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Understanding smallholder dairy productivity and poverty reduction in Eritrea: An A-WEAI approach

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Abstract

Improving the poverty status of smallholder dairy farmers in Eritrea necessitates an increase in dairy production efficiency. This study investigated the influence of empowerment programs on smallholder dairy production, specifically those aimed at fostering the development of knowledge and skills for both male- and female-headed households. The Abbreviated Women Empowerment in Agriculture Index (A-WEAI) and an instrumental variable estimator (IVE) were used to analyze data collected from 379 households in three Eritrean communities. The findings show that male household heads are more empowered than their female counterparts. Analysis at the Zoba (regional) level showed disempowerments for all households in Anseba

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Author Contributions

Conceptualization, Stephen Onakuse; methodology, Lilian Treasure and Stephen Onakuse; software, Stephen Onakuse and Lilian Treasure; investigation, Okbasilassie Msghina and Kahsay Negash; data curation, Lilian Treasure; writing—original draft preparation, Lilian Treasure; writing—review and editing, Lilian Treasure and Stephen Onakuse; supervision, Stephen Onakuse; project administration, Stephen Onakuse; funding acquisition, DeSIRA project team. All authors have read and agreed to the published version of the manuscript.

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(65.42%), followed by Debub (57.02%) and Maekel (33.11%). Empowerment had a positive effect on labor productivity among male- and female-headed households, resulting in increases of 11.50% and 18.49%, respectively, and on poverty reduction, with empowerment increases of 10.57% and 9.91%, respectively. In addition, the level of education, the farmers' age, and the price of milk had a negative effect on labor productivity among male and female dairy farmers. Dairy experience, labor cost, and membership in a cooperative had a positive effect on the labor productivity of male farmers. Herd size (with a positive coefficient), type of dairy production practice, and perception of government policies on dairy farming (with negative coefficients) were essential factors that affected labor productivity among male and female dairy farmers in Eritrea. Land rent, frequency of extension visits, milk unit price, dairy experience, and number of lactating cows affected asset accumulation among Eritrean dairy farmers. We recommend context-specific innovative empowerment strategies to boost productivity and market access and reduce poverty, particularly for female farmers. Gender disparities in Eritrean dairy farming show that women face greater disempowerment. Involving more women in these strategies can reduce the gender gap, promote gender equality, and support sustainable development in Eritrea.

Keywords
smallholder, dairy, women, market, A-WEAI, productivity, instrumental variable (IV), Eritrea

Introduction and Literature Review

Like many other developing countries, the agricultural sector employs about 80% of Eritreans (World Bank, 2021), and dairy farming constitutes a significant component (Climate Smart Agriculture Research and Innovation Support for Dairy Value Chains in Eritrea [CSARIDE], 2021). Eritrean small-scale subsistence farmers own approximately 90% of all dairy animals (Doss et al., 2013). Dairy farming is a significant source of income and an important livelihood activity for most households in Eritrea, contributing to food security and poverty reduction (CSARIDE, 2021). All land in Eritrea is owned by the government, which reduces dairy farmers' access to the Agricultural Land Food and Agriculture Organization database (FAOLEX, 2023). The Eritrean government temporarily grants access to land for farmers and can be inherited. On the one hand, the land reforms only allow allocation of land on usufruct, or for temporary use, though land can be inherited and leased, but not sold or granted as a gift (Castellani, 2000; Fullerton Joireman, 1996). This individual allocation of land restricts large-scale allocation and further enforces settlement for small farms. Enforced settlement increases production costs for small-scale farmers and is ineffective (Fullerton Joireman, 1996). Dairy farming in Eritrea allows women to earn income that contributes to their livelihoods, provides room for women to make decisions, propose ideas that improve household and community poverty status, and take on leadership roles (Ahn, 2022). Consequently, smallholder dairy farming activities promote women's participation in decision-making and enhance their economic and social status (Ahn, 2022; Dohmwirth & Hanisch, 2018; Heyde, 2001).

Although robust legal frameworks that incorporate gender equality and equity exist in developing countries, social norms and customs work against women's rights and limit their potential to contribute to decisions that will improve dairy farming and reduce poverty within households (Boeding, 2017; Doss et al., 2013; Price, 2020). Gender discrimination exacerbates household poverty by limiting access to agricultural resources and reducing the bargaining power of women within households, communities, and society. There is a paucity of data on the actual population of Eritrea and the rates of poverty (World Bank, 2021); however, about 66% was estimated to live below the

Conflict of Interest Disclosure
The authors declare no conflict of interest as the authors agreed to the design of the study, data collection, analysis, or interpretation of the literature materials, the writing of this manuscript, and the decision to publish the results. The views expressed and arguments employed in this paper are the authors' sole responsibility and do not necessarily reflect the official position or opinions of the organization with which the authors are affiliated.

Data Availability Statement
Data for this study will be made available upon request.

poverty line in 2018 (Jennings, 2018), and the poorest among them are female-headed households (United Nations International Children's Emergency Fund [UNICEF], 2022). Several agricultural transformation models are currently being implemented to improve the poverty status of Eritreans (Ministry of Women Affairs, 2017). However, due to a significant shortage of agricultural resources and poor program implementation (Adams, 2017), poverty persists, especially among the 65% of the population residing in rural areas, who depend on agriculture for livelihood (Boeding, 2017).

Consequently, most agricultural projects in Eritrea are designed to improve productivity and reduce poverty among dairy farmers, often focusing on empowering women. Empowerment is a multidimensional process ensuring that essential capacities, participation in socioeconomic and sociocultural domains, and the legal rights of the most vulnerable people are achieved (Patel & Patel, 2022). Women's empowerment increases autonomy over their lives, bodies, finances, social interactions, and external environment (Idris et al., 2023; Kabeer, 2005; Kishore & Lekha, 2008). However, this result is paradoxical. Studies have shown that while ownership of cows by women enhances empowerment and gender equity, it may also disempower them by increasing women's "time poverty," that is having too many things to do but with limited time to do them, due to increased labor responsibility (Bain et al., 2020; Hyde et al., 2020; Rodgers, 2023)

Dairy farming is labor-intensive. Labor accounts for approximately 15–20% of the total cost of production (Durst, 2020) and can easily be under- or overutilized. Therefore, to avoid productivity loss, proper labor management in dairy farms is necessary because it enhances the scale and volume of production and improves cost efficiency (Stankov, 2020). Because labor is an essential factor in dairy production, it was used to evaluate productivity in this study. To develop a comprehensive measure of the effect of interventions on labor productivity and poverty reduction among small-scale dairy farmers, the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) approach was used. This measure is used in the context of gender inequality in access to agricultural resources. A-WEAI comprises five domains (5DE): production, resources, income, leadership, and time. According to Alkire et al. (2013), the production domain is concerned with sole or joint decision-making about inputs in crops/food, livestock, or fisheries production. The resource domain is concerned with ownership of at least one major household asset as well as sole or joint access to and decision-making authority over credit, and the income domain concerns control over the use of household income and expenditure either solely or jointly among household members. The leadership domain focuses on being an active member of at least one formal or informal social or economic group, and time is an indicator of the workload of household members in dairy production, either solely or jointly, while deriving satisfaction for leisure activities.

Though there are empirical studies on agricultural productivity and poverty reduction, very few studies have focused on dairy farming, poverty reduction, and empowerment (Bain et al., 2018, 2020; Kabunga, 2014; Lyatuu et al., 2022; Martin et al., 2020; Ruiz-Torres et al., 2022; World Bank, 2016). Dairy farming can reduce farmers' (CSARIDE, 2021). However, with the notable exception of Bain et al. (2020) and Bain et al. (2018), there is very little literature on dairy productivity, poverty reduction, and empowerment as measured by WEAI. Thus, this study addressed the following questions:

- How does empowerment, as measured by A-WEAI, affect the productivity of smallholder dairy farmers in Eritrea?
- Are there any regional differences in the levels of empowerment and disempowerment among smallholder dairy farmers in Eritrea?
- Which factors are the most significant determinants of labor productivity and poverty among Eritrean dairy farmers?
- How do household characteristics, such as education, age, and dairy experience, influence dairy farming productivity and the economic status of households?

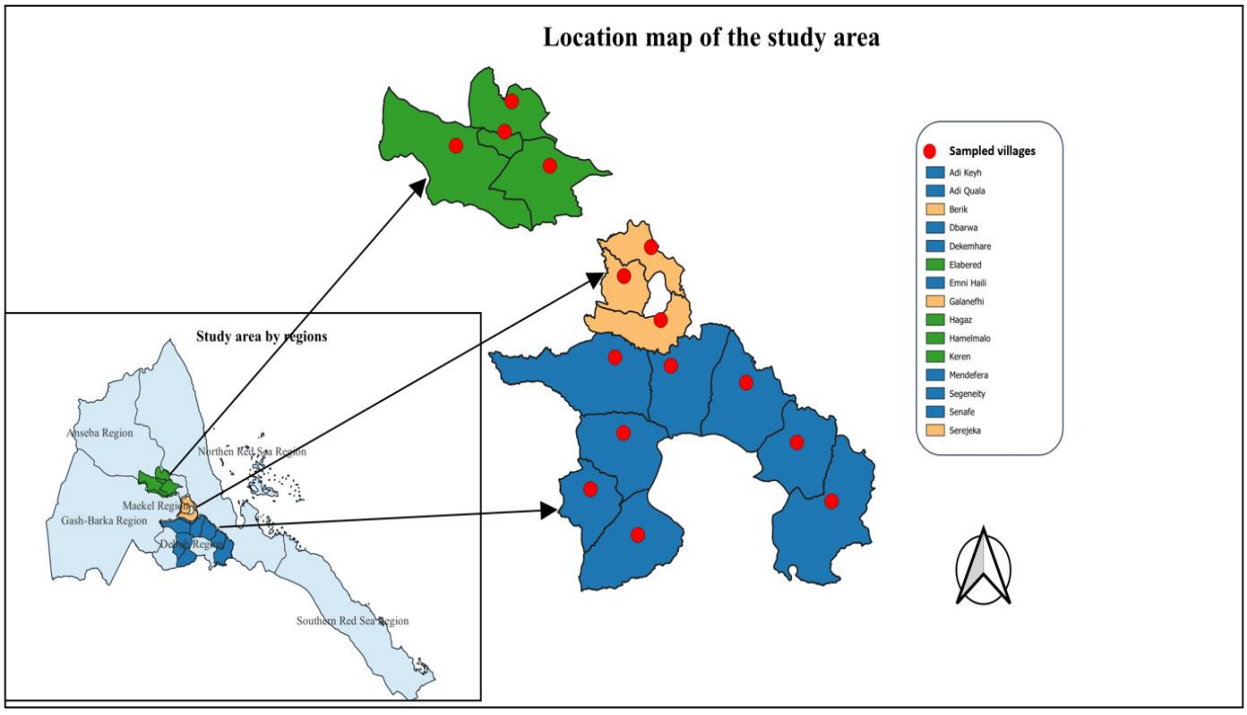
To address these questions, this study focuses on labor productivity and poverty reduction, measured as the asset index score (AIS) among small-scale dairy farmers. Additionally, empowerment was measured using the A-WEAI tool. The effect of empowerment on labor productivity and poverty reduction was specified using an instrumental variables (IV) estimator. However, this study was limited by the low participation of women in the intervention programs because of social norms and culture. This may have influenced the outcome of this study, particularly in comparing the level of empowerment between male- and female-headed households in Eritrea.

Research Methods

Three key dairy regions in Eritrea were carefully selected for this study: Debub, Maekel, and Anseba (CSARIDE, 2021). These regions, which are among the most populous and economically significant in the country (World Bank, 2011), were chosen for their administrative importance. Maekel includes the capital city of Asmara, and Debub is central to the country's governance and economy, making the two regions critical areas for understanding broader regional dynamics (Efrem et al., 2023). In addition, both regions have substantial dairy cattle populations. Studies reveal that Maekel has an estimated 4,696 dairy cattle in 1,118 herds, whereas Debub has 7,778 dairy cattle in 1,511 herds (Efrem et al., 2023). Furthermore, Maekel offers reliable infrastructure and accessibility, facilitating data collection and sample analysis.

The chosen regions represent different agro-ecological zones, with Maekel and parts of Debub being highland areas and Anseba representing midland areas (Figure 1). The study population comprised all male- and female-headed dairy farming households in Debub, Maekel, and Anseba. From each zoba, or administrative region, sub-sobas were randomly selected, and 421 dairy farmers were randomly chosen across all the zobas based on the number of participants from each. The selection of these regions is necessary because they are areas of project intervention (CSARIDE, 2021). In total, 140 dairy farmers were chosen from Debub, 141 from Maekel, and 140 from Anseba. Maekel has many dairy farmers in its zobas (CSARIDE, 2021).

Figure 1. Map of the Study Area



Author's description of the study area using QGIS 3.30.3, 2024.

However, owing to missing values, only 379 dairy farmers were included in the analysis. The data showed a higher proportion of male dairy farmers than female dairy farmers. The data collected included demographic and individual characteristics of dairy farmers, dairy production information, and intrahousehold decision-making on dairy production.

Conceptual and Analytical Framework

Recently, initiatives and strategies have been implemented in Eritrea to enhance farmers' knowledge and production capabilities. These efforts aim to modernize traditional agriculture and livestock systems using advanced technologies, with the goal of boosting productivity and alleviating poverty (African Development Bank [AfDB], 2017; CSARIDE, 2021; Climate Smart Dairy Eritrea [CSDE], 2023). Specifically, enhanced cow breeds and technological practices have been introduced to dairy households to improve milk production (AfDB 2017). Therefore, a collective approach that considers the multifaceted nature of household members with different preferences was adopted in this study to conceptualize the relationship between these empowerment programs and dairy productivity. This approach assumes an intrahousehold bargaining process among household members (Vermeulen, 2002) with heterogeneous preferences for allocating resources, such as time and money, to maximize individual utilities (Doss, 2013; Lundberg & Pollak, 2008; Saelens, 2019). This differs from the unitary model, which views a household as a single unit that pools all household resources, thus implying equal welfare among members (Alderman et al. 1995; Beninger & Laisney, 2002; Falkingham & Baschieri, 2005; Lundberg & Pollak, 2008). Empirical evidence (Ankrah et al., 2020; Deschênes et al., 2020; Diiro et al., 2018; Wekwete, 2013) shows that intrahousehold bargaining power depends on an individual's ability to access, control, and use agricultural resources, which in turn influences dairy productivity and household poverty reduction.

Dairy productivity within this framework was measured using the Partial Factor Productivity (PFP) index instead of the Total Factor Productivity index, which combines all the inputs used to produce outputs. The choice of PFP was based on innovative dairy technologies and practices introduced to farmers to enhance labor and on the available data. PFP measures technological change and development in agriculture and is easily calculated and interpreted, although there are accuracy issues (Hayami & Ruttan, 1991). For instance, innovative technologies, such as milking machines or the mechanization of other production processes, primarily affect the labor requirements of dairy farmers (Jansik &, Irz 2015). Productivity is usually measured as the ratio of gross output or value added to gross input (Organisation for Economic Co-operation and Development [OECD], 2001). A wide range of indicators, such as land and labor, are used to measure productivity. Labor productivity can be calculated using monetary values such as turnover, revenues, gross and net value added, or labor units, such as the number of hours worked, worker-days, work shifts, or the average number of employees (Stankov, 2020; Zdeněk & Lososová, 2014). Jansik and Irz (2015) and Van Der Meulen et al. (2014) expressed labor productivity as the mean number of cows per annual working unit. However, Trakia (2020) and Feng and Patton (2018) expressed labor productivity as the actual volume of milk produced per worker in litres/work-hour (natural method) or income or revenue/wage (value method). In this study, labor productivity was calculated as the total quantity of milk per work-hour, i.e.,

$$\mathrm{LP_i} = \frac{\mathrm{Q_i}}{\mathrm{L_i}} \quad (1)$$

where *LP* is the labor productivity of *i* dairy farm, Q_i is the quantity of milk produced per day and L_i is the labor spent per day in hours. The total quantity of milk produced per household was used in the study. The value of milk consumed by households or gifted to friends was included in the total quantity estimated. It is important to note that because of the poor milk value chain in Eritrea, the major dairy product is milk, and the bulk of farm production is sold at local markets or to individuals (AfDB, 2023b; CSARIDE, 2021).

The asset index score (AIS) proposed by Filmer and Pritchett (1999, 2001) was used to

measure poverty reduction. AIS has been used to measure household economic status and is a valid proxy for poverty measures (Alleluyanatha & Treasure, 2021; Filmer & Pritchett, 2001; McKinnon et al., 2014; Saif-Ur-Rahman et al., 2018; Smith et al., 2020; Tareq et al., 2021; Van de Poel et al., 2008). The AIS was preferred in this study because other poverty measures, such as household income and expenditure, are endogenous (Alleluyanatha & Treasure, 2021). Principal component analysis (PCA) was applied to define the household asset index scores categorized into quintiles of the asset index.

Furthermore, the relationship between household empowerment, dairy productivity, and poverty reduction was examined by including the empowerment variable (M_i) as an additional input variable to the vectors of household (H_i), farm (F_i), and community (C_i) characteristics that influence milk production. Thus, the outcome variables, labor productivity and poverty reduction, *Y*, are functions of

$$Y = f(X = M_i, H_i, F_i, C_i) \quad (2)$$

where *Y* is labor productivity, *M* is the measure of women's empowerment status, and *H*, *F*, and *C* are household, farm, and community characteristics, respectively.

Using ordinary least squares regression, the effect of empowerment on labor productivity and poverty reduction can be expressed as:

$$Y_i = \alpha + \beta X_i + u_i \quad (3)$$

where the subscript *i* denotes household *i*. Y_i are the outcome variables: labor productivity and poverty reduction of household *i*; X_i means a vector of covariates of *M*, *H*, *F*, and *C*; *a* and β are the coefficients to be estimated; and u_i is the random error term. However, empowerment could be endogenous because of hidden traits in an individual, such as management and leadership, that the researcher could not observe. To this, ordinary least squares regression is not a good fit for this analysis. Therefore, an instrumental variable estimator was used to account for unobservable variables embedded in empowerment. Following Diiro et al. (2018) and Alkire et al. (2013), the equation is expressed as

$$Y_i = \alpha + \psi M_i + \beta X_i + \varepsilon_i \quad (4)$$

$$M_i = \pi V_i + \delta Z_i + \mu_i \quad (5)$$

where $E(\mu_i|Z_i) = 0$ and $E(\mu_i, \varepsilon_i) \neq 0$, V = vector of the explanatory variables, Z = vector of instruments, and ε_i and μ_i = error terms.

The instruments used included perception of government policies, cooperative membership, number of improved-breed cows, sub-zoba, and agreement with potential buyers. Several intervention projects in Eritrea have resulted in the development of new policies that ensure smooth implementation, including the formalization of the dairy value chain, increasing the number of breeding cows for enhanced productivity, and developing the capacity and knowledge of small-scale dairy farmers in the use of modern technologies (CSARIDE, 2021). Farmers' perceptions of the outcomes of government policies, such as providing breeding cows to farmers and training in modern dairy practices, are believed to encourage farmer participation in some of the organized interventions for small-scale farmer empowerment. Thus, farmers' perceptions of government policies and several improved cow breeds are included as instruments. Extension cooperative formation is also a component of some intervention projects, and dairy farmers are encouraged to join them. Farmer membership in cooperative associations is essential to project participation (CSARIDE, 2021). Therefore, interventions in empowerment projects that involve policies on dairy farming can directly influence farmers to form and subsequent join cooperative societies, which then impacts farmers' empowerment and ultimately affects labor productivity. Similarly, sub-zobas are included as instruments because most intervention projects start with pilot zobas and sub-zobas before extending to other locations. This gives farmers from pilot zobas or sub-zobas an advantage in terms of experience over other farmers due to the dominance of available milk markets. To this end, the project's benefits may vary depending on location. Furthermore, depending on the location, dairy farmers may have a purchase agreement with buyers who

provide financial support or inputs, such as feed, concentrates, milking machines, or vaccines, empowering farmers to produce milk for that buyer. In these cases, farmers are bound to supply milk to particular buyers, which is a form of empowerment that will not have a direct effect on farmers' poverty status, except through this empowerment.

Furthermore, factors influencing the individual indicators of 5DE—production, resources, income, leadership, and time—were determined using a multivariate regression equation (MRE). MRE measures the angle of more than one dependent variable and estimates the relationship between multiple independent variables if they are linearly correlated (Alexopoulos, 2010). It is used to predict the outcome behavior and the subsequent relationship with the predictor variables, as well as the changing patterns of these predictor variables (Alexopoulos, 2010).

Estimation Methods

To compute farmer empowerment, equal weights of ⅕ were assigned to each of the five domains. First, an aggregate score of a farmer's empowerment was determined across the five domains. Then, the level of empowerment of a farmer's A-WEAI was defined as empowered = 1 if the farmer achieved more than 80% of the weighted domains; otherwise, the farmer was deemed disempowered = 0. Following Alkire et al. (2013), the disempowered headcount ratio (H_P) was calculated as the ratio of disempowered farmers to the total population, while the intensity of the disempowered (A_P) was obtained as the average of the disempowered farmers.

Afterward, the five A-WEAI domains were used to examine the effect of each domain on the outcome variables. Production, resources, income, and leadership domains were counted, while time was expressed (as a dummy variable) in work-hours of 0 to 10.5 hours = 1 otherwise, 0. The disempowerment index across the five domains (M_0) is the product of the disempowered headcount ratio (H_P) and the intensity of the disempowered (A_P); then 5DE was computed as $1 - M_0$. To calculate the AIS, asset variables were categorized into dummies: 1 if the household had assets; otherwise, 0. To distinguish between the households' frequency of occurrence of each asset included in the AIS, percentages of less than 5% or more than 95% were eliminated. Principal component analysis (PCA) was then used to assign indicator weights and index values, which were standardized to calculate the factor loadings for each household. The indicator values were multiplied by the loadings and added to generate the index value for each household. The first principal component generates an asset index that assigns a larger weight to assets that differ the most across households while giving a weight of zero to an asset found in all households (McKenzie, 2005). Additionally, the asset score for each household is calculated by summing the standardized value of each variable, as shown in equation 6:

$$AIS_i = \sum_{i=1}^{k} \mathrm{S_i}\left(\frac{Xi-\bar{x}}{\sigma_i}\right), \mathrm{i} = 1,2 \ldots\ldots\ldots n \quad (6)$$

where Si = scoring factor for the asset i, $\bar{x}$ = mean of asset i, and σi = standard deviation of asset. Then, the scores for each household were ranked in ascending order and divided into quintiles, with approximately 20% of the population in each quintile ranging from 1 to 5. The variables—dependent, independent, instrument, and other covariates used in the data analysis—are presented in Table 1.

Results

This section includes the distribution of the level of empowerment among male- and female-headed households, the effect of empowerment on labor productivity and poverty reduction among small-scale dairy farmers, and the determinants of empowerment across the 5DE in Eritrea.

Level of Empowerment Among Small-Scale Dairy Farmers

Appendix A presents the 5DE in Eritrea, showing the male- and female-headed household disempowerment index and average inadequacy score. The results show that 48.58% of male-headed households and 56.45% of female-headed households are disempowered (Table 1). The inadequacy achievement scores for male- and female-headed households were 63.73% and 58.96%, respectively.

On average, the disempowerment indices for Eritrean (overall), male-headed, and female-headed households were 0.687, 0.690, and 0.667, respectively. This result was further validated by subjecting it to a z-test, and there was no significant difference between male- and female-headed households (see Table A2). This test was necessary due to the sample size of female-headed households.

Figure 2 shows the decomposition of 5DE by dimension and indicator. Resources (which are determined by household decisions regarding ownership and access to land and other productive assets) were the most significant indicator leading to disempowerment in dairy farmers' households, followed by leadership, especially among women. However, production was the least important factor contributing to farmers' disempowerment.

Table 2 shows the decomposition of the disempowerment of small-scale dairy farmers according to the sex of the household head and the zobas of interest. At the zoba level, the least empowered is Anseba (65.42%), followed by Debub (57.02%) and then Maekel (33.11%).

Effect of Empowerment on Labor Productivity and Poverty Reduction

Tables A2, A3, A4, and A5 in the appendices present the first-stage regression and two-stage

Table 1. Results of the 5 Domains of A-WEAI (5DE): Production, Resources, Income, Leadership, and Time

Indexes	Eritrea	Male	Female
Disempowered headcount (H)	49.87%	48.58%	56.45%
Average inadequacy score (A)	62.85%	63.73%	58.96%
Disempowerment Index (M_0)	0.313	0.310	0.332
5DE Index ($1 - M_0$)	0.687	0.690	0.667
Number disempowered	189	154	35
Number of observations	379	317	62

Source: Field survey, 2023. Authors' calculation.

Figure 2. Decomposition of 5 Domains of A-WEAI (5DE): Production, Resources, Income, Leadership, and Time by Dimension and Indicator

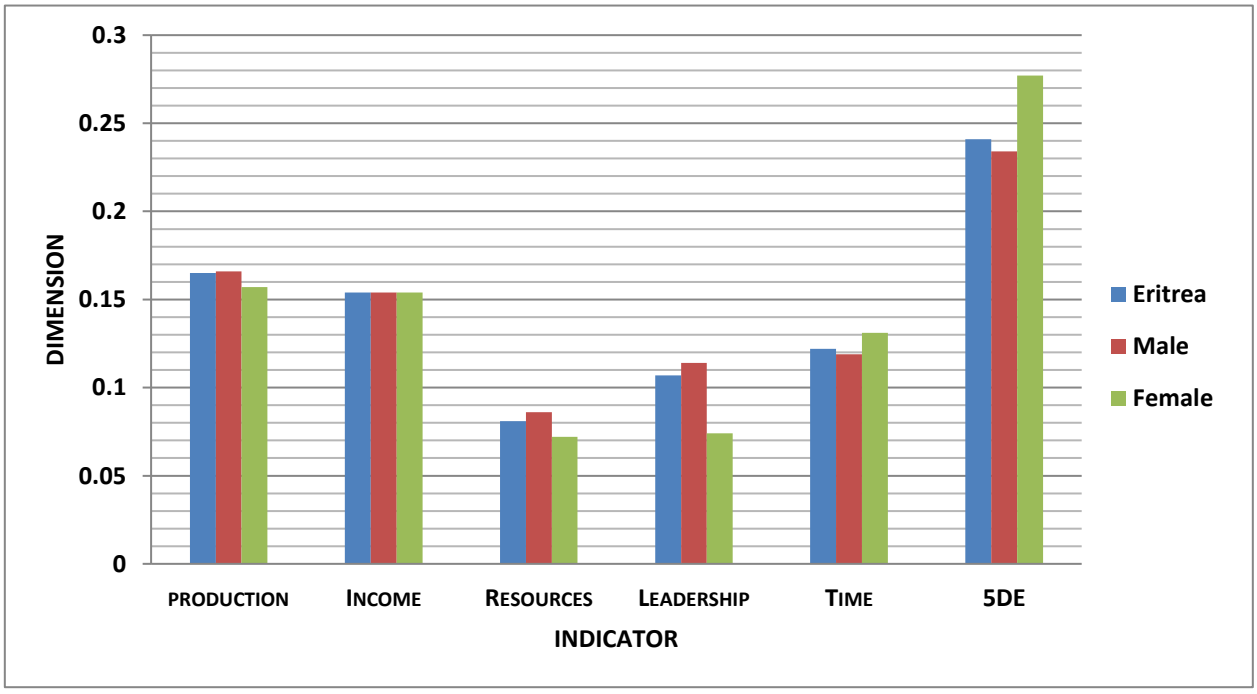


Table 2. Distribution of the Level of Empowerment

Level of Empowerment	Number Disempowered	Number Empowered	Frequency	Percentage	Number Disempowered	Number Empowered	Frequency	Percentage	Number Disempowered	Number Empowered	Frequency	Percentage	Number Disempowered	Number Empowered	Frequency	Percentage	Number Disempowered	Number Empowered	Frequency	Percentage
	Male				Female				Anseba				Debub				Maekel			
0.2–0.39	7	0	7	2.21	4	0	4	6.45	5	0	5	4.67	4	0	4	3.31	2	0	2	1.32
0.4–0.59	33	0	33	10.41	13	0	13	20.97	20	0	20	18.69	23	0	23	19.01	3	0	3	1.99
0.6–0.79	114	0	114	35.96	18	0	18	29.03	45	0	45	42.06	42	0	42	34.71	45	0	45	29.80
0.8–1	0	163	163	51.42	0	27	27	43.55	0	37	37	34.58	0	52	52	42.98	0	101	101	66.89
Total	154	163	317		35	27	62		70	37	107		69	52	121		50	101	151	

Source: Field survey, 2023. Authors' calculation

least-squares instrumental variable (IV) estimations of the effect of empowerment on labor productivity and asset index scores for Eritrea, male-headed households, and female-headed households, along with validity and endogeneity tests of the instruments used. The first-stage F-statistic was employed to test for the weakness of the instruments based on the Stock & Yogo (2002) rule of thumb, indicating a value of less than 10. All the instruments used had F-statistics above 10. In addition, the Durbin and Wu-Hausman endogeneity tests were significant at under 5% across the estimations, except for the female farmers, for whom some instruments were significant at 10%. This signifies that the instruments, which include the number of improved cow breeds, sub-zobas, share of dairy income, membership in a cooperative, and perception of government policies, are related to the endogenous variable (empowerment) in the models for labor productivity and poverty reduction. Furthermore, the Sargan and Basmann tests for overidentification were insignificant across the relevant instruments, implying that the instruments were not overidentified. This shows that the choice of instruments is consistent with the model's assumptions, and there is no evidence to indicate that the instruments are invalid or that the model is misspecified. All the signs and magnitudes of the instruments correspond with the a priori expectation that an increased number of improved cow breeds, residing in a more empowered sub-zobas, larger share of dairy income, and membership of a cooperative improve the labor productivity and poverty status of dairy farmers, whereas their negative perception of government policies influences the outcome variables. Therefore, we are confident that the instruments utilized in our regression model are valid in assessing the effect of empowerment on labor productivity and poverty reduction for dairy farmers in Eritrea.

Table A2 shows that while the educational level of female-headed households was significantly positively associated with women's empowerment in Eritrea, the number of lactating cows had a negative relationship with women's empowerment. Similarly, extensive dairy production is a specific factor that contributes to men's disempowerment. Furthermore, the price of milk and cooperative membership contributed to empowerment. At the same time, farmers' perceptions of government policies as deterrents to production resulted in the disempowerment of both male- and female-headed households. See Table A2 for results from the first-stage IV regression on dairy empowerment.

The coefficient for 5DE is significant and positive (Table A3), indicating that empowerment increased labor productivity among male- and female-headed households by 11.57% and 17.56%, respectively, representing an overall increase of 12.58% across all households. Increased herd size is associated with higher labor productivity. Additionally, the adoption of semi-intensive practices

contributed to lower labor productivity. The coefficients of dairy experience, the price of milk, and the perception of government policies were particularly important factors influencing labor productivity in male-headed households. While the price of milk negatively affected labor productivity, the other two factors had a positive relationship, suggesting that an additional year of dairy experience and viewing government policies as a major constraint increased labor productivity. The age and educational level of the household head, as well as practicing extensive dairy production, were factors that influenced labor productivity among female-headed households, although negatively in this case. Older women and women with higher levels of education were less productive in dairy farming. This necessitates the creation of opportunities to make investment and engagement in dairy farming attractive to young people.

Table A4 shows the factors affecting empowerment in Eritrea based on the AIS. Milk price was the core factor that determined the level of empowerment in the study area. The relationship between milk production and asset accumulation was inverse, suggesting that higher milk production may not be sufficient to alleviate poverty in male-headed households. Meanwhile, the number of lactating cows among female-headed households served as a source of empowerment, whereas the educational level acted as a source of disempowerment.

Table A5 shows the coefficients of 5DE to be positive and significant, indicating that empowerment increased asset accumulation among small-scale dairy farmers overall, as well as among both male- and female-headed households, reducing household poverty in the study areas by 7.42%, 5.81%, and 11.89%, respectively. Dairy experience and the number of lactating cows were significant and positively related to household asset accumulation, while semi-intensive dairy production is significant and negatively related to asset accumulation in Eritrea. This suggests that increased dairy experience and the number of lactating cows lead to a corresponding increase in asset accumulation for both male- and female-headed households in Eritrea. Enhanced dairy experience and the number of lactating cows may thus improve asset accumulation for both male- and female-headed households in Eritrea, while semi-intensive dairy farming diminishes asset accumulation. Extensive dairy production and low milk prices are two key factors that have a significant negative impact on asset accumulation among male-headed households.

Determinants of Empowerment (5DE) Indicators in Small-Scale Dairy Farming

Table A8 presents the marginal effects of empowerment in dairy farming, with labor productivity and asset index scores included as covariates alongside other individual, farm, and community characteristics. The two variables were regressed against the 5DE indicators, both with and without covariates. Table A1 presents the detailed results of the coefficients for male- and female-headed households. Labor productivity has an increasing influence on production, resources, and income. By contrast, the asset index score has an increasing effect on production and leadership indicators but a decreasing effect on time. This indicates that, with increased labor productivity and a reduced poverty status, decision-making and autonomy can be managed more efficiently within small-scale dairy households regarding input purchasing, land and asset ownership, sales, transfers, credit access, and the management of dairy income and expenditures. With greater access to assets, social and economic capital increase, creating a conducive environment for farmers to be recognized and lead in the community. Assets accrued within a dairy household could reduce the time spent on dairy production by allowing farmers to purchase labor-saving equipment, such as milking machines (Jansik & Irz, 2014).

However, by including other covariates in the equation, labor productivity and asset index scores were significant and held both positive and negative relationships with the time indicator, while remaining insignificant with respect to other indicators. It can be inferred from this result that for sustainable dairy production among small-scale dairy farmers in the study area, individual characteristics such as dairy experience, frequency of extension visits, gender, and the educational level of the household head are most important. Adequacy among female-headed households in the

leadership indicator is significantly negative, reflecting societal gender inequality. The educational level of the household head was significant but negatively related to the production indicator, meaning that additional years of education were associated with reduced household production adequacy in dairy farming. Dairy experience is also significantly and positively related to production indicators. Similarly, it has a significant and negative relationship with the time indicator, meaning that as farmers' experience in dairy farming increases, the time spent on labor decreases. Furthermore, increased extension visits to dairy farmers reduced the resource indicator while increasing the time indicator. Regarding farm characteristics, the number of lactating cows, milk processing, and the method of dairy production are essential for empowerment in dairy production. A unit increase in the number of lactating cows reduces the time indicator, suggesting the need to encourage farmers to adopt improved labor-saving dairy technologies. The probability of processing milk was significantly and negatively associated with the production, resources, and income indicators. This implies that the more farmers are involved in milk processing, the less they participate in decisions about the input market, assets or land acquired or transferred, and income and expenditure. Semi-intensive dairy production methods were significantly and positively related to the production, resources, and income indicators of empowerment. Therefore, farmers should be encouraged to adopt semi-intensive production methods for sustainable empowerment and poverty reduction.

Community characteristics, such as the price of milk and the zoba, were significantly and positively associated with the production indicator, showing that a unit increase in the price of milk results in an increase in production capability among farmers. Farmers in Maekel had a significant and positive relationship with all 5DE, which could stem from the position of zoba as the administrative center of Eritrea. Most dairy farms are intensive, and milk processing collectors are closer to farmers, with many intervention programs using it as a pilot region (CSARIDE, 2021). This has given Maekel an advantage over other zobas.

Discussion

Thus, there is a need to examine productivity and poverty reduction among small-scale dairy farmers in Eritrea. Most interventions to improve people's lives and livelihoods are funded for limited periods; however, there is a need for sustainable, long-term outcomes. Previous projects aimed at promoting dairy production in Eritrea have addressed improving farmers' skills and knowledge of innovative dairy production for increased income, employment opportunities, and the general growth of the nation's economy, thereby reducing poverty among small-scale dairy farmers in the short term. The skills and knowledge acquired during project implementation are expected to guarantee sustainable empowerment among beneficiaries, thereby maintaining the productivity of the entire dairy value chain while simultaneously accruing assets. Invariably, farmers' levels of productivity and poverty status in the long run have become sources of empowerment for farmers. We used the A-WEAI approach to understand the impact of these interventions on the empowerment of dairy farmers in Eritrea. Women were more disempowered than men, and as such, they had inadequate achievements. Likewise, the 5DE indicated a high intensity of disempowerment among women, likely due to the high level of gender inequality that reduces women's access to agricultural inputs and resources in Eritrea (Tesfamariam, 2015).

The most important factor that jeopardized empowerment and labor productivity in the dairy sector was the low level of education, particularly among women. Most of the women had a primary education, whereas some men were able to receive secondary education. Recall that the educational level of both men and women had a nonsignificant negative relationship with labor productivity, and AIS was used as a proxy for poverty reduction. Nevertheless, education is an important factor for empowerment among female-headed households. The lack of significance in education could be associated with the level at which it exists. One compelling explanation for the decrease in productivity among dairy farmers with higher education levels is the potential disparity between the skills and knowledge gained from academic learning and the hands-on demands of dairy farming. Occasionally,

well-educated dairy farmers prioritize theoretical understanding and managerial elements, overlooking the essential practical skills and experience needed for effective farm management. This discrepancy may result in inefficiencies, delays in decision-making, and less-than-optimal farming methods, ultimately causing a decline in productivity on dairy farms. Therefore, this calls for policy reform that improves both men's and women's access to formal and informal education and training to enhance labor productivity in dairy farming, which will increase dairy output and income, and bring about poverty alleviation. This is especially relevant for female-headed households, which are most affected by poverty. It is well established that education for girls and women provides knowledge and skills that enable them to compete in the labor market, make personal decisions about their lives, and achieve socioemotional stability; thus, it is a prerequisite for poverty reduction (Awan & Malik, 2020; UN, 2022; World Bank, 2022). Similarly, Diiro et al. (2018) and Mobaork (2021) proved that empowering women increased agricultural productivity through independent decisions that positively influenced productivity, efficiency, and technical change.

Respondents' ages negatively influence dairy labor productivity because productivity decreases with age. Since the average age of respondents in this study is above 50 years, ensuring improved labor productivity among small-scale dairy farmers in Eritrea necessitates creating opportunities and making dairy farming attractive to young people (Olagunju et al., 2022). It was also observed that those who are more educated in Eritrea are less productive in dairy farming, suggesting a tendency toward greater involvement in non-dairy farming. This aligns with Bragg and Dalton's (2004) observation that higher diversification of farm income, poor proceeds relative to variable costs, and higher non-dairy income are likely factors influencing the decision to exit dairy farming. Particular attention should be paid to women, who were more productive than men in this study. Additionally, herd size, the type of dairy production practice (i.e., semi-intensive and extensive), and membership in a cooperative are other important factors in the dairy sector. Increased herd size heightens the tendency to apply practices and technologies that improve milk yields and labor productivity (MacDonald, 2016), thus enhancing efficiency (Deming et al., 2020). Qi et al. (2022) observed that unimproved managerial ability impedes labor productivity as herd size increases due to the low adoption of improved dairy practices. Promoting dairy production among small-scale farmers entails intensive development of farmers' skills and knowledge of new innovations in dairy production. The intensive method of dairy production was reported to be more labor productive than the semi-intensive and extensive methods (Wijethilaka et al., 2018), while membership in a cooperative increased labor productivity (Ahmed & Mesfin, 2017; Kumar et al., 2013). However, the findings of this study suggest that with increased herd size and more lactating cows, women tend to reduce their involvement in dairy production and diversify their sources of income into higher-yielding livelihood activities along the dairy value chain, such as processing. Murphy (2009) emphasized that Eritrean women are more involved in food processing than in production. However, this finding contradicts the findings of Niketha et al. (2017). There is also a need to create awareness of the importance of small household sizes to promote empowerment in both male- and female-headed households, which corresponds with Ayevbuomwan et al. (2016). Dairy experience, total production cost, and milk prices were specifically important factors influencing labor productivity in male-headed households. However, Zdeněk and Lososová (2014) reported an insignificant connection between milk prices and labor productivity.

Empowerment increased asset accumulation among small-scale dairy farmers in Eritrea and male- and female-headed households in the study area by 12.10%, 10.57%, and 9.91%, respectively, thereby showing a reduction in household poverty. Correspondingly, Yasmin and Ikemoto (2015) and Wei et al. (2021) found that women's empowerment increased women's economic power, independence, and financial autonomy, which helped women in dairy farming to improve their quality of life and advance out of their poverty status. Again, dairy farming was confirmed as the cause of higher household welfare (Food and Agriculture

Organization of the United Nations [FAO] et al., 2018). Further reduction of poverty among small-scale dairy farmers in Eritrea will require the development of extension systems along with increases in milk prices and herd size.

The 5DE indicators, namely production, resources, income, leadership, and time, were affected by different factors among male- and female-headed households. Improving labor productivity and the assets index among dairy farmers could be an essential tool for enhancing the 5DE indicators. The results showed that women's access to leadership positions or to organizations in Eritrea might still be impeded, thus requiring policies that would enhance women's involvement in intra- and interhousehold decision-making and community decision-making for economic growth within households and society at large. Taliento and Madgavkar (2016) and OECD (2001 reinforced the importance of women's participation in the household and community economy for equitable governance, economic growth, and public trust. Another factor is the use of intensive methods of dairying, which are more profitable than semi-intensive and extensive methods (Bandara et al., 2011). However, this method was more common in Maekel than in the other zobas, highlighting regional inequality among the three zobas studied. Dairy empowerment should be spread evenly among dairying zobas to support poverty reduction in all regions. A favorable environment and favorable market conditions, especially in Debub, can boost dairy farming productivity, making dairy farming economically viable using value-additive techniques. This could increase product value, expand market share, reduce milk price risks, and make Eritrea's dairy industry competitive. Therefore, there is a need to decentralize some input outlets, such as milking facilities, to enhance milk processing and increase the price for dairy farmers, who mostly sell raw milk and thus may not maximize profit.

Conclusion

Small-scale dairy farming in Eritrea is a promising industry with the potential to reduce poverty among dairy farmers if productivity is improved. Thus, efforts to develop the dairy sector in Eritrea have increased since Eritrean independence in 1991.

The results show that male household heads were more empowered than their female counterparts, and among the 5DE indicators, resources and leadership had a glaring evidence against empowerment, especially among women. At the zoba level, Anseba showed the highest level of disempowerment (65.42%), followed by Debub (57.02%) and then Maekel (33.11%). Empowerment has a positive effect on labor productivity and poverty reduction at varying levels. Among male and female household heads, empowerment resulted in increases in productivity of 11.50% and 18.49%, respectively, and reduced poverty by 10.57% and 9.91%, respectively. This suggests that gains in productivity reduced poverty more among female dairy farmers than among male dairy farmers.. The specific factors that affected labor productivity among the female dairy farmers were the level of education and age. In contrast, dairy experience, labor costs, milk prices, and belonging to a cooperative were particularly relevant to men. However, for both male and female dairy farmers, factors such as herd size, type of dairy production practice, and perceptions of government policies on dairy farming had a negative impact on labor productivity. Nonetheless, the frequency of extension visits, the unit price of milk, dairy experience, and the number of lactating cows influenced asset accumulation among dairy farmers in Eritrea.

Furthermore, important factors require adequate attention for the 5DE indicators to be improved, ensuring that dairy farmers, both male and female, are empowered in the long term. These factors include education and household size, particularly among women, dairy experience, frequency of extension visits, the number of lactating cows, milk processing, and the price of milk. Additionally, for the overall empowerment index, membership in cooperatives and government interventions must be enhanced for sustainability.

The findings from this study call for policy reform to improve women's access to formal and informal education and training, not only in dairy production for increased productivity but also for general capacity building among women. Improving the educational status of women and

girls is a prerequisite for poverty reduction. Innovative approaches are required to reduce the demand for labor through improved technology. This is crucial in creating opportunities that will make dairy farming attractive to young and educated individuals. Furthermore, there is a need to provide milk processing plants for dairy product processing to raise prices. In other words, developing the dairy value chain is paramount for increasing prices and encouraging dairy production in Eritrea. Similarly, the availability and affordability of improved cow breeds are necessary to enhance the overall productivity of farmers.

For further studies, WEAI has a gender disparity aspect that was not covered in this study due to the lack of data on primary males and females within households. Understanding intrahousehold gender disparity, coupled with the 5DE, will shed light on the levels and dynamics of intrahousehold decision-making for poverty reduction. There is also a need to thoroughly examine the dairy production value chain and productivity along the chain.

In sum, this study examined the role of empowerment initiatives in enhancing the productivity of smallholder dairy farms and reducing poverty in Eritrea, utilizing the A-WEAI framework. The findings revealed a disparity in empowerment between male and female household heads, with males typically being more empowered than females. The research established a positive effect of empowerment, productivity gains, and poverty alleviation in households, with a notably higher impact observed in those headed by females. Key determinants affecting productivity and poverty include the level of education, age, experience in dairy farming, herd size, and the influence of governmental policies, underscoring the need for tailored empowerment strategies to bolster the dairy sector and combat poverty.



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Appendix. Data Tables

Table A1. Description of Variables

Variable		Eritrea		Male		Female	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Number of observations		379.00		317.00		62.00	
Outcome variables							
Asset index score		3.01	1.43	3.03	1.43	2.94	1.47
Labor productivity		2.97	4.52	3.14	4.75	2.092	3.01
Production		0.18	0.05	0.18	0.04	0.17	0.04
Resources		0.09	0.03	0.09	0.02	0.08	0.03
Income		0.18	0.06	0.18	0.06	0.17	0.05
Leadership		0.15	0.85	0.16	0.81	0.13	0.96
Time		0.16	0.08	0.16	0.08	0.16	0.08
Endogenous variables							
Disempowerment index	Index from 0–1 (0.0–0.79 = disempowered, 0.81= empowered)	0.50	0.50	0.51	0.50	0.44	0.50
Instruments							
Perception on government policies	Ranked 1-8	3.14	2.30	2.96	2.20	4.03	2.59
Member of cooperative	Yes = 1 No = 0	0.77	0.42	0.79	0.41	0.65	0.48
Number of improved cow breed	Number (counts)	2.39	4.59	2.32	4.25	2.73	6.08
Sub-zoba		12.26	5.16	12.47	4.92	11.19	6.16
Agreement with buyer	Yes = 1 No = 0					0.50	0.50
Household characteristics							
Age of household head	Years	57.21	12.72	57.61	12.65	55.21	13.02
Sex of household head	Yes = 1 No = 0	1.16	0.37	1.00	0.00	2.00	0.00
Educational level of household head	No education = 1, primary school = 2 Secondary School = 3; Vocational School = 4; University education = 5	2.43	0.99	2.47	0.97	2.21	1.03

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Dairy experience	Years	16.51	10.81	16.65	10.92	15.82	10.32
Household size	Number	6.89	2.93	7.07	2.92	5.98	2.82
Share of dairy income to household income	Proportion between 0 and 1	0.36	0.28	0.35	0.27	0.41	0.30
Dairy farm characteristics							
Rent on land	Nafka	4,047.26	13,536.91	3,706.31	11,305.07	5,790.48	21,674.25
Land size for food production	Acre	0.69	0.38	0.69	0.37	0.68	0.43
Frequency of extension visit	Number	2.22	1.15	2.15	1.12	2.56	1.22
Number of lactating cows	Number	3.25	3.48	3.27	3.32	3.11	4.26
Herd size	Number	6.83	7.15	6.96	6.58	6.15	9.58
Total cost of production	Nafka	102,243.40	148,614.80	105,838.30	149,642.50	83,862.69	143,003.70
Type of dairy production practice	Intensive system = 1; Semi-intensive = 2; Extensive = 3	1.36	0.57	1.33	0.54	1.53	0.69
Price of milk	Nafka/litre	16.35	5.70	16.56	5.32	15.25	7.27
Perceived income from milk	Decreased Much = 1; decreased = 2; Same = 3; Increased = 4; Increased much = 5	2.83	1.04	2.87	1.04	2.65	1.01
Quantity of milk produced	Litre/day	11.91	46.25	12.36	50.44	9.64	8.33
Processed milk	Yes = 1 No = 0	0.21	0.41	0.21	0.41	0.21	0.41

Source: Field survey, 2023.

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Table A2. IV First-Stage Regression on Dairy Empowerment

	Eritrea			Male			Female		
Empowerment	Coef.	Std. Err.	T-test	Coef.	Std. Err.	T-test	Coef.	Std. Err.	T-test
Age of household head	0.000	0.002	0.33	-0.000	0.002	-0.3	0.003	0.004	0.80
Gender of household head	-0.041	0.059	-0.78						
Educational level of household head	0.018	0.024	0.67	-0.004	0.027	-0.13	0.102**	0.051	2.00
Dairy experience	0.000	0.002	0.07	0.000	0.002	0.05	0.003	0.005	0.73
Household size	0.001	0.007	0.13	0.001	0.008	0.13	0.022	0.016	1.37
Herd size	-0.011***	0.003	-3.30	-0.010	0.004	-2.69			
Number of lactating cows							-0.34***	0.012	-2.94
Semi-intensive dairy production practice:	0.127**	0.054	2.33	0.045	0.061	0.74	0.080	0.097	0.83
Extensive dairy production practice	-0.068	0.099	-0.69	-0.225*	0.128	-1.76	0.107	0.145	0.74
Price of milk	0.018***	0.004	4.69	0.020***	0.005	4.42	0.016**	0.006	2.61
Member of cooperative	0.602***	0.052	11.51	0.615***	0.060	10.17	0.529***	0.104	5.08
Perception on government policies	-0.042***	0.009	-4.40	-0.035***	0.011	-3.16	-0.201*	0.118	-1.7
Debub	0.023	0.065	0.36	-0.010	0.074	-0.13			
Maekel	-0.016	0.066	-0.25	-0.041	0.073	-0.56			
Number of improved cow breed	0.012**	0.006	2.19						
Sub-zoba	0.015***	0.004	3.77						
Share of dairy income	0.345***	0.088	3.93	0.438***	0.102	4.29			
Agreement with buyer							0.291***	0.091	3.21
Constant	-0.490***	0.176	-2.78	-0.272	0.201	-1.35	-0.676**	0.317	-2.13
No of observation		379			317			62	
F-stat	19.07***			15.29***			11.17***		
R-squared	0.457			0.396			0.659		
Adj. R-squared	0.433			0.370			0.600		

Source: Field survey, 2023.

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Table A3. IV Estimation of Empowerment on Labor Productivity

	Eritrea			Male			Female		
Log of labor productivity	Coef.	Std. Err.	Z-test	Coef.	Std. Err.	Z-test	Coef.	Std. Err.	Z-test
Empowerment (5DE)	1.258***	0.304	4.14	1.157***	0.467	3.36	1.756***	0.647	2.71
Age of household head	-0.007*	0.004	-1.83	-0.004	0.004	-1.08	-0.015*	0.009	-1.69
Gender of household head	-0.287**	0.112	-2.56						
Educational level of household head	-0.035	0.049	-0.72	-0.023	0.050	-0.45	-0.249*	0.129	-1.92
Dairy experience	0.011***	0.004	2.62	0.009**	0.005	1.96	0.004	0.011	0.4
Household size	-0.015	0.014	-1.06	-0.017	0.015	-1.18	-0.013	0.068	-0.19
Herd size	0.063***	0.008	8.36	0.088***	0.008	11.06			
Number of lactating cows							0.187***	0.027	6.81
Semi-intensive dairy production practice	-0.513***	0.104	-4.92	-0.469***	0.125	-3.74	-0.940***	0.214	-4.39
Extensive dairy production practice	-0.428**	0.190	-2.25	-0.232	0.270	-0.86	-0.847***	0.314	-4.39
Price of milk	-0.032***	0.010	-3.08	-0.038***	0.014	-2.76	-0.012	0.018	-0.65
Perception of government policies	-0.943***	0.218	-4.33	0.097***	0.028	3.48	0.047	0.041	1.15
Member of cooperative	0.062***	0.021	2.92	-1.015***	0.301	-3.37	-0.996**	0.417	-2.38
Debub	-0.410***	0.124	-3.32	-0.488***	0.146	-3.35			
Maekel	0.093	0.122	0.76	0.119	0.145	0.82			
Constant	0.589*	0.337	1.75	0.894**	0.420	2.13	1.532*	0.817	1.87
No of observation	379			317			62		
Wald chi2	369.22***			230.24***			113.04***		
R-Squared	0.452			0.312			0.611		
Test of instruments									
F stat	13.378***			18.403***			12.192***		
Durbin (score) chi2(1)	8.701***			8.104***			4.152**		
Wu-Hausman F(1,362)	8.529***			7.923***			3.518*		
Sargan (score) chi2(1)	2.637			3.689			0.436		
P-value	0.268			0.158			0.509		
Basmann chi2(1)	2.537			3.532			0.417		
P-value	0.281			0.171			0.518		

Source: Field Survey, 2023

Table A4. IV First-Stage Regression on Dairy Empowerment

	Eritrea			Male			Female		
Empowerment (5DE)	**Coef.**	**Std. Err.**	**T-test**	**Coef.**	**Std. Err.**	**T-test**	**Coef.**	**Std. Err.**	**T-test**
Age of household head	0.002	0.002	0.87	0.000	0.002	0.12	0.005	0.004	1.17
Gender of household head	-0.080	0.058	-1.38						
Educational level of household head	0.036	0.025	1.47	0.006	0.028	0.22	0.116**	0.055	2.12
Dairy experience	-0.000	0.002	-0.10	0.000	0.002	0.11	0.002	0.005	0.33
Household size	0.003	0.007	0.39	0.001	0.008	0.08	0.009	0.019	0.48
Semi-intensive dairy production practice	0.045	0.050	0.91	0.024	0.056	0.43	0.132	0.105	1.26
Extensive dairy production practice	-0.083*	0.101	-0.82	-0.180	0.129	-1.39	0.155	0.159	0.98
Price of milk	0.020***	0.004	5.24	0.019***	0.005	4.24	0.021***	0.007	3.17
Number of lactating cows	-0.012*	0.006	-1.86	0.009	0.007	1.24	-0.006**	0.017	-0.38
Quantity of milk produced	-0.000**	0.000	-2.23	-0.000*	0.000	-1.80	-0.000	0.000	-1.40
Perception of government policies	-0.034***	0.009	-3.58	-0.033***	0.011	-3.02	-0.037**	0.018	-2.03
Member of cooperative	0.605***	0.050	12.04	0.614***	0.058	10.55	0.594***	0.106	5.59
constant	-0.362**	0.182	-1.99	-0.353*	0.214	-1.65	-0.819**	0.377	-2.17
No. of observation		379			317			62	
F-stat	19.08***			14.60***			9.25***		
R-squared	0.4046			0.3656			0.6626		
Adj. R-squared	0.3834			0.3403			0.5793		

Source: Field survey, 2023.

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Table A5. IV Estimation of Empowerment on Asset Index Score

	Eritrea			Male			Female		
Asset Index Score	**Coef. nb.**	**Std. Err.**	**Z-test**	**Coef.**	**Std. Err.**	**Z-test**	**Coef.**	**Std. Err.**	**Z-test**
Empowerment	0.742***	0.245	3.03	0.581**	0.269	0.216	1.189**	0.52	2.28
Age of household head	-0.002	0.006	0.34	-0.005	0.007	-0.70	-0.011	0.016	-0.73
Gender of household head	0.092	0.177	0.52						
Educational level of household head	-0.020	0.078	-0.26	-0.041	0.084	-0.49	-0.179	0.180	-1.00
Dairy experience	0.027***	0.007	4.10	0.020***	0.007	2.90	0.051***	0.017	3.02
Household size	0.001	0.023	0.07	0.015	0.027	0.54	-0.067	0.068	-0.99
Semi-intensive dairy production practice	-1.141***	0.151	-7.55	0.000***	0.000	3.80	-0.621*	0.334	-1.86
Extensive dairy production practice	-0.846	0.321	-2.64	-0.138*	0.073	-1.89	-0.195	0.135	-1.45
Price of milk	-0.045***	0.012	-3.57	-0.067***	0.014	-4.81	0.018	0.027	0.67
Number of lactating cows	0.093***	0.030	3.02	0.075**	0.037	2.04	0.210***	0.058	3.64
Quantity of milk produced	-0.000	0.000	-0.33	-0.000	0.000	-0.04	-0.000	0.000	-1.52
Constant	3.171***	0.559	5.67	3.752***	0.618	6.07	2.554*	1.360	1.88
No of observation	379			317			62		
Wald chi-squared	169.00***			155.42***			21.154***		
R-squared	0.2517			0.2824			0.4343		
Test of instruments									
F stat	82.47***			60.81***			18.96***		
Durbin (score) chi2(1)	16.05***			11.82***			2.98*		
Wu-Hausman F(1,362)	16.14***			11.78***			2.48*		
Sargan (score) chi2(1)	0.0885			0.2736			0.0314		
P-value	0.7660			0.6010			0.8593		
Basmann chi2(1)	0.0852			0.2626			0.0249		
P-value	0.7703			0.6084			0.8747		

Source: Field survey, 2023.

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Table A6. Determinants of the 5DE Indicators in Dairy Farming

	Delta-method			Delta-method			Delta-method			Delta-method			Delta-method		
	dy/dx	Std. Err.	T-test	dy/dx	Std. Err.	T-test	dy/dx	Std. Err	T-test	dy/dx	Std. Err.	T-test	dy/dx	Std. Err.	T-test
	Production			Resource			Income			Leadership			Time		
LOG Labor productivity	0.004*	0.002	1.90	0.004***	0.001	2.90	0.007**	0.002	2.31	0.003	0.004	0.66	0.002	0.004	0.43
Asset Index Score	0.003**	0.001	2.26	-0.000	0.000	-0.21	0.000	0.002	0.21	0.010***	0.003	3.37	-0.012***	0.003	-4.26
Other Covariates	No			No			No			No			No		
LOG Labor productivity	0.002	0.003	0.96	0.001	0.002	0.54	0.005	0.005	1.09	-0.005	0.006	-0.81	0.041***	0.004	7.26
Asset Index Score	0.001	0.002	0.37	0.000	0.001	0.02	-0.001	0.002	-0.39	-0.002	0.004	-0.46	-0.001***	0.003	-3.37
Age of household head	-0.000	0.000	-1.35	-0.000	0.000	-0.48	-0.000	0.000	0.02	0.000	0.000	-0.47	0.001	0.000	1.55
Gender of household head	-0.005	0.005	-0.98	-0.004	0.003	-1.15	0.002	0.008	0.27	-0.034***	0.012	-2.88	-0.004	0.008	-0.43
Educational level of household head	-0.006**	0.002	-2.71	-0.001	0.001	-0.83	0.000	0.003	0.08	-0.003	0.005	0.60	0.005	0.005	1.21
Dairy experience	0.000**	0.000	2.06	0.000	0.000	0.49	0.000	0.000	0.34	0.000	0.000	-0.98	-0.001***	0.000	-3.17
Household size	-0.001	0.001	-1.29	0.000	0.000	0.38	0.000	0.001	0.01	0.002*	0.001	1.68	-0.001	0.001	-0.52
Frequency of extension visits	-0.002	0.002	0.9	-0.002**	0.001	-2.31	-0.001	0.003	-0.23	0.003	0.004	0.80	0.008**	0.003	2.28
No lactating cows	0.001	0.001	1.11	-0.000	0.001	-0.02	0.000	0.001	0.35	-0.001	0.002	-0.66	-0.009***	0.002	-4.55
Quantity of milk	0.000	0.000	-0.49	0.000	0.000	0.01	0.000	0.000	0.8	0.000	0.000	0.34	0.000*	0.000	1.74
Processed milk	-0.013***	0.005	-2.57	-0.009**	0.003	-2.52	-0.018**	0.008	-2.22	-0.007	0.011	-0.7	-0.007	0.008	-0.78
Semi-intensive	0.016***	0.006	3.07	0.010***	0.004	2.77	0.014*	0.008	1.78	0.009	0.011	0.77	-0.027***	0.010	-2.72
Extensive	-0.034***	0.009	-3.71	-0.004	0.006	-0.65	0.006	0.015	0.39	-0.036*	0.020	-1.75	-0.018	0.016	-1.16
Price of milk	0.001***	0.000	2.92	0.000	0.000	1.34	-0.001	0.001	-1.41	0.001	0.001	1.27	0.003	0.001	-3.67
Zoba: Debub	0.022***	0.006	3.72	0.000	0.004	0.04	0.003	0.010	0.34	0.043***	0.013	3.22	0.036***	0.012	3.06
Maekel	0.040***	0.056	7.24	0.019***	0.004	4.94	0.037***	0.009	4.14	0.083***	0.012	6.69	-0.030***	0.011	-2.71
Ramsey RESET test	3.76**			11.40***			2.90**			3.68**			9.50***		
Breusch-Pagan / Cook-Weisberg test	150.69***			146.17***			104.80***			62.55***			61.27***		

Source: Field survey, 2023.

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Table A7. Multivariate Analysis of Determinants of the 5DE Indicators in Dairy Farming among Male and Female Household Heads

	Female			Male			Eritrea		
5DE indicators / Production	**Coef.**	**Std. Err.**	**t**	**Coef.**	**Std. Err.**	**t**	**Coef.**	**Std. Err.**	**t**
LOG Labor productivity	-0.001	0.009	-0.14	0.002	0.003	0.51	0.002	0.003	0.68
Asset Index Score	0.002	0.005	0.35	-0.002	0.002	-0.96	-0.001	0.002	-0.62
Age of household head	0.000	0.000	0.02	0.000*	0.000	-1.94	0.000	0.000	-1.59
Gender of household head	0.000	(omitted)		0.000	(omitted)		-0.008	0.005	-1.45
Educational level of household head	-0.005	0.006	-0.91	-0.007***	0.002	-2.74	-0.006***	0.002	-2.71
Dairy experience	0.000	0.001	0.05	0.000*	0.000	1.94	0.000**	0.000	2.06
Household size	-0.001	0.002	-0.48	-0.001	0.001	-0.78	-0.001	0.001	-1.02
Frequency of extension visits	-0.001	0.004	-0.22	0.000	0.002	-0.06	-0.001	0.002	-0.38
No lactating cows	0.000	0.004	-0.07	0.001	0.001	0.87	0.000	0.001	0.48
Quantity of milk	0.000	0.000	-0.06	0.000	0.000	-0.86	0.000	0.000	-0.79
Processed milk	0.015	0.013	1.15	0.013**	0.006	2.34	0.016***	0.005	3.07
Semi-intensive	-0.024	0.017	-1.39	-0.041***	0.011	-3.59	-0.034***	0.009	-3.71
Extensive	0.002**	0.001	2.52	0.001	0.000	1.46	0.001***	0.000	2.92
Price of milk	0.053***	0.020	2.64	0.020***	0.007	2.94	0.022***	0.006	3.72
Zoba: Debub	0.074***	0.020	3.68	0.038***	0.006	6.31	0.040***	0.006	7.24
Constant	0.102**	0.044	2.31	0.186***	0.018	10.12	0.178***	0.018	9.84
Resources									
LOG Labor productivity	0.012*	0.007	1.78	0.002	0.002	0.84	0.003	0.002	1.45
Asset Index Score	-0.006	0.004	-1.58	-0.001	0.001	-0.98	-0.002	0.001	-1.45
Age of household head	0.000	0.000	-0.21	0.000	0.000	-0.32	0.000	0.000	-0.36
Gender of household head	0.000	(omitted)		0.000	(omitted)		-0.002	0.004	-0.59
Educational level of household head	0.000	0.005	0.06	-0.002	0.002	-1.19	-0.001	0.001	-0.83
Dairy experience	0.000	0.000	-0.02	0.000	0.000	0.55	0.000	0.000	0.4
Household size	-0.001	0.002	-0.32	0.000	0.000	-0.48	0.000	0.000	-0.24
Frequency of extension visits	-0.004	0.003	-1.08	-0.002*	0.001	-1.67	-0.003**	0.001	-2.31
No lactating cows	0.001	0.003	0.17	0.000	0.001	-0.18	0.000	0.001	-0.02
Quantity of milk	0.000	0.000	-0.37	0.000	0.000	-0.17	0.000	0.000	-0.44
Processed milk	0.021**	0.010	2.05	0.006*	0.004	1.65	0.010***	0.003	2.77
Semi-intensive	0.015	0.013	1.09	-0.020***	0.007	-2.68	-0.010	0.006	-1.6
Extensive	0.001	0.001	1.46	0.000	0.000	0.65	0.000	0.000	1.34
Price of milk	0.030*	0.016	1.89	-0.004	0.004	-0.9	0.000	0.004	0.04

Zoba: Debub	0.050***	0.016	3.15	0.015***	0.004	3.73	0.019***	0.004	4.94
Constant	0.059*	0.035	1.68	0.097***	0.012	8.05	0.092***	0.012	7.50
Income									
LOG Labor productivity	0.002	0.016	0.14	0.005	0.005	1.05	0.005	0.005	1.09
Asset Index Score	-0.004	0.008	-0.47	-0.004	0.003	-1.38	-0.004	0.003	-1.44
Age of household head	0.000	0.001	-0.05	0.000	0.000	-0.28	0.000	0.000	-0.02
Gender of household head	0.000	(omitted)		0.000	(omitted)		0.002	0.008	0.28
Educational level of household head	0.002	0.011	0.17	-0.002	0.004	-0.43	0.000	0.003	-0.11
Dairy experience	0.000	0.001	-0.13	0.000	0.000	0.49	0.000	0.000	0.5
Household size	-0.004	0.004	-0.89	0.001	0.001	0.46	0.000	0.001	0.15
Frequency of extension visits	-0.007	0.008	-0.87	0.001	0.003	0.34	-0.001	0.003	-0.23
No lactating cows	0.001	0.007	0.11	0.000	0.002	0.17	0.000	0.002	0.03
Quantity of milk	0.000	0.001	-0.21	0.000	0.000	-0.21	0.000	0.000	-0.16
Processed milk	0.022	0.024	0.91	0.010	0.009	1.14	0.014*	0.008	1.78
Semi-intensive	-0.012	0.031	-0.38	-0.006	0.018	-0.34	-0.006	0.015	-0.41
Extensive	0.000	0.002	-0.31	-0.001	0.001	-1.08	0.000	0.001	-0.88
Price of milk	0.040	0.037	1.09	-0.001	0.010	-0.12	0.003	0.010	0.34
Zoba: Debub	0.083*	0.037	2.24	0.033***	0.009	3.55	0.037***	0.009	4.14
Constant	0.177**	0.081	2.17	0.181***	0.029	6.31	0.170***	0.029	5.94
Leadership									
LOG Labor productivity	-0.021	0.021	-1.02	-0.005	0.007	-0.83	-0.005	0.006	-0.81
Asset Index Score	0.019*	0.011	1.73	-0.002	0.004	-0.39	0.002	0.004	0.62
Age of household head	0.002	0.001	1.41	-0.001*	0.000	-1.67	0.000	0.000	-0.96
Gender of household head	0.000	(omitted)		0.000	(omitted)		-0.034***	0.012	-2.88
Educational level of household head	-0.004	0.014	-0.3	-0.002	0.005	-0.33	-0.003	0.005	-0.6
Dairy experience	0.000	0.001	-0.12	0.000	0.000	-0.32	0.000	0.000	-0.19
Household size	0.014***	0.005	2.71	0.002	0.001	1.27	0.002*	0.001	1.68
Frequency of extension visits	-0.007	0.010	-0.68	0.005	0.004	1.32	0.003	0.004	0.8
No lactating cows	-0.020*	0.010	-2.01	-0.001	0.002	-0.34	-0.002	0.002	-0.81
Quantity of milk	0.002	0.001	1.63	0.000	0.000	0.32	0.000	0.000	0.39
Processed milk	-0.015	0.032	-0.47	0.012	0.012	0.96	0.009	0.011	0.77
Semi-intensive	-0.080*	0.041	-1.94	-0.019	0.024	-0.76	-0.036*	0.020	-1.75
Extensive	0.000	0.002	0.12	0.001	0.001	0.71	0.001	0.001	1.5
Price of milk	-0.005	0.049	-0.11	0.049***	0.014	3.45	0.043***	0.013	3.22

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Zoba: Debub	0.060	0.049	1.21	0.088***	0.013	6.87	0.083***	0.012	6.69
Constant	-0.043	0.108	-0.39	0.127***	0.039	3.22	0.133***	0.040	3.30
Time									
LOG Labor productivity	0.025	0.015	1.61	0.041***	0.006	6.73	0.041	0.006	7.26
Asset Index Score	0.000	0.008	0.03	-0.013***	0.004	-3.57	-0.011	0.003	-3.37
Age of household head	0.001	0.001	0.99	0.000	0.000	1.18	0.001	0.000	1.55
Gender of household head	0.000	(omitted)		0.000	(omitted)		0.005	0.010	0.45
Educational level of household head	0.017*	0.010	1.66	0.004	0.005	0.78	0.005	0.004	1.21
Dairy experience	0.001	0.001	0.56	0.000	0.000	-1.18	0.000	0.000	-1.26
Household size	0.009**	0.004	2.33	0.000	0.001	-0.12	0.000	0.001	0.17
Frequency of extension visits	-0.005	0.008	-0.61	0.011***	0.004	2.81	0.008	0.003	2.28
No lactating cows	-0.029***	0.007	-4.04	-0.007***	0.002	-3.29	-0.009	0.002	-4.55
Quantity of milk	0.001**	0.001	1.99	0.000	0.000	-1.33	0.000	0.000	-1.06
Processed milk	-0.031	0.023	-1.33	-0.030***	0.011	-2.66	-0.027	0.010	-2.72
Semi-intensive	0.018	0.030	0.59	-0.049**	0.023	-2.17	-0.026	0.018	-1.44
Extensive	0.002	0.001	1.2	0.002***	0.001	2.92	0.003	0.001	3.67
Price of milk	-0.045	0.036	-1.25	0.041***	0.013	3.09	0.036	0.012	3.06
Zoba: Debub	-0.084**	0.036	-2.36	-0.027**	0.012	-2.31	-0.030	0.011	-2.71
Constant	0.118	0.078	1.51	0.127***	0.036	3.47	0.114	0.036	3.18

Source: Field Survey, 2023.