To sell or not to sell – Maasai milk marketing in Ngerengere, Tanzania

Tim K Loos*
University of Hohenheim (490a), Stuttgart, Germany E-mail: tim.loos@uni-hohenheim.de

Manfred Zeller
University of Hohenheim (490a), Stuttgart, Germany. E-mail: manfred.zeller@uni-hohenheim.de

*Corresponding author

Abstract

In Maasai culture, responsibilities and labour are divided between the genders. Men are in charge of the herd and thus control the main income source. Women take care of the family and are responsible for milking. Milk sales provide the women's main income source. In this paper, using olmarei- *(= household) and* enkaji- *(= sub-household) data from the milk catchment area of a collection centre in Ngerengere, Tanzania, we assess the potential impact of milk sales on* enkaji *income. We estimate the effect by employing propensity score-matching procedures. Our findings suggest that milk sellers earn significantly higher average income per capita than non-sellers. This appears to be especially true for* enkajijik *selling milk to other buyers rather than to the collection centre. Other buyers reach more remote areas, usually offer higher prices, but only purchase limited amounts of milk. The collection centre, on the other hand, is a guaranteed market with large capacity.*

Keywords: milk sales; income effect; propensity score matching; Maasai; Tanzania

1. Introduction

Livestock are one of the major agricultural sub-sectors in Tanzania. Its contribution to the national gross domestic product is estimated at 4.7%, of which about one third is attributed to the dairy sector (URT 2012). The vast arid and semi-arid rangelands of East Africa are particularly suitable for rearing animals. The region extends from the centre of Tanzania north into Kenya, and is characterised by the Maasai ethnic group; it therefore is often referred to as Maasailand. Many Maasai still follow their customs as "people of cattle", relying on their animals and dominating the country's livestock and milk production with their traditional systems and indigenous breeds. Among the Maasai, as in similar pastoral societies, everyday tasks are divided between the genders. While men usually own and manage livestock as the families' primary means of production, women are responsible for milking. The women also manage the milk supply, i.e. they decide which shares are consumed by the family members, left for the calves and traded on local markets. However, the Maasai way of life faces pressure from a growing population, loss of land to agriculture and more frequent and extreme climatic conditions.

Therefore, apart from anthropological studies, previous research on the Maasai mostly investigated either the implications of gender roles or, more recently, potential coping strategies to sustain their livelihood in a changing political, social and natural environment (see e.g. Coast 2002; McPeak &

Doss 2006; Radeny *et al*. 2007; Wangui 2008; Homewood *et al.* 2009; McCabe *et al*. 2010). Special attention was paid to diversifying income sources through non-farm or non-livestock activities, and the studies focused almost entirely on the northern area. In regions without income alternatives, however, selling milk is often the only income source for women. Little research has been done on the potential contribution to *enkaji* income that is made when Maasai women choose to sell milk on the local market (guesthouses, hawkers) or to milk collection centres (MCC). Hence, we address this knowledge gap and contribute to the pastoralist, especially Maasai, livelihood literature through an analysis of the potential impact of milk sales on *enkaji* income in Ngerengere, Tanzania. We also consider the special Maasai household structure and distinguish between husbands and wives as separate household units.

We first present the research area and describe the considerations regarding the Maasai setting. Then we will discuss propensity score matching as a methodology to estimate income effects. After an overview of the data, we will provide descriptive statistics on important socio-economic characteristics of the interviewed Maasai. In the empirical analysis, we estimate the average effect of milk sales on *enkaji* income. Here, we distinguish between non-suppliers and suppliers to two different markets. We provide separate estimates for two spatial strata representing the current milk shed of an MCC, and the long-term potential milk shed if expansion takes place.

2. Research area and Maasai setting

This section describes the research area and explains the spatial differentiation applied. We also explain the special considerations needed in the Maasai case, and define the household units being studied.

2.1 Research area

This study focuses on the two wards of Ngerengere and Kidugalo, Morogoro rural district, Tanzania. At an altitude of 100 to 300 metres above sea level, the area features sparsely wooded, rolling plains that connect the coastal lowlands with the higher elevations of the central region. River valleys and basins shape the landscape and provide a continuous water supply throughout the year. The bodies of water are crucial to the Maasai pastoralists' survival during the dry season, which usually lasts from June to mid-November. The 500 to 1 000 mm of precipitation that falls during the rainy season follows a somewhat bimodal pattern, with a dry spell around February (URT 2007). Average monthly temperatures are around 25 to 28°C (URT 2008).

The research area has a low population density and can be divided spatially into a western and an eastern part. The town of Ngerengere and several villages containing government offices, periodic markets, credit institutions and milk collection centres are located in the western half. The eastern part is rather remote, with more seasonal roads, limited public transportation and generally poorer infrastructure. We therefore looked at two strata: (1) the western area as the "actual milk shed", and (2) the whole area as the "extended milk shed".

Close to the village centres we find mainly non-Maasai farmers. The Maasai pastoralists live further away where they graze their livestock on communal and government-owned rangelands. The grazing areas are used in a transhumant fashion known locally as *ronjo*. During the rainy season, the herds return daily from the pastures to the homesteads. During the dry season, the grazing areas to the southeast provide sufficient fodder reserves. Parts of the herds usually are driven to the distant pastures by young Maasai men, while the women remain at the compounds with their children and older men, and continue with their daily activities, keeping only enough cows to meet the families' milk requirements. This further reflects the traditional division of labour between the genders that is anchored in Maasai society.

2.2 Definition of a Maasai household unit

In Maasai society it is common for men to be married to several wives if their wealth and social status allows. Most studies base their analyses on this whole *olmarei* (household) as the primary unit of production, i.e. the husband, his wives and all their dependants (see e.g. Grandin 1991; Homewood *et al.* 2009). However, each wife usually lives in her own house with her children and other dependants, is independent regarding food and nutritional decisions, and is partly autonomous in certain economic decisions like milk sales (see McPeak & Doss 2006; Wangui 2008). We follow McCabe *et al.* (2010) and consider this *enkaji* (sub-household) as the smallest household unit. It may also be formed by other female relatives, like unmarried sisters or a widowed mother. Coast (2002) also notices this differentiation problem. Grandin (1991, p. 22) provides a schematic overview of the Maasai socio-spatial organisation and its respective characteristics.

3. Methodology

In this section we describe the methods of data collection and discuss the principles of propensity score matching, which we use to estimate the average income effect of participating in milk marketing.

3.1 Database

The data used in this study were obtained from a survey of 171 *olmarei* heads and 357 *enkaji* heads from the Ngerengere and Kidugalo wards. We took a census approach and aimed at interviewing all Maasai families living in the research area. The survey was carried out between August and November 2009 and information was collected from about 70% of the *olmarei* heads and 95% of the *enkaji* heads. Since milk marketing is the responsibility of the *enkaji* head, in this paper we focus on those data only. Considering the spatial differentiation we make, the information of all 357 *enkajijik* for the extended milk shed and a subsample of 286 *enkajijik* for the actual milk shed are analysed separately.

To be able to also address non-Swahili-speaking respondents and to avoid gender issues, the survey interviews were carried out by a team of trained enumerators consisting of both male and female, as well as Maasai and non-Maasai, students from the Sokoine University of Agriculture, Morogoro. They followed a structured questionnaire with questions on the socio-economic characteristics of the Maasai. To accommodate the traditional divisions of labour and responsibilities, two customised versions of the questionnaire were developed, one for the *olmarei* head and one for the *enkaji* head. In addition, qualitative information was collected during formal and informal group discussions with *olmarei* heads or *enkaji* heads, and key person interviews.

Apart from the milk-collection centres, there are also local shops, restaurants and guesthouses that regularly purchase milk. During the dry season, when the milk supply throughout the district is generally low, hawkers and sometimes another milk-processing company enter the Ngerengere milk market to provide more sales options. Hence, the milk-selling patterns become more apparent when focusing on the dry season. The MCC offers a contractual arrangement with a guarantee to accept all milk of sufficient quality at a seasonally agreed upon price. The other buyers often pay higher prices with more lenient quality controls; however, the quantity purchased is limited. For this study, we therefore differentiate between *enkajijik* that do not sell milk (No-Sale) and those that do (Milk-

Sale). We further split the Milk-Sale group into those that sell to the MCC (MCC-Sale) and those that sell to other buyers (Other-Sale).

3.2 Selection bias and propensity score matching

For assessing the effect of milk sales on an *enkaji*'s income, we want to compare the outcome of different sales decisions. In the impact evaluation literature this is reflected as a treatment problem and formalised in the Roy-Rubin Model (Roy 1951; Rubin 1974) of potential outcome and causal effects. In principle it implies that each *enkaji* has a realised and a hypothetical, or counterfactual, response to its sales choice. Since only one of the potential outcomes is observed, the individual treatment effect cannot be estimated. The evaluation problem becomes a missing data problem (Rosenbaum & Rubin, 1983). This shortcoming may be addressed by resorting to the (population) average treatment effect (ATE), defined as the difference between the expected outcomes after participation and nonparticipation. Most popular in the evaluation literature is the average treatment effect on the treated (ATT), defined as the analogous difference for those who actually participated in the treatment (Heckman, 1979), which we estimated in the progress of this paper.

However, as all Maasai are informed about sales possibilities in the area and, with respect to the collection centres, are invited to deliver milk, the *enkaji* heads are free to choose whether to sell milk or not. Consequently, this self-selection into milk suppliers and non-suppliers is most likely influenced by systematic differences between the respective groups. The factors influencing the decision to sell milk probably influence the outcome too. This leads to a difference between the counterfactual mean and its estimation substitute, which is referred to as 'selection bias' (Heckman 1979). We address this problem by implementing propensity score matching (PSM) as a method to reduce selection bias and to estimate the effect of selling milk on *enkaji* income.

The core principle of PSM is to match participants to non-participants with a similar vector of observed pre-treatment characteristics. Provided that treatment assignment is strongly ignorable, Rosenbaum and Rubin (1983) show that the propensity score, i.e. the conditional probability of assignment to a certain treatment: $p(X) = \Pr(d = 1|X)$, is a suitable single-index balancing score to find matching partners. Strong ignorability comprises two central assumptions: (1) the conditional independence assumption (CIA) states that, for a given set of observable covariates, participation assignment is independent of potential outcomes (Caliendo & Kopeinig 2008); (2) there needs to be a region of common support. Within the overlap, households with the same characteristics have a positive probability of being both participant and nonparticipant (Heckman *et al*. 1998). These assumptions may be somewhat weakened if on focuses on the ATT only (Caliendo & Kopeinig 2008), and/or generalised if one considers multiple treatment scenarios (Imbens 2000; Lechner 2001a).

In the empirical results section, we show that the assumption of overlap is met. The CIA, however, remains problematic. It may well be that unobserved or omitted variables influence the participation and the outcome variable, implying that PSM is not robust against this "hidden bias" (DiPrete & Gangl 2004). In order to assess the sensitivity to hidden bias, Rosenbaum (2002) suggests a bounding approach to identify the critical level of influence (gamma, Γ) a variable excluded from the model may reach, before the implication of the matching analysis needs to be questioned. We show the results of this sensitivity test together with the respective matching quality tests. However, the Rosenbaum bounds only reflect worst-case scenarios (DiPrete & Gangl 2004) and may be uncalled for when choosing the set of observables according to economic theory.

3.3 PSM implementation

For implementing the PSM on our data we followed the guidelines described by Caliendo and Kopeinig (2008). We started by running a bivariate probit model to determine the propensity score. This allowed us to consider the *enkajik*'s main income activities, i.e. cropping and milk marketing. Practically, the milk sales decision is a recursive scenario. Deciding on selling or not selling milk is followed by a choice between two major sales options, resulting in the three stages of no sale, sale to the MCC and sale to other buyers. Therefore, we evaluated the milk sale decision as such and then addressed the multiple-treatment scenario. The work by Lechner (2001a, 2001b, 2002) on multiple treatments suggests that a multinomial approach and a series of binomial models result in similar estimations of treatment effects. When interested in the pairwise comparison, the latter may even be preferable. Thus, we used a series of bivariate probit models to calculate the respective propensity scores. The covariates included in the models were selected so as to capture the *enkajijik*'s socio-economic characteristics and other factors influencing both the participation decision and the outcome variable.

We applied the variant of radius matching suggested by Dehejia and Whaba (2002), which uses all neighbours within a given caliper (tolerance level on the maximum propensity score distance of matched cases) to construct the counterfactual. This allows for using extra (or fewer) units when good matches are (not) available, hence improving matching quality (Caliendo & Kopeinig 2008). Cochran and Rubin (1973) suggest that the caliper (c) should be a share of the standard deviation (sd) of the logistic model of the propensity score. Based on this, Rosenbaum and Rubin (1985) suggest one fourth of the standard deviation of the propensity score ($c = 0.25 * sd$).

Rosenbaum and Rubin (1985) also suggest comparing the standardised bias of each covariate before and after matching as one suitable indicator to assess matching quality. As this approach is commonly used in many evaluation studies (see e.g. Sianesi 2004; Maertens & Swinnen 2009), we used it to test matching quality. The SB is defined as the difference in covariate means as a percentage of the average standard deviation:

$$SB = 100 \cdot \frac{\overline{X}_T - \overline{X}_C}{\sqrt{0.5 \cdot [s_T^2(X) + s_C^2(X)]}}$$

where $\overline{X}_T$ and $\overline{X}_C$ are the sample means in the treated and control group and s_T^2 and s_C^2 are the corresponding sample variances.

Although there is no clear guideline on the tolerance level of remaining bias in the matched sample, Caliendo and Kopeinig (2008) state that most empirical studies consider a mean residual of 3% to 5% as sufficient.

In addition, we show the results of the sensitivity analyses. To get an idea of the hidden bias we report the critical level of gamma, i.e. the Rosenbaum bounds (see Rosenbaum 2002). Furthermore, we report the number of (treated) cases lost to the overlap restrictions as an indicator for potential information lost to common support restrictions.

4. Data and descriptive analysis

As shown in Table 1, about 55% and 47% of the Maasai *enkajijik* sell milk in the actual and the extended milk shed respectively. Both market options seem to be used equally. However, the lower share of milk suppliers in the extended milk shed indicates that the distance and travelling time to markets hamper milk sales.

This led us to run two separate analyses, even though most other socio-economic characteristics were found to be fairly similar. The outcome variable we employed was the total gross income per *enkaji* member. It considers all income activities reported to be carried out by the *enkaji* members (head or other) and represents all income over which the *enkaji* head has full power. These include earnings from selling milk, milk products, crops, animals or animal products, small jobs, handicrafts or likewise and remittances; excluded, for example, are household money received from the *olmarei* head and earnings on the whole *olmarei* level.

Table 1: Socio-economic characteristics of *enkajijik*, by milk shed

	Actual milk shed		Extended milk shed	
	Sample mean	Standard deviation	Sample mean	Standard deviation
Dependent variables				
Income per capita (1 000 TZS)	247.69	178.12	235.23	170.85
Milk sale in dry season+	0.55	0.50	0.47	0.50
Milk sale to MCC+	0.29	0.47	0.24	0.42
Milk sale to other buyers+	0.25	0.43	0.24	0.42
Independent variables				
Enkaji size	4.29	1.84	4.23	1.80
Olmarei size (*enkajijik*/*olmarei*)	2.22	1.39	2.24	1.39
Dependency ratio[1]	1.87	1.27	1.89	1.26
Age of *enkaji* head (years)	29.37	25.26	27.80	27.60
Education level of *enkaji* head (years)[2]	0.66	1.77	0.57	1.64
Average travel time to MCC (min)	64.57	41.27	83.37	55.72
Remoteness indicator+	-	-	0.20	0.40
Number of meetings in last seven days	3.05	4.81	2.96	4.59
Organisation membership+	0.49	0.50	0.50	0.50
No. of people to rely on in case of need	1.85	1.30	1.81	1.32
Cattle per *enkaji* member	8.14	7.39	8.18	7.26
Ownership of a mobile phone+	0.14	0.35	0.11	0.32
Ownership of a bike+	0.21	0.41	0.21	0.41
Improved housing+	0.19	0.39	0.16	0.36
Other income sources+	0.65	0.48	0.60	0.49
Cropping activities+	0.27	0.44	0.24	0.43

+ indicates dummy variables (yes = 1, no = 0)
[1] Ratio (persons aged 0-14 or aged 65 and above) divided by (persons aged 15-65); exceptions: married woman aged 14, elder still considered *enkaji* head
[2] Informal/traditional training was considered equal to 0.5 years of formal schooling
Source: Own data

Differences in the features of each milk sale group are presented in Table 2. The results of the significance tests indicate that the groups varied with respect to several *enkaji* characteristics. Milk-Sale *enkajijik* in the actual milk shed seem to have larger, but fewer, *enkajijik* in the *olmarei*, and fewer people to rely on in case of an emergency. They are also more involved in cropping activities and are more likely to own a mobile phone, but they live in more traditional houses. The shorter travelling time to the nearest milk-collection centre for milk suppliers already points to a transaction cost threshold for supplying milk to collection centres. However, this constraint may easily be overcome by resorting to hawkers or pooling all of an *olmarei*'s milk and having one person be responsible for its delivery and sale. The differences in the extended milk shed are small and, as expected, emphasise remoteness as a key factor. With regard to *enkaji* income per capita, significant differences arise between the Milk-Sale and No-Sale groups. The MCC-Sale group in the actual milk shed, however, does not appear to be different from the other two groups. The findings suggest that *enkajijik* who decide to sell milk are generally better off than those that do not. However, comparing the mean differences does not account for bias arising from self-selection into milk suppliers and non-suppliers. It is likely that systematic differences between the groups need to be considered.

Table 2: Differences in characteristics of milk sellers and non-sellers included in the bivariate probit model, by sales group and milk shed

	Actual milk shed				**Extended milk shed**			
	Milk-Sale (N=156)	**No-Sale (N=130)**	**MCC-Sale (N_1=84)**	**Other-Sale (N_2=72)**	**Milk-Sale (N=168)**	**No-Sale (N=189)**	**MCC-Sale (N_1=84)**	**Other-Sale (N_2=84)**
Dependent variable								
Income per capita (1 000 TZS)	280.72*	208.06[a]	256.34[ab]	309.16[b]	275.76*	199.19[a]	256.34[b]	295.18[b]
Independent variables								
Enkaji size	4.46[#]	4.08	4.61	4.29	4.46*	4.03[a]	4.61[b]	4.31[ab]
Olmarei size	1.99*	2.49[a]	2.12[ab]	1.85[b]	1.99*	2.46[a]	2.12[ab]	1.87[b]
Dependency ratio	1.91	1.83	2.02	1.78	1.92	1.86	2.02	1.83
Education level (years)	0.71	0.60	0.76	0.65	0.68	0.47	0.76	0.60
Travel time to MCC (min)	69.37*	58.81[a]	54.90[a]	86.25[b]	73.05*	92.54[a]	54.90[b]	91.19[a]
Remoteness indicator[+]	-	-	-	-	0.07*	0.31[a]	0.00[b]	0.14[c]
No. of people to rely on	1.69[#]	2.05	1.68	1.69	1.70	1.90	1.68	1.71
Cows per capita	3.78	3.31	3.54	4.07	3.77	3.34	3.54	4.01
Ownership of mobile phone[+]	0.19*	0.08[a]	0.18[ab]	0.21[b]	0.18*	0.06[a]	0.18[b]	0.18[b]
Living in improved housing[+]	0.12*	0.28[a]	0.13[b]	0.11[b]	0.12[#]	0.19	0.13	0.11
Cropping activities [+]	0.36*	0.16[a]	0.42[b]	0.29a[b]	0.34*	0.15[a]	0.42[b]	0.26[ab]

* ([#]) indicates significant differences at $\alpha = 0.05$ ($\alpha = 0.10$) between No-Sale and Milk-Sale
[a, b, c] Different superscripts indicate significant differences at $\alpha = 0.05$ between No-Sale, MCC-Sale and Other-Sale
Source: Own data

When matching on the propensity score, the variables included in the logistic model should influence the participation decision, in our case milk sale, and the outcome variable simultaneously (Smith & Todd 2005). Furthermore, only variables that are unaffected by participation should be included (Caliendo & Kopeinig 2008). Therefore, we distinguished between milk sales and cropping as main sub-household activities, ran bivariate probit models to calculate the propensity score, and selected covariates based on theoretical considerations supported by the qualitative information gathered during the survey.

5. Empirical results

The empirical analyses of the effect of milk sales on *enkaji* income follow the procedure described earlier (see Section 3.3 – PSM implementation). First, for each milk shed and each pairwise comparison, a bivariate probit model was employed to predict the marginal probability of deciding to sell milk. In this study we focused on matching and evaluating the ATT, and therefore do not discuss the results for the logistic model for the milk sale decision thoroughly. However, the models' predictive powers are generally high and the variables included exhibit the expected signs.[1]

As we decided to use radius matching for estimating the average income effect on milk sellers, we restricted ourselves to the area of common support, which we obtained by defining the caliper width as a quarter of the standard deviation of the propensity score. The distribution of the propensity score and the common support is shown in Figures 1 and 2 for the actual and extended milk shed respectively. This reveals the unequal distribution in the propensity scores for the different groups and shows the cases of support.

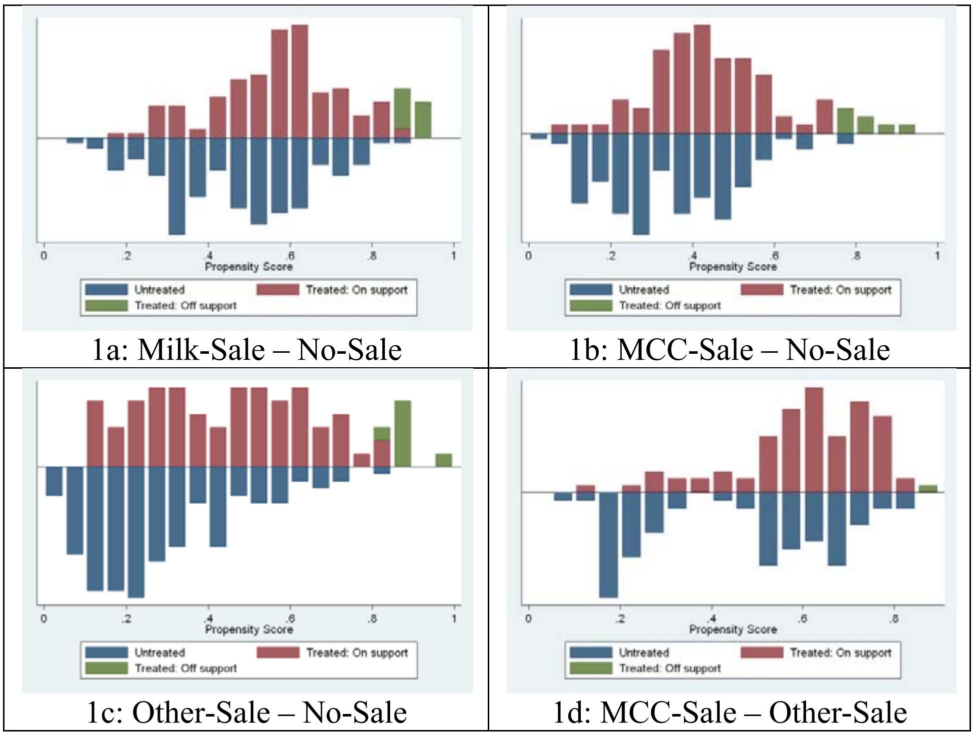

Figure 1: Propensity score distribution and common support area, actual milk shed
Source: Own data, calculation using *psgraph* (Leuven & Sianesi 2003)

[1] Results of the bivariate probit models of the pairwise comparisons are available on request. The likelihood ratio tests of the correlation coefficients show that the bivariate model has a superior fit compared to the univariate probit models.

Figure 2: Propensity score distribution and common support area, extended milk shed

Source: Own data, calculation using *psgraph* (Leuven & Sianesi 2003)

The estimates of the unmatched and matched ATT are reported in Tables 3 and 4. The bootstrapped standard error for the matched ATT and the treatment and control cases appear alongside. Table 3 reflects the results for the actual milk shed. We find a significantly higher average income per capita for those *enkajijik* selling milk. Specifically, after matching, the estimates suggest a causal effect of milk sale on *enkaji* welfare of about 64 950 TZS (US$52). When considering the two milk markets separately, we see that, with 77 190 TZS (US$62), the Other-Sellers seem to earn more, although insignificantly, from milk sales than the MCC-Sellers, with 64 140 TZS (US$51). This may be due to the higher prices paid by other buyers who enter the area, especially during the dry season. Those *enkajijik* that can arrange to supply their often limited demand seem to benefit. However, reducing selection bias by applying PSM shows that, contrary to the initial indication, the loyal MCC-Sellers profit significantly from milk sales too.

Table 3: Average income effect (ATT) by pairwise comparison, actual milk shed

	ATT unmatched	**ATT matched**	**Standard error§**	**No. of treated**	**No. of control**
Milk-Sale – No-Sale	72.66**	64.95**	20.68	156	130
MCC-Sale – No-Sale	48.28	64.14**	24.16	84	130
Other-Sale – No-Sale	101.09**	77.19**	30.84	72	130
MCC-Sale – Other-Sale	-52.81	3.77	28.73	84	72

ATT in 1 000 TZS

* (**) Significant at $\alpha = 0.05$ ($\alpha = 0.01$)

§ Bootstrapped (500 reps)

Source: Own data, calculation using *psmatch2* (Leuven & Sianesi 2003)

Table 4 reflects the results for the extended milk shed. The estimated figures generally point in the same direction as the findings for the smaller area. In detail, the estimates after matching indicate that the decision to sell milk leads to an additional amount of 66 260 TZS (US$53) available to the *enkaji*. With 74 530 TZS (US$60) and 55 340 TZS (US$44), the Other-Sellers and MCC-Sellers deviate more, yet are not significantly different from each other. Nevertheless, extending the milk shed results in many non-sellers and only a few additional milk sellers, all selling to other buyers. Hence, they are expected to achieve higher prices and consequently experience a stronger income effect. However, it becomes clear that the possibilities to sell milk decrease with the distance to the market-active centres in the western part of the research area. In other words, while the milk sellers in the more remote area may benefit from higher prices, the whole population faces limited demand, e.g. a hawker only has the capacity to transport ca. 60 to 80 litres per trip.

Table 4: Average income effect (ATT) by pairwise comparison, extended milk shed

	ATT unmatched	ATT matched	Standard error§	No. of treated	No. of control
Milk-Sale – No-Sale	76.57**	66.26**	20.25	168	189
MCC-Sale – No-Sale	57.15**	55.34*	26.70	84	189
Other-Sale – No-Sale	95.99**	74.53**	25.97	84	189
MCC-Sale – Other-Sale	-38.84	0.87	29.88	84	84

ATT in 1 000 TZS
* (**) Significant at $\alpha = 0.05$ ($\alpha = 0.01$)
§ Bootstrapped (500 reps)
Source: Own data, calculation using *psmatch2* (Leuven & Sianesi, 2003)

Indicators of matching quality and the results of the sensitivity analysis are presented in Tables 5 and 6. Comparing the mean standardised bias (SB) before and after matching, as well as the reduction in mean absolute standardised bias, is widely applied and considered a good approach for testing the balancing power of the matching procedure.

For the actual milk shed, the different SB measures are displayed in Table 5, before matching the SB ranges between 19% and 29% for the different pairwise comparisons. With a remaining mean SB of 1.87% after matching, the Milk-Sale – No-Sale pair achieves a remarkable reduction rate of 92%. The other pairs are left with a slightly higher mean SB of 4.30% to 4.77%, which still meet the generally accepted threshold of 5% remaining bias. The bias reduction is around 75% to 85%. In terms of sensitivity analysis the critical levels of gamma (Γ) are reported. They indicate how strongly an unobserved variable may influence the participation decision before we need to question the causal inference we make (DiPrete & Gangl 2004). For example, if an unobserved covariate caused the odds ratio of Milk-Sale to differ between sale and non-sale by a factor of about 1.25, we would have to reconsider our interpretations. Although this does not justify the conditional independence assumption, it does provide an idea of how sensitive the model is to hidden bias. To us, the critical levels appear sufficiently high.

Table 5: Matching quality and sensitivity analysis, actual milk shed

	Mean SB_{before}	Mean SB_{after}	% |SB| reduction	R-bounds ($\Gamma_{critical}$)	Cases lost to CS	% lost to CS
Milk-Sale – No-Sale	23.44	1.87	92.02	1.20 – 1.25	21	7.34
MCC-Sale – No-Sale	21.28	4.63	78.24	1.10 – 1.15	10	4.67
Other-Sale – No-Sale	29.01	4.30	85.18	1.20 – 1.25	25	12.38
MCC-Sale – Other-Sale	19.01	4.77	74.91	n.a.	3	1.92

Source: Own data, calculation using *psmatch2*, *pstest* (Leuven & Sianesi 2003) and *rbounds* (Gangl 2004)

Table 6 shows the results of the matching quality tests and the sensitivity analysis for the extended milk shed. Compared with the smaller area, the different pairwise comparisons reach a rather similar reduction in mean SB of 80% to 86%. After matching, the mean SBs remain at 3.31% to 4.87%. Again, the values are below 5%. When looking at the critical levels of gamma we find identical figures to those in the previous analysis for the actual milk shed. Somewhat troubling, however, are the high number of cases lost to the common support restriction when focusing on the MCC-Sale – No-Sale pair. These stem from the many non-suppliers living in remote areas that are included in the sample, but dropped because they do not have sufficient overlap and cannot be matched with the MCC-Sellers. It is likely that this causes some sort of unobserved bias due to the excluded information they carry. In our case this is probably the remoteness as the critical factor for selling milk at the MCC. This finding highlights the importance of considering the cases lost to common support as a potential source of hidden bias. Although Lechner (2001b) mentions this aspect, it is not commonly applied in the evaluation literature.

Table 6: Matching quality and sensitivity analysis, extended milk shed

	Mean SB_{before}	Mean SB_{after}	% |SB| reduction	R-bounds ($\Gamma_{critical}$)	Cases lost to CS	% lost to CS
Milk-Sale – No-Sale	26.18	3.86	86.26	1.20 – 1.25	10	2.80
MCC-Sale – No-Sale	33.35	4.87	85.40	1.10 – 1.15	70	25.64
Other-Sale – No-Sale	20.91	3.31	84.17	1.20 – 1.25	14	5.13
MCC-Sale – Other-Sale	23.08	4.73	79.51	n.a.	16	9.52

Source: Own data, calculation using *psmatch2*, *pstest* (Leuven & Sianesi 2003) and *rbounds* (Gangl 2004).

6. Conclusions

The main aim of this paper was to estimate the potential contribution of selling milk on local markets to *enkaji* income. Based on the considerations related to the special Maasai household structure and activities, we estimated the average income effect of selling milk. In order to account for sample and self-selection bias, propensity score matching was applied. The results indicate that bias did occur in the covariate distribution, which justified the application of bias-reducing methods.

For the empirical analysis we first distinguished between the actual and the extended milk shed. While the former captured those *enkajijik* that appear to have relatively easy access to milk markets, the latter included more remote settlements with limited opportunities to sell milk. The results indicate that milk sales significantly increased *enkaji* income, by 64 950 TZS and 66 260 TZS for the actual and extended milk shed respectively. When dividing the milk sellers into MCC-Sellers and Other-Sellers, the income effects for each group compared with the non-sellers remained significant. The difference between the MCC-Sale – Other-Sale pairing appeared to be insignificant, hence suggesting that it is irrelevant to whom the *enkaji* decides to sell. However, the data revealed that, in the remote area, proportionately few *enkajijik* were involved in milk marketing. In fact, remoteness is the critical factor for supplying milk to the MCC. Therefore, we conclude that, within its milk shed, the MCC offers a sustainable and reliable market that purchases large quantities. Outside the MCC milk shed, producers are restricted to other buyers with limited capacity. In a wider sense, the findings of this study support the generally accepted opinion that establishing new markets or expanding and strengthening existing markets may contribute to increasing the incomes of agricultural or pastoral households.

In this study we focused on the decision to sell milk and how milk sales affect the (gross) per capita income of Maasai *enkajijik*. Due to the lack of data on intra-*olmarei* cash flows, we were unable to properly track who actually received the sales revenues. It remains to be seen whether the *enkajijik* add the earnings to their budget or pass it on to the *olmarei* head. In the latter case, the increased income may benefit the family as a whole, if, for example, the money is invested in better animal healthcare, leading to stronger and possibly more productive cows. It may be that the decision to sell milk negatively influences the quantity available for home consumption. If reduced milk consumption is accompanied by increased grain consumption, and assuming positive caloric terms of trade, than the food security of the *enkaji* may even be strengthened by commercialisation (e.g. see Dietz *et al*. 2001). However, we leave the estimation of the effect of milk marketing on food security to future analyses.

Limitations of the research may be seen in different areas. First, the data was collected during the dry season. Hence all wet season figures may be somewhat inaccurate due to the long recall period. We therefore asked in the questionnaire for average or normal situations and included cross-checking questions. Second, despite carefully explaining the purpose and setting of the research, the respondents may have been cautious and given euphemised answers. Finally, although the data collection followed a census approach, not all households and sub-households were interviewed. This may have resulted in unobserved, systematic differences between present and absent interviewees. As PSM is not robust against hidden bias (omitted variables), we need to recognise that we can only analyse the income effect of milk sales against the background of selling and non-selling *enkajijik*, which are similar on a set of key characteristics. However, we believe that the data sufficiently captured the situation on site, and may serve as a reference for other Maasai communities or pastoralists with comparable socio-economic characteristics and infrastructural settings.

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