number of lactating cows did not affect the intensity of use of purchased dairy inputs. On average, each additional lactating cow increases the probability of input market participation by 4.1%.

An increase in time taken to reach the nearest livestock input market decreases the probability of input market participation, albeit only slightly. A household located within 30 walking minutes radius from livestock input market (the 25th percentile) has a 53% probability of participating in the input market, while an otherwise comparable households located some 2 hours (the 75th percentile) away has an 49% percent chance. The negative relationship between distance to market and input market participation is consistent with pervious agricultural market participation studies (Alene et al., 2008; Ouma et al., 2010).

Compound feeds and hay shops in the PA are positively and significantly associated with the probability of participating in input market. Compared to households in a PA where no such feed suppliers exit, any given household's likelihood of participating in input market is 28.7% higher in areas where compound feed supplier exists and 17.2% where hay supplier exits. The implication is that there is potential to increase input use by dairy farmers through improved input distribution system. Likewise, population density and access to communal grazing land, which affect the quality and quantity of forage, have statistically significant positive and negative effect on the amount spent on purchased dairy input, respectively.

Unexpectedly, results show that milk/butter producers who are located far from the district towns are more likely to participate in input markets than are their counterparts. It is not clear why this is so. On the other hand, distance to DA office, which was included in the model to capture access to extension services, negatively affects the intensity of input market participation, consistent with other studies where extension services has been identified as an essential ingredients to promote commercialized agriculture in developing countries (Holloway et al. 2000; Lerman 2004).

5. Conclusion and implications

This paper estimates two triple-hurdle models using a data set collected from 5000 households and 497 rural *kebeles* in the highlands of Ethiopia to analyse the factors influencing household decisions to engage in milk production and butter marketing, and to participate in dairy input markets.

Econometric results show that availability of feed stands out as an important factor influencing household decision to engage in milk production. Households with larger size of cultivated land who produce more crop residues, and who live in communities with larger communal grazing land per TLU are more likely to be involved in milk production. These results imply the urgent need to develop feed resources to support dairy production in rural Ethiopia. Moreover, household labour supply seems to be an important consideration in milk production, reflecting the labour requirements for feeding, herding, milking and other farm management practices.

Milk production in rural Ethiopia seems to have an interesting and complex gender dimension. While female-headed households are less likely to be engaged in dairy production than their male-headed counterparts, they are more likely to participate in butter market as sellers, conditional on being milk producer. Interestingly, conditional on being a butter seller, female-headed households sell less amount of butter. Female-headed milk producers also use higher amount of purchased inputs, suggesting that such households manage their dairy farms more intensively. These results suggest that targeted support to female-headed households to engage in dairy production may be a useful policy direction to promote dairy production in rural Ethiopia.

Household milk consumption needs also stands out as an important factor in the decision to engage in milk production, butter marketing and the use of purchased dairy inputs. Households with higher numbers of children of up to 5 years of age, and larger family size, are more likely to be milk producers, and less likely to sell butter, and households with higher number of children of up to 5 years of age sell less butter. Similarly, volume of milk produced increases probability of selling butter as well as increases the volume of sales. Conditional on being a milk producer, the probability of using purchased dairy inputs increases with the number of children under 5 years of age and the number of working age family members.

Opportunity cost of factors of production also seems to matter in milk production. In areas where wage rate for off-farm employment for males is higher, involvement in dairy production is less, indicating the trade-off in the use of labor for dairy production and off-farm activities. Butter sellers with larger small ruminant flock size purchase less dairy inputs. The relative price of maize to butter is also negatively associated with the value of purchased dairy input use. This result suggests that improving the profitability of dairy production or adoption of labour saving technologies and practices may help promote dairy production.

Marketing costs also matter in milk production in rural Ethiopia. Distance to market discourages butter market participation. Moreover, distance to livestock input market decreases the probability of input market participation. These results imply the need to develop livestock output and input markets to promote market oriented dairy production.

Clearly dairy producers in rural Ethiopia are facing liquidity constraints. Access to credit is associated with higher probability of dairy production, and income from off-farm employment and the sale of small ruminants encourages the use of purchased inputs. These results suggest that credit facilities targeted at dairy production are needed in rural Ethiopia.

Our results also indicate that market orientation in dairy production in rural Ethiopia is low. Milk production and butter sales is considered as an alternative source of income to the household, but not necessarily meant as a business enterprise aimed at maximizing profit. While engagement in milk production is positively influenced by butter prices, participation in butter market as seller or the amount of butter sales do not respond to price signals, suggesting a need to understand among other things the behavioural aspect of dairy marketing decision in Ethiopia. Moreover, households with higher off-farm income are less likely to sell butter.

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