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Kevin W. Maina, Martin C. Parlasca and Elizaphan J.O. Rao

Social gains or losses? Evidence from dairy systems under alternative herd health management practices in Kenya

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Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Genscherallee 3
D – 53113 Bonn
Germany
Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: zef@uni-bonn.de
www.zef.de

The author[s]:
Kevin W. Maina, Center for Development Research (ZEF), University of Bonn; and Policies, Institutions, and Livelihoods (PIL), International Livestock Research Institute, Kenya. Contact: kevin.maina@uni-bonn.de
Martin C. Parlasca, Center for Development Research (ZEF), University of Bonn. Contact: mparlasc@uni-bonn.de
Elizaphan J.O. Rao, Policies, Institutions, and Livelihoods (PIL), International Livestock Research Institute, Kenya. Contact: j.rao@cgiar.org

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Abstract

Strategies for sustainable intensification of livestock are becoming increasingly important in designing interventions to develop the sector. In dairying systems, herd health management is among such strategies. While adoption patterns and productivity gains have been analyzed in previous studies, the social implications are still not well understood. This paper provides insights into the relationship between herd health management and intra-household labor demand as well as women empowerment. We test the hypotheses that the adoption of herd health management practices (HHPs) increases intra-household labor demand among male and female household members and, thereby, affects women empowerment. We use primary data from smallholder dairy farmers in Kenya on time use, women's participation in decision-making and livestock asset ownership, adoption status of important HHPs, as well as household demographic characteristics and apply censored regression and multinomial logit regression models to test our hypotheses. The results show that adopting HHPs is associated with more labor demand in dairy production for both men and women. The magnitude of the change differs across production systems but is always higher for men. Additionally, herd health management practices are negatively associated with different aspects of women empowerment including women's livestock asset ownership and control over income from dairy. The study underscores the importance for gender-sensitivity in the sustainable intensification of livestock production in the Global South.

Keywords: Herd health management; gender; labor demand; dairying; Greenhouse gases (GHGs)

JEL Codes: C31; D13; O12; O33; Q16; Q18

1. Introduction

In order to nourish a growing population while staying within planetary boundaries, the livestock sector needs to become more sustainable. Improvements in animal health represent a promising strategy for reducing the environmental footprint of livestock production while simultaneously increasing productivity. The productivity gains of improved animal health present opportunities to reduce emission intensity, especially in the Global South where the emission intensities of livestock production are comparatively high, while expenditures for herd health have, thus far, remained relatively low (FAO, 2023; Herrero et al., 2013; Özkan et al., 2022). Herd health management, which encompasses a preventive approach to livestock disease management, holistic nutrition, and enhanced reproductive management (LeBlanc et al., 2006; Magnusson et al., 2021), has, therefore, been incorporated into the low-emission development agenda in livestock development planning in the Global South (Crane et al., 2020; Ericksen & Crane, 2018).

Research on the implications of herd health management tends to focus on productivity outcomes (Notenbaert et al., 2017; Thornton et al., 2018), while social indicators are rarely considered, especially in quantitative analyses (Parlasca & Qaim, 2022). However, livestock represents a crucial element in many people's lives, especially women in the Global South, offering avenues for gender equality and women empowerment (Baltenweck et al., 2024). Changes in farming practices, such as the adoption of herd health management activities, may result in an increased time burden for the household and imply a higher capital intensity of production, both of which have the potential to challenge the pathways for female empowerment. Innovations in livestock production systems must, therefore, also be assessed from gender perspectives to achieve a more holistic understanding of their sustainability.

Against this background, this article addresses the question of how activities related to herd health management affect female and male dairy farmers in Kenya with regards to their time devoted to agricultural activities and their access and control over productive resources. Using primary data collected in Kenya in 2023, we first investigate the relationship between different herd health management practices and men's and women's time use related to farming. Given that herd health management may influence the relative involvement of women in the households' livestock husbandry activities, we also analyze if the adoption of herd health management practices can be associated with women's involvement in different agricultural decisions as well as their asset ownership.

In the study site, dairy production is primarily classified into three systems, namely extensive grazing systems, semi-intensive, and intensive systems (Benard, 2016). Intensive systems are characterized by the adoption of high-yielding breeds that are zero-grazed mainly in regions with small-landholding and high population density and peri-urban areas. Semi-intensive systems are characterized by relatively lower adoption of high-yielding breeds with farmers practicing semi-confined systems that combine grazing and stall feeding on largely unimproved fodder (Lukuyu et al., 2018). As labor requirements and gender roles often depend on where and how animals are kept, we also address possible heterogeneity across these production systems.

Our study aims to add to the literature on animal health provision in the Global South, as well as to the literature on gendered implications of emission-efficient agricultural development. While previous research shows that the distribution of costs and benefits of innovations related to low-emission development can be systematically different between men and women (Basu et al., 2019; Basu & Galiè, 2021; Doss & Quisumbing, 2020; Ndiritu et al., 2014; Quisumbing et al., 2015), these results have so far largely been based on qualitative assessments. Previous quantitative research on herd health management practices tends to focus on drivers of adoption or milk yields effects (Kebebe, 2017; Korir et al., 2023; Ries et al., 2022; Wairimu et al., 2022; Weyori, 2021), but rarely considers social dimensions. The article closest to our study is Lenjiso, (2019), who finds that the adoption of improved fodder technology, which is one of many aspects related to herd health management, can be associated with a higher amount of time women spent on dairy farming in Ethiopia. We extend this literature by analyzing the adoption of multiple herd health management practices, some of which are relatively time intensive, some of which are capital intensive, under different production systems and their implications on time allocation as well as on women's control over productive resources.

The rest of the paper is organized as follows. Section 2 provides a background of the dairy sector in Kenya and a brief conceptual framework. Section 3 outlines the study context, the sampling procedure, the measurement of key variables, and an econometric framework for our analysis. Section 4 presents the results and discussions. In section 5, we conclude with the key findings of the study.

2. Conceptual framework

Livestock play important roles as sources of income, storage of wealth, and sources of food and nutritional security for many rural farming households in Sub-Saharan Africa (Baltenweck et al., 2020; Clay & Yurco, 2020). In Kenya, the dairy sub-sector accounts for 8% of the national GDP and 14% of the agricultural GDP (Ericksen & Crane, 2018; Odero-Waitituh, 2017; Okello et al., 2021). The dairy sector in Kenya is considered among the largest in Sub-Saharan Africa (Omondi et al., 2017; World Bank, 2013), while smallholder farmers owning two to three cows account for around 80% of national dairy production (Basu & Galiè, 2021; Ngeno, 2018).

Despite the importance of dairy production in Kenya and many other countries in sub-Saharan Africa, the adoption of herd health practices often remains low (Gertzell et al., 2021). The main broad pillars of herd health include preventive animal health, holistic nutrition, and better reproductive management (LeBlanc et al., 2006). For some of the practices such as routine vaccination and the use of artificial insemination, adoption remains relatively low (Omondi et al., 2017; Teufel et al., 2021). Some practices are already adopted much more widely, including deworming and routine spraying. However, even for those activities, utilization remains below optimum levels and farmers often only respond ex-post to signs of infestation (Ericksen & Crane, 2018). Barriers to adoption are linked to limited access to information about the practices, liquidity constraints, and in some cases high costs (Maina et al., 2024; Marsh et al., 2016; Omondi et al., 2022; Railey et al., 2018).

Herd health management can increase yields, income, and GHG emission efficiency, but its implementation may also have social implications for the household. In the context of our study, we expect the adoption of productivity-enhancing technologies around herd health management to influence farmers' time use. Based on the household production function framework proposed by Udry, (1996), we assume that households maximize their labor utility by allocating their labor resources to both agricultural and non-agricultural activities subject to their current level of technology and resource constraints. A shift in the technology function would, therefore, cause households to reallocate their labor supply.

However, whether these technologies increase or decrease the time spent on farming activities most likely depends on the specific technology and the households' livestock production systems. While some herd health management practices, such as routine vaccinations, are not labor intensive per se, they have been shown to generally improve the health of animals, averting livestock death and resulting in larger herd sizes (Jumba et al., 2020). Moreover, some practices, such as better reproductive management through artificial insemination, lead to a higher proportion of improved breeds which demand new management skills among farmers, which, again, may increase time burden for farmers (Omondi et al., 2022; Quisumbing et al., 2015).

Changes in time use may be different for female and male household members due to the distinct roles and responsibilities of women and men in the study area. Women typically participate more in husbandry practices such as feeding and milking, whilst men are typically more involved in the delivery of milk, engagement in the cooperatives and hub services, purchase of inputs such as feed supplements and medicine, and collection of payments (Hovorka, 2012; Kristjanson et al., 2010; J. Njuki & Sanginga, 2013; Tavenner & Crane, 2018). Given these gendered roles in dairy farming, we analyze time burdens associated with the adoption of different herd health management practices for women and men separately.

Therefore, our first hypotheses are:

H1a: The adoption of herd health management practices is positively associated with time spent on agricultural activities by female household members.

H1b: The adoption of herd health management practices is positively associated with time spent on agricultural activities by male household members.

Data on specific time requirements for different aspects of herd health management practices and under different production systems are very scarce. It is likely that in open grazing farming systems, most herd health management practices take significantly more time compared to confined and semi-confined systems due to the additional time requirements needed for outreach, gathering animals, and possibly animal transport. It is also likely that, if herd health increases productivity, intensity is also raised in some husbandry practices such as feeding, where recommendations on holistic nutrition may require better processing of forages. In such cases, herd health may lead to more demand on women's time in confined/ semi-confined systems than in grazing systems. The effect may be indeterminate and context-specific. We, therefore, test what is applicable in the context of our study.

Our second hypotheses, which due to the scarcity of empirical literature on this topic are rather explorative, state:

H2a. For men, the additional time requirements of herd health management practices are larger under open grazing farming systems compared to confined and semi-confined systems.

H2b: For women, the additional time requirements of herd health management practices are smaller under open grazing farming systems compared to confined and semi-confined systems.

The adoption of herd health management may also influence women’s access to and control over livestock. Based on the existing literature, we propose two main channels. The first channel directly relates to time and financial resources spent on agricultural activities. When men invest more time and money in dairy farming, e.g. by purchasing veterinary inputs or carrying out activities around herd health management, men's involvement in dairy farming increases and so may their determination to influence household decisions on these matters (Grassi et al., 2015; Tavenner et al., 2019). Women may also invest more time in agriculture, but research shows that this often fails to translate into higher female empowerment (Khed & Krishna, 2023). Women rather experience a reduction in leisure time, further exacerbating issues of time poverty.

The second channel is commercialization and increased milk sales. Beyond time investments by men, the adoption of herd health management may also increase productivity and higher milk sales. Research from both livestock and arable farming suggests that increases in sales often reduce female control over decisions related to sales of output. Commercialization in dairy farming, for example, has caused an uneven distribution of labor and control in Rwanda (Clay et al., 2020).

However, context-specific gender norms are important. In the study region, evening milk, for example, is usually either consumed by the household or sold to informal markets such as neighbors. This decision is considered to be made by women. Yet, if production or sales increase substantially, the control over this decision may shift toward men (Tavenner et al., 2019). This is in line with the general finding that control of smaller and lesser-valued crop and livestock products is relatively often left to women, but when stakes increase, men tend to become more involved in these types of decisions (Chege et al., 2015; Fischer & Qaim, 2012). For the specific case of herd health management practices, gender implications are not yet well understood.

Therefore, we further hypothesize:

H3a: The adoption of herd health management practices is negatively associated with women's control and access to household livestock assets.

H3a: The adoption of herd health management practices is negatively associated with women's decision-making power related to dairy farming.

3. Materials and methods

3.1 Study area and sampling

To analyze adoption and social implications of herd health practices, we conducted a household survey in Elgeyo Marakwet, Uasing Gishu and Nandi Counties representing semi-intensive dairy systems in Kenya. The study sites also form part of a larger project led by the International Livestock Research Institute (ILRI) within the OneCGIAR initiative on Sustainable Animal Productivity for Livelihoods, Nutrition, and Gender Inclusion (SAPLING) in Kenya. We followed a multistage sampling technique to select farmers for the survey that was conducted in October-November 2023.

In the first stage, we purposively selected 5 dairy cooperatives with active membership (Lessos, Lelelchego, Tarakwo, Ainabkoi and Chepkorio). Second, we determined eligible milk collection clusters with a minimum of 20 farmers, which is the least number of farmers that can allow random replacement in case selected farmers become unavailable, and randomly selected 64 milk collection clusters. Third, using proportionate random sampling, we randomly selected 49 routes and subsequently randomly sampled 578 dairy farmers. Figure 1 shows a map of the sampled area, and a detailed sample distribution is provided in the online appendix (see Table S1). Data were collected through face-to-face interviews with the household head and the spouse to ensure questions regarding labor participation and decision-making were fully answered.

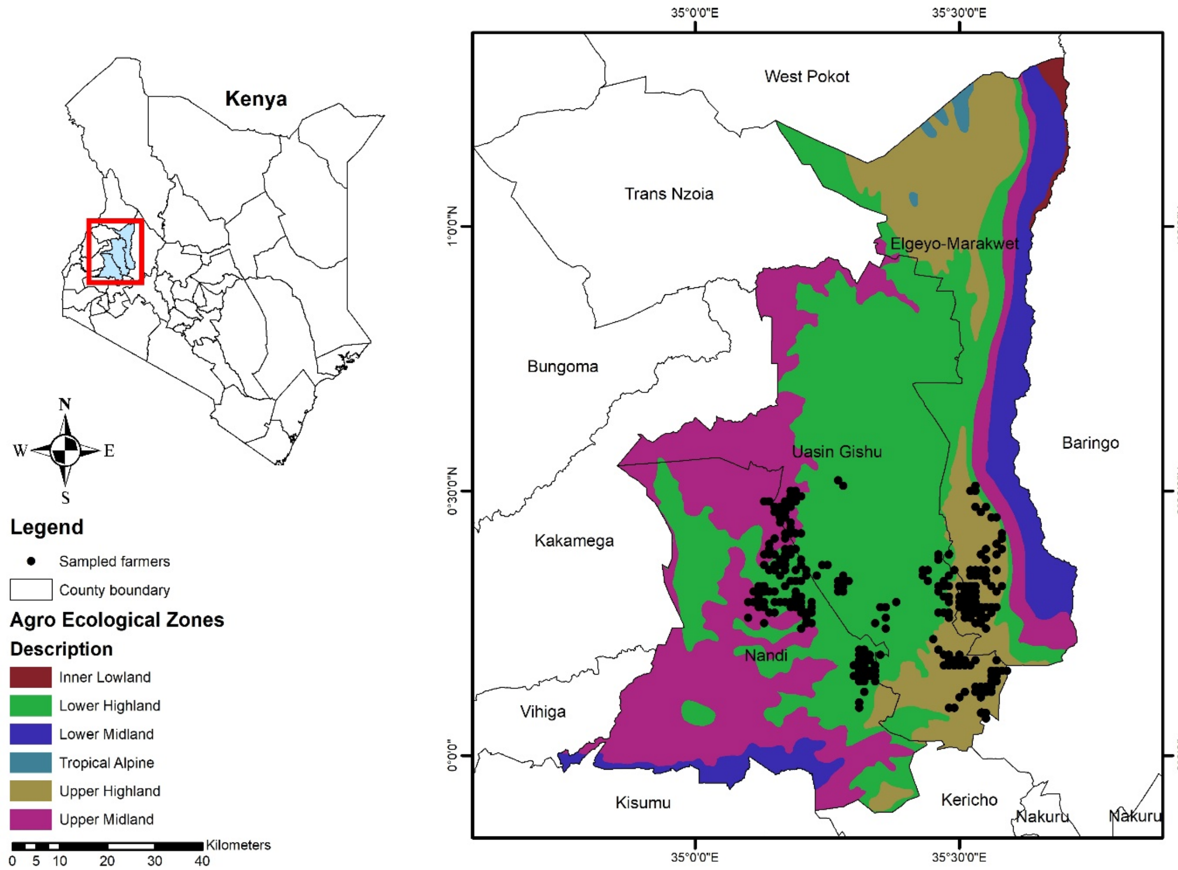

Figure 1: Map of the sampled area

3.2 Definition and measurement of key variables

For herd health management practices, we collected data on several different practices based on literature (Derks et al., 2014; Ericksen & Crane, 2018; Green et al., 2012; Hall et al., 2004; Skjølstrup et al., 2021). Farmers' use of commercial dairy meals and mineral blocks relates to the pillar of holistic nutrition. The use of artificial insemination reflects better reproductive management. We also include practices related to preventive animal health, namely deworming using anthelmintics, tick control through spraying, and routine vaccination against [1]notifiable and [2]non-notifiable diseases prevalent in the region. For the main analysis, we focus on the extent of adoption, which we measure as the number of herd health management practices adopted by

[1] Notifiable diseases refer to zoonotic diseases whose vaccination is provided for free or for a subsidized cost by the government e.g. Rift Valley Fever (RVF), Foot and Mouth (FMD) and Anthrax.

[2] Non-notifiable diseases include tick-borne diseases such as East Coast Fever (ECF).

the household. This indicator ranges from zero (no practices adopted) to five (all practices adopted), but we also analyze individual practices.

Data on labor use in dairy production covers family labor in dairy-related activities measured by average weekly hours spent per person, captured for both primary adult male and female household members who contributed to family labor in the last 12 months preceding the survey. Labor data encompass participation in different activities including, the collection of manure, grazing, crop production, feeding (collection and preparation), on-farm fodder production, milking, and cleaning of animal sheds. Children in the study area are typically engaged in schooling activities so that active child labor is rare.

For women's decision-making and control, we adapt measures of decision-making and control over resources from the Women Empowerment in Livestock Index (WELI) tool[3] developed by Galiè et al., (2019). We evaluate women's decision-making in production decisions and on use of income. Specifically, we collect data on decisions regarding dairy production (e.g. decision on livestock breeds, animal treatment, growing of fodder), and decisions on the use of income received from the sale of livestock, and sale of milk (morning and evening). Decisions are categorized to be made by either the woman alone, or jointly by the woman and man, or by the man alone. We also measured livestock asset ownership by women (owned both individually and jointly). This is quantified as the number of livestock, measured in Tropical Livestock Units (TLUs), owned by the women divided by the total amount of livestock owned by the household.

[3] See Table S2 in the online appendix.

3.3 Estimation strategy

To test hypotheses 1a and 1b, we first analyze the association between the adoption of herd health management practices and time used for farming by women and men. Given that time spent on farming is left-censored at zero, our analysis is based on the following Tobit model (Tobin, 1958), which we estimate separately for men and for women:

$$y_i^* = \beta\left(\sum_{k=1}^{5} t_i\right) + X_i\omega_i + \varepsilon_i, \text{with}$$

$$y_i = max(y_i^*, L)\begin{cases} y_i = y_i^* if \;\; y_i^* \geq \; L \\ \vdots \quad \vdots \quad \vdots \\ y_i = L \; if \; y_i^* < \; y_i^* \end{cases} \quad where\ L\ is\ a\ lower\ threshold\ for\ y \tag{1}$$

where y_i^* is the observed weekly labor hours spent by female or male household members in dairy production activities for household i. The extent of adoption is measured as the sum of the adoption dummies of five specific herd health management practices t_i. Our main coefficient of interest for hypotheses 1a and 1b is β.

Given that the adoption of herd health management practices is not random, we adjust for a range of household and farm characteristics captured by the vector X_i. These variables include gender, age, and dairy farming experience of the household head, herd size, a dummy indicating whether dairy farming is the households' main occupation, a categorical variable for the production system, the household size, and a dummy indicating whether or not households hired labor for their dairy farming operations. We estimate robust error terms denoted by ε_i.

Despite controlling for a range of socio-economic control variables, we cannot rule out potential bias resulting from unobserved heterogeneity. We aim to grasp a better understanding of the importance of the inclusion and exclusion of control variables, by estimating specification curves for the coefficient β (Simonsohn et al., 2015). In particular, we plot point estimates and confidence intervals for all possible combinations of control variables, with the exception of the dummy for hired labor, which is always included due to the strong link to farmers' time use. Still, it is important to mention that the coefficients estimated in equation 1 represent conditional associations and should not be interpreted as causal estimates.

In the analysis of time use, we also consider a model where each herd health management practice is included as a separate treatment variable. This allows insights into time burdens associated with specific practices. The respective model is:

$$y_i^* = \gamma_i t_i + X_i\omega_i + \epsilon_i, \text{with} \tag{2}$$

$$y_i = max(y_i^*, L)\begin{cases} y_i = y_i^* if \;\; y_i^* \geq \; L \\ \;\;\vdots \quad\;\; \vdots \quad\;\; \vdots \\ y_i = L \; if \; y_i^* < \; y_i^* \end{cases}$$

where γ_i is a vector of coefficients associated with each of the five practices t_i.

To test hypotheses 2a and 2b, we estimate the following tobit model:

$$y_i^* = \beta\left(\sum_{k=1}^{5} t_i \,|G_i\right) + X_i\omega_i + \epsilon_i, \text{with}$$
$$y_i = max(y_i^*, L)\begin{cases} y_i = y_i^* if \;\; y_i^* \geq \; L \\ \;\;\vdots \quad\;\; \vdots \quad\;\; \vdots \\ y_i = L \; if \; y_i^* < \; y_i^* \end{cases} \tag{3}$$

Here, we estimate three parameters of interest, namely the association between the extent of herd health management practices and time use, for each of the three management systems G_i, again adjusting for the same control variables as in equations 1 and 2.

To test hypotheses 3a and 3b, we estimate a multinomial logit model following McFadden, (1973) for each of the gender-related outcome variables discussed in the previous section:

$$D_{ij}^* = m_{ij}\beta_{ij} + X_{ij}\omega_{ij} + \varepsilon_{ij} \tag{4}$$

where D_{ij}^* are gender-related outcomes on asset ownership and involvement in management decisions and control of income discussed in detail in the previous section. D_{ij}^* is measured as a categorical variable capturing decisions by men alone, women alone, and joint ($j = 1, 2, 3$). We then estimate the probability of the effect of adopting HHPs (β_{ij}) on D_{ij}^* by maximum likelihood and obtain consistent estimates as:

$$P_{ij} = \Pr\left(\beta_{ij}, \omega_{ij} < 0 | m_{ij}, X_{ij}\right) = \frac{\exp\,(m_i\beta_j, X_i\omega_j)}{\sum_{n\neq 1}^{j} \exp\,(m_i\beta_n, X_i\omega_n)} \quad j = 1{,}2{,}3 \tag{5}$$

Again, these results do not represent causal estimates, but rather conditional associations.

4. Empirical results

4.1 Descriptive statistics

Descriptive statistics of the sampled households are presented in Table 1.

Table 1: Descriptive statistics of sampled farmers

Variables	Mean	Std dev
Male household head (male = 1)	0.79	
Age of household head (years)	53.53	14.19
Education of household head (years of schooling completed)	13.03	4.41
Dairy farming experience (years)	21.20	14.27
Household head main occupation (farming = 1)	0.74	
Household size (count)	5.33	1.99
Livestock ownership (TLU)	4.89	3.85
Grazing system (yes = 1)	0.38	
Wealth index	59.76	12.89
Hired labor (yes = 1)	0.42	
Individual HH practice		
Deworming	1.00	
Routine vaccination	0.28	
Tick control	0.74	
Artificial insemination (AI)	0.40	
Adoption intensities of HH practices		
One practice	0.01	
Two practices	0.16	
Three practices	0.39	
Four practices	0.36	
Five practices	0.08	

Notes: N = 578. TLU = tropical livestock units with conversion factors based on Njuki et al., (2011) for Sub-Saharan Africa. Herd health (HH)

The majority of sampled households are headed by men who practice farming as their main occupation, owning an average herd size of 5 tropical livestock units (TLU) with 38% under grazing type of production systems. We also find that farmers adopt practices related to holistic nutrition, deworming, and tick control. However, routing vaccination and artificial insemination have a lower rate of utilization. Similarly, a majority of farmers adopt between 3-4 practices and seldom observe the adoption of one practice.

4.2 Associations between the adoption of herd health practices and time allocation

Table 2 presents the regression estimates on the association between the adoption of HHPs and time allocation to dairy-related production activities for both primary adult male and female household members. We find that the adoption of herd health management practices is associated with an increase in the time spent on livestock activities for both men and women. Each additional practice is associated with more than 3h additional workload per week for women (column (1)) and 8 hours per week for men (column (3))

Moreover, even when we look at specific practices, we find statistically significant and positive associations for most practices on time use for both men and women. The magnitudes of the coefficients are particularly large for practices related to improved nutrition. One exception is artificial insemination, which is associated with fewer hours spent on farming for women. This may be explained by the fact that AI is less labor-intensive compared to the use of bulls for insemination, which requires more time in handling animals.

Table 2: Regression estimates on the association between herd health management practices and intra-household labor demand

	Female members		Male members	
	(1)	(2)	(3)	(4)
Number of practices adopted	3.45**		8.00***	
	(1.44)		(2.25)	
Individual practices				
Deworming		2.82		-10.72
		(15.52)		(22.66)
Routine vaccination		7.92***		11.15***
		(2.68)		(4.34)
Tick control		7.23**		11.01**
		(3.09)		(4.70)
Artificial insemination (AI)		-5.23**		1.87
		(2.71)		(4.32)
Holistic nutrition (commercial dairy		16.08**		16.16*
meal/mineral blocks)		(6.76)		(9.20)
Household controls				
Male household head (male = 1)	0.12	0.88	27.88***	28.22***
	(3.28)	(3.26)	(5.76)	(5.77)
Age of household head (years)	-0.16	-0.15	-0.64***	-0.63***
	(0.15)	(0.15)	(0.23)	(0.23)
Dairy farming experience (years)	0.06	0.08	0.43**	0.43**
	(0.15)	(0.15)	(0.22)	(0.22)
Household head main occupation (farming = 1)	-3.82	-5.31*	12.13***	10.98**
	(3.11)	(3.10)	(4.50)	(4.53)
Household size (count)	0.05	0.02	-0.78	-0.79
	(0.75)	(0.74)	(1.11)	(1.10)
Livestock ownership (TLU)	-0.46	-0.46	-0.47	-0.46
	(0.36)	(0.36)	(0.55)	(0.55)
Wealth index	-0.38***	-0.31***	-0.60***	-0.56***
	(0.13)	(0.13)	(0.19)	(0.19)
Grazing system (yes = 1)	-6.60***	-8.25***	-9.71**	-11.11***
	(2.67)	(2.70)	(4.11)	(4.20)
Hired labor (yes = 1)	-5.58*	-5.41*	-5.76	-5.58
	(2.98)	(2.92)	(4.52)	(4.50)
Pseudo R^2	0.01	0.02	0.02	0.03

Notes: N = 578. Regression coefficients are shown with robust standard errors in parentheses. Statistical significance at *p < 0.1, **p < 0.05, ***p < 0.01.

To analyze the potential sensitivity of the coefficients in column 1 and 3 to omitted variables, we present specification curves for the coefficients in Figure 2.

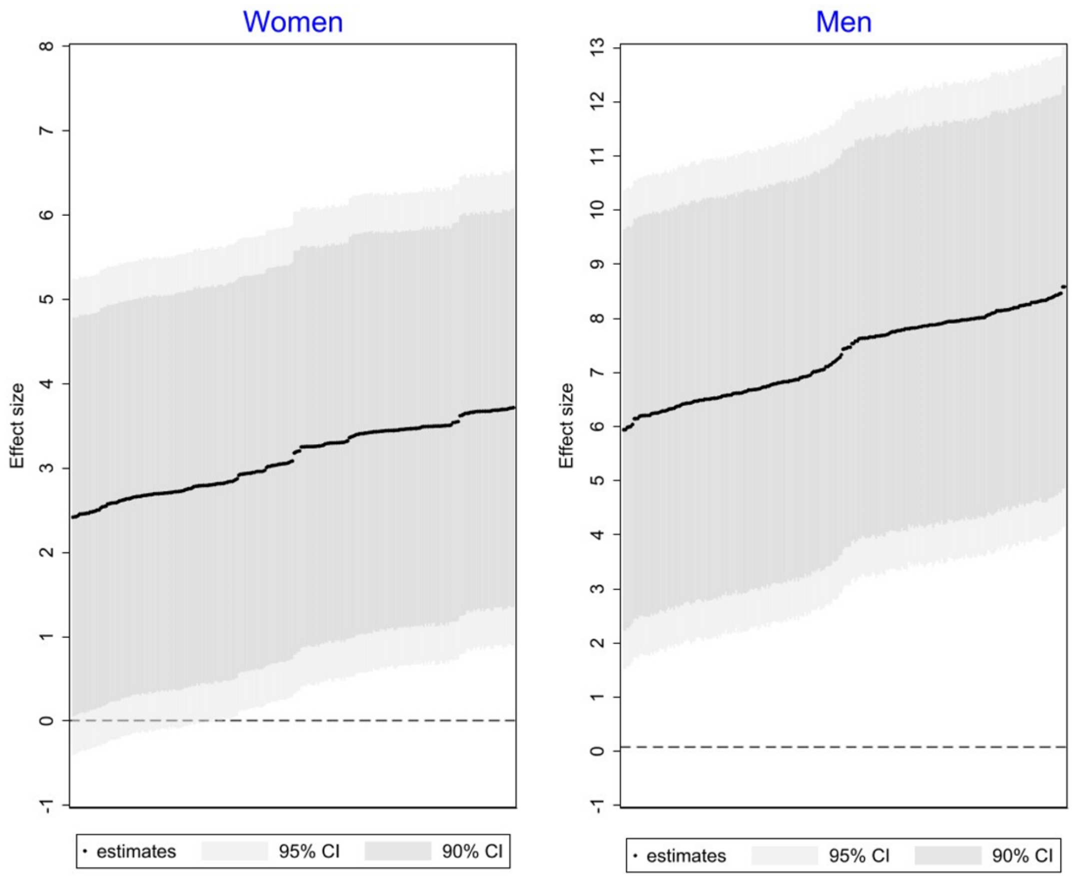

Figure 2: Specification curve on the effect of herd health practices on time use for men and women

Our coefficient point estimates are rather stable. For all 256 possible combinations of control variables, the coefficient for female time use is statistically significant at least at a 10% level and the coefficient for male time use is statistically significant at a 5% level. We, therefore, find empirical support for both Hypothesis 1a and 1b.

To test hypotheses 2a and 2b, we compare if the relationship between time use and herd health management practices differ across production systems (eq. 3) (grazing vs confined/ semi-confined systems). Regression results are shown in Table 3.

Table 3: Associations between herd health management practices and intra-household labor demand by livestock management system

	Female members	Male members
	(1)	(2)
Number of practices adopted	4.21***	9.16***
	(1.45)	(2.27)
Number of practices adopted X grazing system	-1.71**	-2.77**
	(0.75)	(1.16)
Household controls	Yes	Yes
Pseudo R^2	0.01	0.03

Notes: N = 578. Regression coefficients are shown with robust standard errors in parentheses. Household controls are gender, age, dairy experience, main occupation of the household head, household size, livestock management system (free-grazing or zero-grazing), herd size (TLU), wealth index, use of hired labor. Statistical significance at *p < 0.1, **p < 0.05, ***p < 0.01.

We find that in grazing systems, the increase in labor hours associated with the adoption of HHPs is lower compared to confined systems. This holds for both women and men. This supports hypothesis 2a but is in contradiction with hypothesis 2b. Still, the fact that the increase in labor demand for women is weaker in grazing systems is not implausible. In confined systems, it is likely that the intensity of some practices such as feeding may require more processes such as preparation compared to grazing systems. This is a particular concern for women since animals are closer home and women are likely to have added responsibilities to their other domestic roles in the homestead. We also find household labor participation in different husbandry practices increases in confined systems compared to grazing systems (see Table S3 in the online appendix).

4.3 Associations between the adoption of herd health practices and intra-household decision-making and control

Table 4 shows regression coefficient estimates for variables measuring intra-household decision-making and control over resources following equations 4 and 5. For livestock asset ownership, we find a negative relationship between the adoption of HHPs and individual livestock asset ownership by women. Thus, the relative probability of men owning livestock assets is double (2.03[4]) that of women as households adopt more HHPs. On the contrary, although not significant, we observe a positive relationship for joint ownership between women and their spouses. This similar pattern is also observed in dairy production decisions as the intensity of adopting HHPs increases.

[4] Computed by taking the exponent of the coefficient.

Table 4: Multinomial regression estimates on the association between herd health management practices and intra-household participation in decision-making and control

	Livestock asset ownership	Decision on			
		dairy production activities	income from sale of livestock	income from sale of milk (morning)	income from sale of milk (evening)
	(1)	(2)	(3)	(4)	(5)
Base = men alone					
Joint	0.17	0.16	-0.05	-0.29**	-0.73**
	(0.11)	(0.12)	(0.14)	(0.13)	(0.30)
Women alone	-0.71***	-0.32	-0.69***	-0.52***	-0.72**
	(0.23)	(0.22)	(0.25)	(0.17)	(0.35)
Household controls	Yes	Yes	Yes	Yes	Yes
Chi2 (20)	161.92***	197.41***	110.54***	153.09***	48.65***
Pseudo R^2	0.27	0.29	0.13	0.18	0.05

Notes: N = 578. Regression coefficients are shown with robust standard errors in parentheses. Household controls are gender, age, dairy experience, main occupation of the household head, household size, livestock management system (free-grazing or zero-grazing), herd size (TLU), wealth index, use of hired labor. Statistical significance at *p < 0.1, **p < 0.05, ***p < 0.01.

For decisions regarding income from the sale of livestock and milk (both morning and evening), there is a negative relationship between the involvement of women in decision-making and the adoption of HHPs. This also includes their participation in joint decision-making with their spouses. Interestingly, milk produced in the evening is usually consumed at home or sold to neighbors - a decision taken by women. It is possible that men finance the HHPs and would therefore like to recoup their invested finances, hence the growing role in decisions over dairy income with increasing adoption of HHPs. Thus, men are likely to take control over income from the sales (Tavenner et al., 2019). The results are comparable even when we control for time use and the level of milk production (see tables S4 online appendix). We find that time use is often statistically significant and also with the expected sign, but we do not see strong mediation effects.

5. Discussion and Conclusion

In this study, we evaluated the social impacts of adopting herd health practices in dairying systems in Kenya. We specified five practices namely, deworming, tick control, routine vaccination, holistic nutrition (use of mineral blocks/commercial dairy meal), and artificial insemination to understand the social implications at the household level. Our findings reveal that the adoption of HHPs area associated with higher demand for family labor for both men and women, potentially increasing issues around women's time poverty. This is consistent with prior studies on multiple agricultural technology adoption and labor demand (Addison et al., 2020; Lenjiso et al., 2016; Mwambi et al., 2021; Teklewold et al., 2013).

Given the role that women play in livestock production in the study context, HHPs will result in labor reallocation increasing the labor burden on women. Further, our heterogenous analysis shows that the association between HHPS and women's time use is stronger in confined/semi-confined production systems. However, at higher intensification/commercialization levels, households are more likely to be able to afford external labor, leading to more time saving for women as in the case of dairying intensification and child nutrition in Kenya (Njuki et al., 2016). Therefore, of policy concern, is the effect of initial intensification on changes to roles and responsibilities between men and women.

In terms of decision and control over resources, we find that the adoption of HHPs reduces individual ownership of livestock assets by women. We also find that the adoption of HHPs reduces women's control over income from the sale of livestock and milk. Therefore, as dairy production becomes more commercialized – herein increased investments in intensification practices such as HHPs, women are likely to be pushed out of the enterprise to other farm enterprises that may not be as lucrative to the men as dairy. Similar findings have also been observed in other studies where men increase their control over incomes when production intensities and sales increase (J. Njuki & Sanginga, 2013; Price et al., 2018). Thus, further scaling of herd health management practices may contribute to the disempowerment of women, negating gains already made in the dairy sector.

It is important to note a few limitations in this study. First, our study does not have comprehensive time-use data that captures other economic and social activities. Second, our study relies on observational data and cannot fully account for all possible sources of heterogeneity. Additionally, the outcome variables are based on recall data which can be biased due to measurement error (Abay et al., 2021).

The findings of this study provide important policy implications required for targeting support and investment in scaling herd health management practices. First, the negative effects of HHPs on women’s time poverty underscores the need to have nuanced policy support that addresses access to institutional services such as extension services by women in varying dairy production systems. Increased labor participation by women needs to be complimented by other interventions that increase their access to knowledge on the use of new technology - which in practice is often not the case (Grassi et al., 2015). This should include both strengthening existing extension service delivery models and establishing alternative approaches such as leveraging the use of ICT and mobile phone services. In Kenya, this is already complemented by an unprecedented growth in the uptake of mobile phones occasioned by improved support infrastructure and internet access.

Second, the negative effects of HHPs on women’s livestock asset ownership, and participation in decisions over incomes from the dairy enterprise call for a need to implement strategies that foster the transformation of gender norms as a start. Future scaling of HHPs should be complemented by interventions that can help transform restrictive gender norms that contribute to disproportionate sharing of labor and responsibilities among men and women. For example, encouraging active membership and participation of women in dairy cooperatives. Such strategies will likely enhance an equitable share of the workload, livestock resources, and income even as adoption is ramped up.

In conclusion, future research should aim to deepen our understanding of how HHPs affect women’s labor allocation and time poverty in different livestock production systems. Moreover, research should explore strategies for transforming restrictive gender norms that limit women’s asset ownership and participation in production and income-related decision-making. This will be vital in developing comprehensive interventions that enables the livestock sector to contribute to women empowerment and gender equity.

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Online supplementary material

S.1 Distribution of sample size

Table S1: Distribution of sampled households by County and gender of household head

County	Number of households		
	Gender of household head		Total
	Female-headed	Male-headed	
Uasin Gishu	30	119	149
Nandi	40	176	216
Elgeyo Marakwet	51	162	213
Total	121	457	578

S.2. Sample questions on decision-making from WELI tool by Galiè et al., (2019)

Table S2: Sample questions on decision making adapted from WELI tool

Variable name	Question	Variable definition
Livestock asset ownership		
Share of assets owned by household members	Number of animals owned by1=Male; 2=Female; 3=Joint	Categorical variable is defined where 1 = women alone 2 = men alone and 3 = joint
Female involved in management decisions		
Livestock activities (categorical)	Who is involved in livestock management decisions including the type of breeds to keep, and breeding methods? (1=Male; 2=Female; 3=Both)	Categorical variable is defined where 1 = women alone 2 = men alone and 3 = joint
Female involved in income decisions and control		
Livestock income (categorical)	Who is involved in deciding on how the income generated from sale of livestock is used? (1=Male; 2=Female; 3=Joint)	Categorical variable is defined where 1 = women alone 2 = men alone and 3 = joint
Milk income morning (categorical)	Who is involved in deciding on how the income generated from sale of milk in the morning is used? (1=Male; 2=Female; 3=Joint)	Categorical variable is defined where 1 = women alone 2 = men alone and 3 = joint
Milk income evening (categorical)	Who is involved in deciding how the income generated from sale of milk in the evening is used? 1=Male; 2=Female; 3=Joint)	Categorical variable is defined where 1 = women alone 2 = men alone and 3 = joint

S.3. Time allocation by household member on different animal husbandry practices by livestock management system:

Table S.3: Time allocation by household member on different animal husbandry practices by livestock management system

	Grazing system		Confined/Semi-confined system	
	Women	Men	Women	Men
Cleaning of animal shed/shelter	0.22	3.00	1.09	1.33
Collection of Farmyard Manure (FYM)	0	3.00	1.84	2.6
Feeding (+ collecting & preparation)	1.64	2.21	1.50	2.32
Fodder/feed production on farm	1.37	2.52	1.77	2.02
Grazing	1.75	2.60	1.92	2.54
Milking and milk processing	0.97	1.89	1.49	2.07
Providing water to the animals	1.48	2.14	1.61	2.05
Selling milk	1.19	2.29	1.17	2.24
Spraying	0	0	1.00	1.00

S.4. Assessment of the association between herd health practices and intra-household participation in decision-making while controlling for the level of milk production and time use:

Table S4: Multinomial regression estimates on the association between herd health practices and intra-household participation in decision-making when controlling for level of milk production and time use

	Livestock asset ownership	Decision on			
		dairy production activities	income from sale of livestock	income from sale of milk (morning)	income from sale of milk (evening)
	(1)	(2)	(3)	(4)	(5)
Base = men alone					
Joint	0.23**	0.24**	-0.03	-0.33**	-0.69**
	(0.12)	(0.12)	(0.14)	(0.13)	(0.31)
Women alone	-0.65***	-0.24	-0.67***	-0.46***	-0.72**
	(0.24)	(0.21)	(0.25)	(0.17)	(0.36)
Women time use	Yes	Yes	Yes	Yes	Yes
Men time use	Yes	Yes	Yes	Yes	Yes
Level of milk production (daily)	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes
Chi2 (26)	172.58***	244.71***	139.47***	159.51***	66.86***
Pseudo R^2	0.29	0.32	0.16	0.18	0.07

Notes: N = 578. Regression coefficients are shown with robust standard errors in parentheses. Household controls are gender, age, dairy experience, main occupation of the household head, household size, livestock management system (free-grazing or zero-grazing), herd size (TLU), wealth index, use of hired labor. Statistical significance at *p < 0.1, **p < 0.05, ***p < 0.01.