# The Effect of Technical Efficiency on Smallholder Taff Producers' Welfare: Evidence from Northern Ethiopia

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## Abstract

This research examines the link between technical efficiency (TE) and household welfare of small-scale Taff-producing farmers in Laelay Maichew District, Northern Ethiopia. A total of 392 farmers were surveyed using a multistage sampling technique, which was subsequently analyzed using stochastic frontier and structural equation model. The mean Technical Efficiency (TE) was 2.459 with a standard deviation of 1.241. The key results are that total income is positively affected by TE. Technical efficiency also has a significant positive effect on total asset value. These findings identify the key roles played by technical efficiency in improving the welfare of the household. Therefore, focused interventions such as increasing access to quality inputs, enhancing agricultural extension services, providing technical training, and providing cheap credit must be targeted towards the low-performing farmers in efficient allocation of resources. Such focused aid would bridge efficiency gap, reduce income disparity, and increase inclusive welfare growth among the teff-growing farmers of Northern Ethiopia.

**Keywords***:* Northern Ethiopia; Stochastic Frontier Analysis; Taff Production; Technical Efficiency; Welfare.

## 1 Background and Justification

Smallholder agriculture inspires food security and supports the livelihoods of millions around the world. About 95% of the total agricultural production of Ethiopia is contributed by smallholder farmers (UNICEF, 2021). Agriculture contributes a gross value of US$27.5 billion to Ethiopian GDP, and 79% of the population, or 12 million farmers, earn their living from the sector (National Planning Commission, 2016; O'Neill, 2024; World Bank, 2016). Among the agricultural production, *Taff* takes its own share of the agricultural contribution to Ethiopian GDP. *Taff* is one of the most important crops farmed in Ethiopia and a vital source of income and nutrition for the majority of people. Rich in protein, fiber, and the most important minerals, like calcium and iron, *Taff* is nutrient-rich and is thought to offer all the nutritional advantages (Gebru et al., 2020; IFPRI, 2022). Over 3 million hectares, 6.77 million farmers cultivate the crop, generating roughly $500 million in revenue for farmers each year (CSA, 2012). For more than 60 million Ethiopians, *Taff* is a staple grain; 78% of urban households and 45% of rural households routinely eat it (CSA; World Bank, 2013; Vandercasteelen et al., 2018). The region's *Taff* producers face numerous obstacles that have a negative impact on household welfare and productivity levels. One of their main drawbacks is inefficient allocation of agricultural input and lack of study on the effect of technical efficiency on welfare.

The actual average production for *Taff* in the country is rather low, standing at 1.66 t/ha when compared to a potential of 40–50 qt/ha. Apart from the challenges mentioned above, it is predicted that climate change will

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lower *Taff* production by 20 to 30 percent by 2050 (Change, 2007), and inefficient allocation of resources contribute to the loss. The same is true for the Tigray case. The main reasons Tigray's prolonged crises and two-year war are making it difficult for farmers to invest in and actively participate in farm operations, which is further exacerbating food insecurity and endangering the region's sources of income. Interventions to improve the current low level of farm productivity are thought to boost smallholder farming incomes by up to 40%, which would improve welfare outcomes like total income, assets, expenditures, better nutrition and education, and better health, all while maintaining peace and security and boosting the confidence of economic agents (IFPRI, 2022). It has been demonstrated that households with higher yields make investments in assets, income, and expenditure.

This study is situated between two theoretical orientations-the household production theory postulated by Becker (1965) and the farm household model forwarded by Singh et al. (1986). The household model theory indicates that households maximize their utility by rationalizing their resource allocation and domestic production as well as purchasing goods and services from the market. On the other hand, the productivity or efficiency theoretical framework has to do with the household production function and how available inputs, given the state of technology, can internally be transformed into outputs (Banker et al., 1984; Coelli et al., 2005; Farrell, 1957; Kumbhakar & Lovell, 2003).

Therefore, estimating the technical efficiency and its determinants become important information to make an informed decision for policy makers. Though the determinants of technical efficiency in smallholder agriculture were studied by a number of researchers (Bachewe et al. 2015; Endalew et al. 2022; Gebrehiwot 2017; Weldegebriel 2014), not much attention has been paid to the relationships between welfare indicators and efficiency, particularly concerning *Taff* production in Northern Ethiopia. Other empirical literature indicates that enhancing technical efficiency can improve both productivity and welfare. For instance, studies have shown that households with higher technical efficiency tend to have 25% higher total income and 30% higher total asset value compared to their less efficient counterparts (Coelli et al., 2005). Moreover, another analysis revealed that improving technical efficiency could reduce poverty levels by an additional 15%, further emphasizing the importance of addressing efficiency in the agricultural sector (Bachewe et al., 2015). The above existing body of literature lacks a comprehensive understanding of how technical efficiency affects welfare indicators, particularly in the case of the smallholder *Taff* production system in Northern Ethiopia.

From the above-mentioned empirical literature, we identified knowledge, contextual, and methodological gaps. These gaps need to be filled to formulate research-driven interventions and policy mandates to improve the livelihoods and resilience of the smallholder *Taff* producers in the region. The first contribution of this paper is to analyze the effect of technical efficiency on welfare indicators, which is mostly absent in the previous literature. The present findings further lay a foundation for policies and programs oriented toward improving the technical efficiency and welfare of the smallholder *Taff* producer. It is based on these insights that this study makes its contribution towards the higher-order objective of sustainable agricultural development.

## 2 Literature review

Fundamental for the understanding of the socioeconomics and agrarian dynamics of smallholder *Taff* production in Northern Ethiopia are the concepts of technical efficiency and welfare themselves. *Taff* is an indispensable staple in Ethiopia, nutritionally and culturally, serving as an economic strength for millions in the country. Farrell (1957) defined TE as those elements output from the set that the farmer would be able to produce or as minimum input usage for producing the expected output level. Thus, key factors such as land, labor, seed, fertilizer, and most importantly, institutional support will have a lot of influence on the TE realized in *Taff* production and hence increasing productivity. Productivity gains achieved via improved TE lift agricultural output, household income, or net worth, and returns on resilience into the better living standards bracket. Such benefits, however, are realizable by structural institutional factors such as access to resources, market opportunities, and infrastructure.

There is not enough empirical evidence showing that the TE among smallholder *Taff* farmers in Ethiopia varies significantly, while there is ample room to improve it. A study on maize production in Zambia by Mwalupaso et al. (2019), observes that informatization exerts a positive effect on TE. Efficiency scores for the farmers vary from 0.41 to 0.82. Furthermore, Belete (2020) found that TE scores ranged from 0.47 to 0.89, indicating significant gaps in productive potential among farmers in Ethiopia's Guji Zone. Afi & Parsons (2023) compared integrated and specialized farming systems in Nebraska, this research noted that 32% of farms had efficiency scores below 0.25. This reflects, among others, imbalances concerning the access to resources, knowledge, and institutional support. Education is elaborated as a key determinant of TE because more educated farmers are usually inclined to modern farming practices and technologies. Apart from this, modern inputs such as improved seed varieties and fertilizers drive higher efficiencies.

Gender differences also do not allow for improved efficiencies since female-headed households obtain limited private and institutional support in accessing resources (Gebre et al., 2022). The finding by Danso-Abbeam & Baiyegunhi (2020) showed that cocoa farmers who had improved their TE enjoyed household welfare increases through higher income, better food security, and improved access to health and education. Research into this study indicated that education, access to credit, and participation in markets were critical elements influencing levels of TE and welfare outcomes achieved.

Other global studies in and of themselves provide a deeper understanding of the TE-well-being debate by comparing the different perspectives found in comparative studies. For example, Nowak et al. (2015) showed that efficient resource management in EU agriculture directly promoted household income through lowering input costs. Identical findings by Khai & Yabe (2011) indicated that much higher TE means improved profitability and lowered household expenditures for the rice farmers in Vietnam. Illukpitiya (2005) proved in Sri Lanka that higher TE reduces farmers' dependence on external resources, hence improving household welfare. Such findings are also reverberated in the studies from Ethiopia (e.g., Gebre et al., 2022), which have established that more TE simply transmits messages on increased incomes and resilience among smallholder farmers. Yet most of these global case studies are often compared with stronger institutional frameworks and improved technological access, both of which are underdeveloped in Ethiopia. And indeed, a great deal of the empirical literature reveals conspicuous knowledge gaps, contextual gaps, and methodological gaps bothersome enough to warrant further investigation. This study shall thus fill in the gaps delineated from previous studies. Based on the theoretical and empirical synthesis, this study produces the conceptual framework (Figure 1) aiming to examine the effect of technical efficiency on welfare indicators in smallholder *Taff* production in Northern Ethiopia.

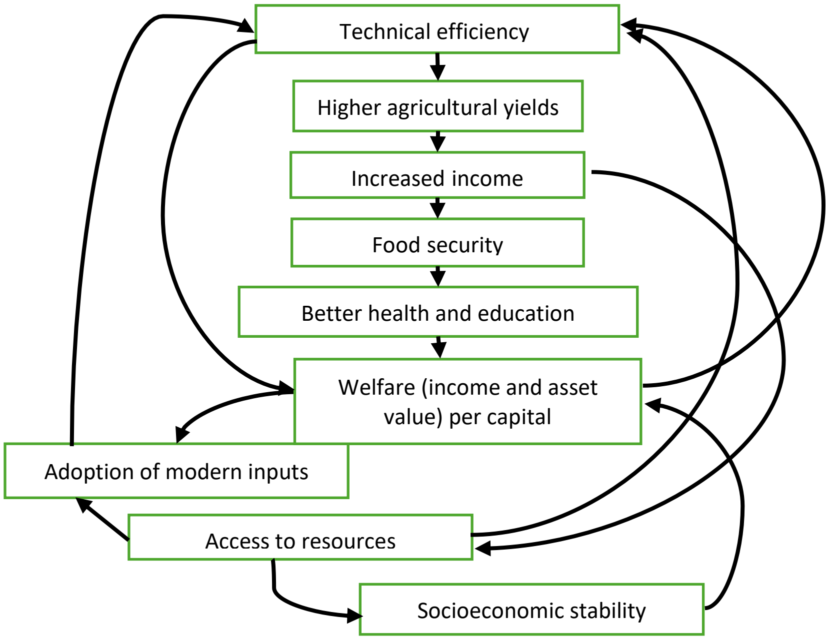


Figure 1 Conceptual framework technical efficiency, welfare indicators and socioeconomic, demographic and institutional variables

# 3 Methodology

## 3.1 Description of the study area

Laelay Maichew district, which is about a distance of nearly 1,024 km from Addis Ababa in northern Ethiopia, boasts an array of agricultural systems and rich cultural heritage. The district receives an annual average rainfall of 720 mm and average temperatures of between 10.9 °C and 27.75 °C. The population is estimated to be around 82,000, with a mean family size of 4.6 persons, and subsistence farming is the primary livelihood, supported by petty business and labor within the area. Major crops such as *Taff*, barley, wheat, horse beans, sorghum, and finger millet are grown in this area, with *Taff* taking up about 7,150 hectares.

## 3.2 Sampling Techniques, Data Type and Method of Data Collection

The study adopted a multi-stage sampling technique to select representative sample respondents. For the first stage, nine Tabias (Hatsbo, Lesalso, Dura, Mai-Weyni, Hadush Adi, Medego, Deberebrhan, Debereqal, and Mahbere-Selam) were deliberately sampled out of 16 Tabias, with a focus on those most highly producing *Taff* in their respective regions. Most usually, within the remaining Tabias, these nine Tabias were selected by agro-climatic zone, thus signifying the multiple climates and soil conditions found in the district. In the second stage, four of these Tabias (Hatsbo, Lesalso, Debereqal, and Mai-Weyni) were selected randomly. Finally, a total of 392 small-scale *Taff* producers were randomly chosen from these four Tabias. For example, the sample size was allocated to each Tabia using probability proportional to size, which provided indicators for any particular Tabia according to its population size. This gives a very robust frame of data collection from the sector in the district, with its varying agroecological conditions influencing *Taff* production within the area.

Both primary and secondary sources of data were utilized in this study. The data collected include primary data, which were collected through face-to-face interviews with sample respondents using a pre-tested and well-structured questionnaire focused on socioeconomic factors that affect *Taff* production and other relevant production information. Moreover, apart from primary data, it acquired secondary data from the Agriculture and Rural Development Office and other published and unpublished sources. It pulls these secondary data to complement and keep for primary findings and give a comprehensive understanding of technical efficiency and welfare in *Taff* production in the district. With these sources, the research was able to very deeply analyze the technical efficiency and household welfare of smallholder *Taff* producers.

## 3.3 Method of Data Analysis

### 3.3.1 Descriptive Statistics

In this study, both descriptive statistics and econometrics were used for the analysis. The descriptive statistics technique includes summarizing and organizing data to get a quick overview of several prime features and patterns within the sample. Measures such as mean, standard deviation, minimum and maximum were computed to describe the socioeconomic factors that affect the *Taff* production and other diverse variables. Descriptive statistics helped in presenting the data in a clear way, hence making it easier to interpret and comprehend the underlying patterns and relationships among the variables. This approach also aided in identifying some important trends and anomalies, creating a solid foundation for further analysis and discussion.

### 3.3.2 Stochastic Frontier Model

In this study, the stochastic frontier model, which was independently proposed by Aigner (1977) and Meeusen & van Den Broeck (1977), extended by Jondrow et al. (1982), and applied by Battese & Coelli (1995), is applied to estimate the technical efficiency *of Taff* production. The general stochastic frontier model with a multiplicative disturbance term is specified as:

$$y_i = f(X_j;\beta)exp(\varepsilon), j = 1,2,\dots,n \quad (1)$$

where $y_i$= output (*Taff* ) in kg for ith farmers; $f(.)$ = an appropriate function; $X_j$= is a vector of conventional inputs used by the ith farmers; $\beta$= is a vector of parameters and $\varepsilon$ is a stochastic disturbance term consisting of two independent elements $v_i \, and \, u_i$ where $\varepsilon = v_i - u_i$; where $v_i$ is the symmetric component of the error term, associated with random factors not under the control of farmers. It is assumed to be normally, independently, and identically distributed as $v \sim N(0,\sigma_v^2)$ random variables independent of $u_i$. The $u_i$ is a nonnegative random variable assumed to account for the inefficiency component of the error term and assumes only positive values. The inefficiency component ($u_i$) assumes different distributional forms like half normal, exponential, truncated-normal, and gamma distributions. There is not any prior justification for choosing one distribution form over the others. Thus, in this study, we applied the truncated normal distribution. Following Kumbhakar & Lovell (2003), the stochastic production frontier in (1) could also be rewritten as:

$$y_i = f\left(X_j;\beta\right)\exp(v_i) * TE_i \quad (2)$$

where the stochastic production frontier $f\left(X_j;\beta\right)\exp(v_i)$ consists of the deterministic part common to all farmers $f\left(X_j;\beta\right)$ and a farmer-specific part $\exp(v_i)$, which captures the effect of random noise or shock on each farmer.

Technical efficiency (TE) from equation (2) is the ratio of the observed *Taff* output ($y_i$) to the corresponding frontier *Taff* output ($y_i^*$) conditional on the levels of inputs used by smallholder farmers and given technology. Thus, the technical efficiency of each smallholder farmer can be given as:

$$TE_i = \frac{y_i}{f(X_j;\beta)exp^{(v_i)}} \approx \frac{f(X_j;\beta)exp^{(v_i-u_i)}}{f(X_j;\beta)exp^{(v_i)}} = \exp(-u_i) \quad (3)$$

The value of $\exp(-u_i)$ is always between 0 and 1, with 1 full technical efficiency and 0 full technical inefficiency (Kumbhakar et al., 2015). The efficiency score estimated from Equation (3) is transformed by the formula $TE\_star = log(TE\,/\,(1 - TE))$, as described by Coelli & Battese (1996); Gopalakrishnan et al.( 2005); Kumbhakar & Lovell (2003); Meeusen & van Den Broeck (1977). This transformation shifts the score from the unit interval [0,1] to the real number range $(-\infty,+\infty)$. $(-\infty,+\infty)$, which also accommodates for factors that are out of the control of farmers.

3.3.3 **Specification of Structural Equation: Welfare Indicators and Technical Efficiency**

Structural equation model (SEM) was used to assess the effect of TE on welfare indicators, i.e., total value of assets per capita and total income per capita. By using SEM, the causal effect of technical efficiency change on these welfare outcomes can be directly examined. With the maximum likelihood estimation employed, the model is also able to deal with the potential measurement error and give more stable parameter estimates, hence a more valid outcome. This approach is particularly helpful in analyzing how variables like gender, education, access to credit, and land in the farm, etc. influence income and asset value, and hence enable deeper understanding of socioeconomic processes. Generally, SEM provides a comprehensive picture of the data, direct and indirect effect, which is particularly essential in proper policy-making and intervention. The two equations used in the Structural Equation Model (SEM) are specified as:

1. Total Income per Capita (TI):

$$TI = \beta_0 + \beta_1 TE + \beta_2 Z_2 + \ldots. + \beta_n Z_n + \epsilon \qquad (4)$$

where

- $Z_i$ are control variables (e.g., education, age, gender, etc.),
- $\beta_1$ & $\beta_1 \ldots \beta_n$ are the coefficients for these variables,
- $\beta_0$ is the constant term (intercept).
- $\epsilon$ is the error term.

2. Total Asset Value per Capita (TA):

$$TA = \gamma_0 \ + \gamma_1 TI + + \gamma_1 TE + \gamma_1 Z_1 + \ldots + \gamma_m Z_m + \epsilon \qquad (5)$$

where:

- $\gamma_1 \ldots \gamma_m$ are the coefficients for the control variables affecting asset value,
- $\epsilon$ is the error term.

### 3.4 Working hypothesis

Null Hypothesis (H0):

- Technical efficiency has no significant effect on the income of smallholder teff producers in Northern Ethiopia.

Alternative Hypothesis (H1):

- Technical efficiency has a significant positive effect on the income of smallholder teff producers in Northern Ethiopia.

## 4 Empirical Results and Discussion

### 4.1 Descriptive results

Table 1 provides summary statistics for two financial variables across a sample of 392 observations. The variables measured are Total Income/Capital and Total Asset Value/Capital, both expressed in Birr, the currency of Ethiopia. The average total income per capita is estimated at 11235.79 birr.

Table 1. Descriptive statistics (N=392)

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Total income/capital in Birr | 11235.79 | 6182.348 | 1783.5 | 46606.801 |
| Total asset value/capital in Birr | 6350.842 | 6401.854 | 215.636 | 37285.398 |

Source: own computation, 2025

From the analysis of the descriptive statistics for the Technical Efficiency Star, the average value comes out to be 2.459, with a positive standard deviation of 1.241, based on which the range spreads between -0.654 and 5.131. Technical Efficiency Star (TE) adjusts for external factors like environmental constraints, policy distortions, market access, and institutional support. The result gives us a picture of how an average household demonstrates, on the whole, somewhat positive technical efficiencies with some variation among the sample. The positive efficiency is consistent with the findings of (Abate, 2019). Most households register efficiencies above the baseline, as indicated by the positive mean; negative values suggest that some households are run inefficiently, possibly poorly allocative or under some other restrictions. This is consistent with findings of Coelli et al. (2005). However, this conversely points towards maximum efficiency at a value of 5.131, meaning that certain households achieve quite good performance regarding effective resource and better production practices. This great considerable variation in efficiency levels indicates the heterogeneity in household performances, probably due to various factors as indicated in Table 2. Although there is a favorable trend in the average, this suggests a requirement to have some targeted intervention to improve resource allocation and assistance to those identified as group inefficiencies.

Household heads have an average score of 0.895 in the demographic gender distribution, indicating that they are predominantly headed by males. The average education level is approximately 3.83 and corresponds to having fairly the same education among household heads, in line with national data where the average is about 4 on the same scale (OECD, 2022). Mean adult equivalent was found to be 3.576 with min and maximum of 0.5 and 8.3 respectively. Average farm size is 1.31 which is below the global average farm size of 1.6 hectares, which is good for the national data because it shares a similar figure but varies across certain regions due to differing availabilities of land (Adamopoulos & Restuccia, 2014). Other issues are access to resources. About 47.2% of the households belong to cooperative members, above the national average of 40% (Bardhan et al., 2019), implying more access to resources and co-governance by the households in this sample. Furthermore, 43.6% of households make up those who have access to agricultural extension services, which is huge in improving farm practices. Such an average of about 35% at the national level shows that more improved agricultural support systems are available for the sample.

Table 2. Descriptive statistics (N=392)

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Technical efficiency star | 2.459 | 1.241 | -0.654 | 5.131 |
| Gender | 0.895 | 0.31 | 0 | 1 |
| Educational level of the household | 3.827 | 3.23 | 0 | 11 |
| Credit | 0.395 | .49 | 0 | 1 |
| Age of the household | 49.656 | 8.47 | 36 | 69 |
| Adult equivalent | 3.576 | 1.333 | 0.5 | 8.3 |
| Farm size in hectare | 1.305 | 0.927 | 0.063 | 6.063 |
| Cooperative membership | 0.472 | 0.5 | 0 | 1 |
| TLU | 4.485 | 3.308 | 0 | 22.28 |
| Distance to market | 18.473 | 15.597 | 0 | 90 |
| Extension access | 0.436 | 0.497 | 0 | 1 |
| Source: Own computation, 2025 | | | | |

Figure 2 portrays the correlation between technical efficiency and welfare measures (income/capital and asset value/ capital). The figure indicates that as welfare measures rise, the technical efficiency also increases. The correlation is overall positive and linear and implies that increased income levels and asset values correspond to increased technical efficiency. This is consistent with economic theory, which requires that increased levels of income and wealth enable more investment in productive assets and technologies, and hence more efficiency. The graph illustrates this correlation and can be helpful in examining the dynamics of the correlation between productive efficiency and economic progress.

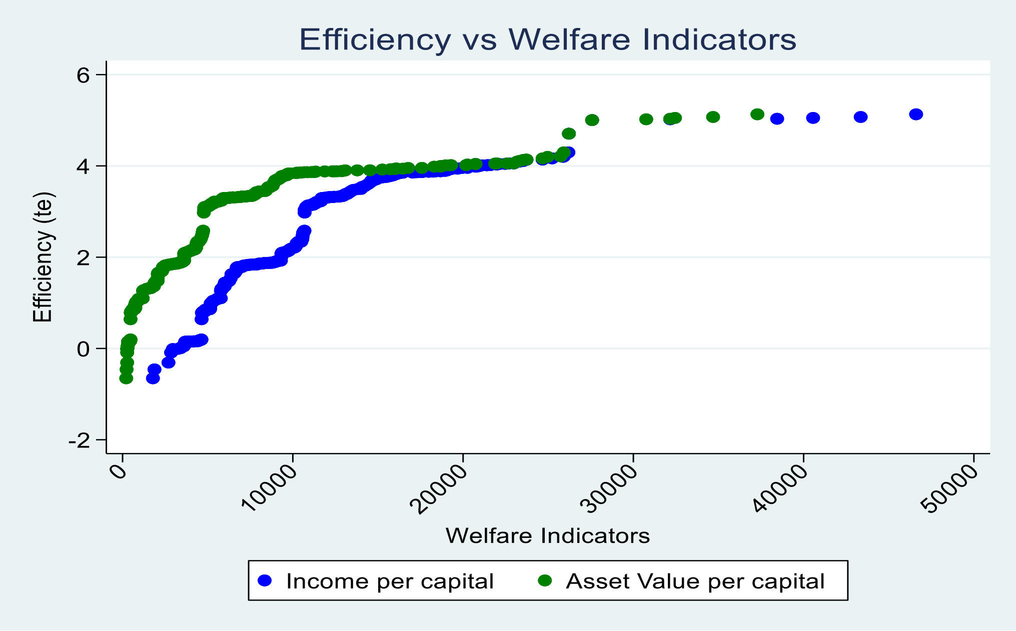


Figure 2. Relationship between efficiency and two welfare indicators

### 4.2 Effect of Technical Efficiency on Welfare

Determinants of welfare indicators portray a multifaceted interaction between efficiency and socioeconomic determinants in influencing welfare outcomes to a large degree (Table 3). The relationship between Ln total income (birr) and Ln total asset value (birr) as embodied in the coefficient (1.201 (0.098)) indicates that there is a positive connection between the two variables. The implication is that with a 1% rise in total income, total asset value increases by 1.201%, and this is statistically significant (as denoted by the asterisks). The result is in line with the findings of Piketty (2014). Notably, technical efficiency positively affects total income (0.209, $p < 0.01$) and total assets (0.179, $p < 0.01$). The result is consistent with Kumbhakar & Lovell (2003), who contend that increased efficiency in the utilization of resources results in improved economic performance. Nevertheless, some empirical research discovers that efficiency by itself would not explain welfare differentials since access to markets and institutional support also perform crucial roles (Zeller & Sharma, 2000). Besides, the education level of the household head had a significant effect on overall income and asset value. This has been verified by Duflo (2001), who stresses the significance of education for better labor market outcomes but clarifies that schooling need not necessarily lead to the accumulation of wealth.

Access to credit is a key determinant with a positive impact on total income and total value of assets. This indicates the contribution of financial capital in stimulating welfare enhancement, implying that policy initiatives towards expanding access to credit would be of great payoff to rural households. This is consistent with the views of Morduch (1999), who established that access to credit drastically increases income-generating activities. The regression also shows that the age of the household head has a negative effect on income and assets, which means older heads may be less actively involved in economic activity, a potential drag on their households' economic opportunities. Farm size correlates with income and asset value. A similar producer can be used to interpret the other determinants of welfare, presented in Table 3.

Table 3. Determinants of welfare indicators (N=392)

| **Variables** | **Ln total income(birr)** | **Ln total asset value (birr)** |
|---|---|---|
| Ln total income(birr) | | 1.201***(0.098) |
| Technical Efficiency star | 0.209***(0.021) | 0.179***(0.046) |
| Gender of the household head | -0.110*(0.063) | -0.234*(0.123) |
| Educational level of household head | 0.038***(0.008) | -0.032**(0.015) |
| Credit access of the head | 0.141***(0.0197) | 0.128***(0.041) |
| Age of household head | -0.044***(0.00418) | -0.032**(0.009) |
| Adult equivalent | -0.097***(0.0255) | 0.227***(0.050) |
| Farm land in hectare | 0.121***(0.0352) | -0.133*(0.070) |
| Extension access | 0.010(0.00792) | 0.005(0.015) |
| TLU | -0.012(0.010) | -0.019(0.019) |
| Distance to market in km | -0.006***(0.001) | -0.001(0.002) |
| Cooperative membership(yes=1) | 0.118***(0.019) | 0.079**(0.038) |
| Constant | 11.03***(0.221) | -1.970*(1.161) |
| var(e.ln_total_icome) | 0.006***(0.0004) | |
| var(e.ln_total_assetvalue) | 0.022***(0.002) | |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Results in Table 3 above show the variances of var(e.ln_total_icome)=0.006(0.0004)) and var(e.ln_total_assetvalue)= 0.022(0.002)) show how much those error terms fluctuate in association with the positional freedom of the logarithm of total income and total asset value, respectively. Those asterisks indicate statistical relevance, which is meant to suggest that those variances are not the product of random chance. Therefore, lower variance for total income indicates a more consistent and much more accurate evaluation compared to total asset value, which indicates greater variability and less precision. This passes the reliability of total estimates concerning income in terms of estimates concerning total asset value thus, informing policy and economic decisions.

## 5 Conclusion and Recommendation

The technical efficiency estimate, with a mean value of 2.459, conveys overall positive efficiency levels, but with considerable variation between households. Whereas some of the households are found to be highly efficient, others are inefficient, possibly as a result of misallocation of resources or external constraints. The heterogeneity indicates the desirability of selective interventions for the improvement of resource use and productivity in the less efficient households. One of the key results of the study is the extremely high correlation between technical efficiency and welfare measures like income and value of assets. More productive households would also have higher income and more wealth, substantiating the assumption that effective management of resources leads to improved economic performance. Therefore, focused interventions such as increasing access to quality inputs, enhancing agricultural extension services, providing technical training, and providing cheap credit must be targeted towards the low-performing farmers in efficient allocation of resources. Such focused aid would bridge the gap in efficiency, reduce income disparity, and increase inclusive welfare growth among the *taff*-growing farmers of Northern Ethiopia.

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