Chapter 7

PRODUCTIVITY AND EFFICIENCY IN HIGH-POTENTIAL AREAS

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A large majority of Ethiopians and those who are poor live in rural areas and derive their livelihood from agriculture. Moreover, the proportion residing in rural areas is predicted to stay high (still around 70 percent in 2040), when there is likely to be 40 percent more rural residents (UN 2014). Agriculture is dominated by smallholder households. During 2013/2014, 94 percent of the area nationwide was cultivated by smallholder farmers (Ethiopia, CSA 2005b–2014b). The average amount of land held by smallholders was about a hectare and has since declined. In addition, the number and size of households increased between 2004/2005 and 2013/2014 (Ethiopia, CSA 2005b–2014b). The facts that most Ethiopians are engaged in agriculture and the bulk of the poor reside in rural areas have provided the impetus for major policy initiatives from the government of Ethiopia that prioritize smallholder agriculture. Most notably, since the launch of the Agricultural Development Led Industrialization strategy in 1993 (Ethiopia, MoPED 1993), agriculture has become a focal point.

In the past, development economists broadly agreed on supporting smallholder agriculture owing largely to its effectiveness in poverty reduction and economic growth in a number of Asian countries during the Green Revolution (Hazell et al. 2010; Diao, Hazell, and Thurlow 2010). Smallholder agriculture is therefore mostly favored among those that give priority to poverty reduction and food security (Fan et al. 2013; FAO 2010; Bill and Melinda Gates Foundation 2011). However, such policies have increasingly been challenged in Africa on various grounds (Collier and Dercon 2009; Dercon and Zeitlin 2009). These include research findings that show medium- and large-scale farmers have superior productivity relative to smallholders (Helfand and Levine 2004; Rios and Shively 2005; Padilla-Fernandez and Nuthall 2012) and that the poor might benefit from improved labor markets generated by more efficient farms (Maertens and Swinnen 2009). Even those that promote smallholder-focused policies as key for growth and poverty reduction point to the diversity within smallholder farmers and underline the need for tailoring such policies to specific conditions (Birner and Resnick 2010; Hazell 2014) and targeting farmers with a viable future in agriculture (Fan et al. 2013).

Growth in agriculture is one of the major drivers of the remarkable growth in real gross domestic product (GDP) recorded in Ethiopia in the past decade. Official national statistics indicate that real gross and per capita GDP grew at average annual rates of 10.7 percent and 7.9 percent during the 2004/2005–2013/2014 period (National Bank of Ethiopia 2014), while World Bank data indicate slightly faster growth rates of 11 percent and 8.1 percent during 2004–2014 (World Bank 2015). During the same period, teff accounted for about a fifth of the nationwide agricultural area and was cultivated by nearly half of smallholder farmers (Ethiopia, CSA 2005a–2014a), while it contributed more than 6 percent to real GDP and growth in real GDP (Bachewe et al. 2015). With 28 percent of total teff output marketed during 2008/2009–2013/2014, it is also the most commercialized crop among cereals, with average marketed output running at 16 percent (Ethiopia, CSA 2009c–2014c).

Various staple crops dominate different parts of Ethiopia. However, teff is either the staple or among the most consumed crops in almost all parts. The share of food expenditure on teff is highest in urban areas and increased by 3.4 percent nationwide between 2005 and 2010, during which period real income increased considerably and the share of all other cereals declined (see Chapter 2). Following the increase in teff demand, which is reflected, among others, by the increase in its real price, the long-run teff supply response of households was faster than growth in its price (Bachewe and Taffesse 2015).

Teff output has grown at an average annual rate of 9.3 percent (Ethiopia, CSA 2005a–2014a) since 2005. The evidence indicates that part of the growth in teff output has been driven by increases in cultivated area (Dorosh, Robinson, and Thurlow 2015). However, it is not well understood how much rising teff yields have contributed to this output growth.

This study employs data envelopment analyses (DEA) to measure productivity of teff-producing households on a dataset collected in the baseline survey of the Agricultural Growth Program (AGP) of Ethiopia.[1] The study also conducts econometric analyses to identify the factors that influence performance in productivity. Since Sen's (1962) observation on the link between farm size and productivity, a number of studies have been conducted that

1 The AGP commenced in 2011 as a component of the government's broad effort to partly achieve the targets of GTP. It is mainly aimed at increasing smallholder productivity sustainably and value-added in agriculture (Ethiopia, MoRAD 2010).

investigate the relationship, including Barett, Bellemare, and Hou (2010); Coelli, Rahman, and Thirtle (2002); Helfand and Levine (2004); Padilla-Fernandez and Nuthall (2012); and Rios and Shively (2005). Yet, despite declining landholdings in Ethiopia and the large international literature, there is little empirical evidence on the link between farm size and productivity. This chapter investigates whether productivity improves with teff area cultivated and whether factors that influence productivity differ across scales of operation. Furthermore, relative productivity levels obtained from DEA are used to compute outputs obtainable at hypothetical levels of productivity and specialization in teff production.

This chapter has three contributions to the international literature. First, it investigates productivity issues using a recently collected large-scale dataset of farm households in Ethiopia that cultivate an important crop and uniquely integrate a number of variables. Second, the study informs the debate on the farm size–productivity relationship that is recently being revisited by development economists. Third, the study provides insights on the relationship between productivity and levels of specialization.

Works that study productivity in Ethiopia include Endale (2011); Nisrane et al. (2011); Taffesse, Dorosh, and Gemessa (2012); and Yami et al. (2013). Relative to these, the dataset used in this study is rich in details and comprises a larger number of households and a wider geographical area than most. A large number of studies employ DEA to measure productivity and use a broad range of variables to investigate factors that influence productivity and efficiency. A number of other studies focus on the effect of a specific set of factors to explain productivity, such as farm size and level of specialization. Coelli and Fleming (2004) use data from Papua New Guinea to study whether productivity improves with specialization in the type of crop and crop group produced. Helfand and Levine (2004) and Padilla-Fernandez and Nuthall (2012) use datasets from Brazil and the Philippines to study the farm size–efficiency relationship, respectively. Latruffe et al. (2005) use Polish data to investigate efficiency differences across farm sizes and levels of specialization. The analyses in this chapter use factors emphasized in the studies referred to above as well as a broad range of other variables.

Important findings of this chapter include DEA results, which indicate that an average teff farmer is only about a third as productive as farmers who are efficient in their practices, both by scale and technical efficiency. Moreover, the results of econometric analyses show that performance in productivity is positively associated with farmers' education. Households with access to financial institutions and production information (through media or extension) have higher productivity. Specialization in the production of fewer crops is positively associated with productivity. Unlike the inverse farm size–productivity hypothesis, our results indicate that largeholders are as productive as smallholders.

The remainder of the chapter is organized as follows: The next section describes the theoretical and empirical models. The two subsequent sections describe the data and discuss the results, respectively. The last section summarizes key findings and explores their policy implications.

Method of Analysis

Relative total factor productivity (TFP) and efficiency of teff farmers is measured using data envelopment analyses (DEA) that employ input and output distance functions to measure comparative performance. Output and input distance functions are defined and the empirical output distance function is specified in the first part of this section. Following this, the relative productivity and efficiency indexes are defined. Finally, the econometric model that is employed to investigate factors that explain relative TFP and efficiency is specified.

Output and Input Distance Function

Consider a production technology T that describes the relationship between an input vector $X = [x_1, x_2, \ldots, x_N]$ and an output vector $Y = [y_1, y_2, \ldots, y_M]$:

$$T = \{(X, Y): X \in \Re_+^N, Y \in \Re_+^M, X \text{ can produce } Y\}$$

Then, Färe, Grosskopf, and Lovell (1985) define an output distance function under some regularity conditions as:[2]

$$D_O^j(X_j, Y_j) = \inf_\theta\{\theta^j: (X_j, Y_j/\theta) \in T\} \text{ for all } j \in [1,2, \ldots, J] \qquad (1)$$

where j indexes producers, in this case, farm households, and $D_O^j(.) \in (0,1)$ stands for output distance function of j. An output distance function measures efficiency by comparing output levels produced by households with those at the boundary of production possibilities. The output distance function of household j is the largest factor by which j's output can be multiplied and increased if it were to produce the optimal quantity from the inputs it is currently using. Similarly, an input distance function is defined as:

2 See Fare and Primont (1995) on regularity conditions assumed.

$$D_I^j(X_j, Y_j) = \sup_\beta\{\beta^j\colon (X_j/\beta, Y_j) \in T\} \text{ for all } j \in [1,2, \dots, J] \qquad (2)$$

where $D_I^j(.)\geq 1$, which stands for the input distance function, is the largest factor by which household j's current input use levels can be divided and minimized if it were optimal in input use and still produce its current output levels.

DEA employs linear programming methods on input-output data to construct nonparametric piecewise linear production or input requirement frontiers. Performance of producers away from the frontier is then measured using their distance relative to those operating on the frontier or using output and input distance functions. Applied studies using DEA often employ Translog distance functions, which are also adopted in this study. The empirical output distance function of teff-producing households that use multiple inputs is defined as:

$$D_O^j(X_j, Y_j) = \alpha_0 + \alpha_1 \ln y_j + \frac{1}{2}\alpha_{1,1}\ln y_j^2 + \sum_{n=1}^{10} \beta_n \ln x_{n,j} + \frac{1}{2}\sum_{n'=1}^{10}\sum_{n=1}^{10}\beta_{n',n} \ln x_{n',j} \ln x_{n,j} + \sum_{n=1}^{10}\delta_n \ln x_{n,j} \ln y_j \quad \text{for all } j \in [1, \dots, J] \qquad (3)$$

where y_j is the quantity of teff output that household j produced using $x_{n,j}$ of input type n, with $x_{n,j} \in$[teff area, labor, oxen, fertilizer, improved seeds, pesticides, irrigation, land quality index, rainfall, and growing degree days]. These variables are formally defined in Table 7.1.

Productivity and Efficiency Indexes

In this part the indexes used to measure performance in relative TFP and efficiency are defined. The study also uses the indexes to compute output levels that can be obtained if farmers were to operate at optimal levels and partially and fully specialize in teff production. Thus, along with the indexes, the equations used in those computations are defined.

Among classes of multifactor productivity indexes, the Färe-Primont and Lowe indexes satisfy all economically relevant axioms and tests in index number theory (O'Donnell 2011a). The study uses the Färe-Primont index because it is suitable for the input-output data used. The index defines the TFP of a multiple-input multiple-output household j as a ratio of an aggregate output and aggregate input index as:

$$TFP_j = \frac{Q_j}{I_j} \qquad (4)$$

TABLE 7.1 Definition of variables used in data envelopment analyses

Variables	Definition	Aggregation
y	Teff output (kilograms)	Crop
x_1	Teff area (hectares)	Crop
x_2	Labor (sum of family and hired labor days)	Crop
x_3	Oxen used to plow land (number)	Household
x_4	Chemical fertilizer (kilograms)	Crop
x_5	Improved seeds (kilograms)	Crop
x_6	Pesticides dummy = 1 if pesticides, herbicides, and/or fungicides used	Crop
x_7	Irrigation dummy = 1 if cropland is irrigated	Crop
x_8	Land quality index = land fertility index × slope of land; where fertility ∈ [1 = infertile, 2 = semifertile, 3 = fertile] and slope ∈ [1 = steep, 2 = gentle, 3 = flat]	Crop
x_9	Total rainfall = sum of daily rainfall during May 1–October 31, 2010 (millimeters)	District
x_{10}	Growing degree days = sum of daily beneficial heat during May 1–October 31, 2010[a]	District

Source: Authors.

Note: [a] Daily beneficial heat = the contribution to yields of any given day's average temperature in excess of the lower bound of a given temperature range, generally 8°C –32°C. Growing degree days = the sum over days in the cropping season of daily beneficial heat [the excess of average daily temperature over the lower bound], multiplied by the probability of the average temperature to occur on that day in that area (see also Roberts, Schlenker, and Eyer 2013).

where $Q_j = Q(y_{m,j})$ is the aggregate output index and $y_{m,j}$ is the magnitude of type m output, such that $y_{m,j} \in Y_j = [y_{1,j}\, y_{2,j} \ldots y_{M,j}]$. Similarly, $I_j = I(x_{n,j})$ is an aggregate input index and $x_{n,j}$ is quantity of input type n, where $x_{n,j} \in X_j = [x_{1,j}\, x_{2,j} \ldots x_{N,j}]$. The aggregator functions $Q(.)$ and $I(.)$ are assumed to be nonnegative, nondecreasing, and linearly homogenous functions of their respective arguments (O'Donnell 2008).

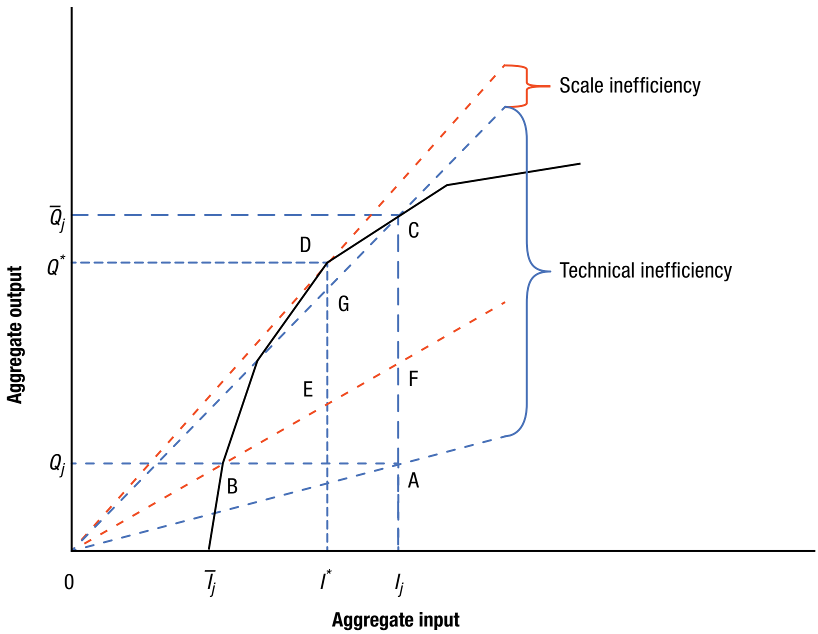
Then $RTFP_{k,j}$, which denotes the TFP of j (TFPj) relative to the TFP of optimal household(s) (TFP*), is given as:

$$RTFP_{k,j} = \frac{TFPj}{TFP^*} = \frac{Q_j/I_j}{Q_k^*/I_k^*} = \frac{Q_{k,j}}{I_{k,j}} \tag{5}$$

where k represents optimal household(s). The index at (5) can be decomposed into technical and scale efficiency indexes that obtain $RTFP_{k,j}$ multiplicatively (O'Donnell 2009 and 2011b). Figure 7.1 is used to illustrate the technical and scale efficiency components of RTFP.

Suppose household j operates at point A where it uses I_j to produce Q_j. The household at A is inferior relative to that at C, which is producing a larger

FIGURE 7.1 **Output-oriented measures of technical and scale efficiency**



Source: Modified from Figures 1 and 2 in O'Donnell (2011b).

aggregate quantity, $\bar{Q}_j \geq Q_j$ using I_j. Then an output-oriented technical efficiency (OTE) of the household at A, relative to that at C, is given as:

$$\mathrm{OTE_j} = \frac{\mathrm{Q_j/I_j}}{\mathrm{\bar{Q}_i/I_i}} = \frac{\mathrm{TFP_j}}{\mathrm{TFP_C}} = \frac{\mathrm{Q_j}}{\mathrm{\bar{Q}_i}} = \mathrm{D_O^j(X_j, Y_j)} \leq 1 \quad (6)$$

Whereas $\bar{Q}_j$ is the aggregate output of C, it is also the maximum output A can produce if it were optimal in output-oriented technical efficiency. These magnitudes are differentiated by denoting the potential aggregate output A can produce by $\bar{Q}_j^O$, which is given as:

$$\bar{Q}_j^O = \frac{Q_j}{OTE_j} \quad (7)$$

The household at B is superior to A in input technical efficiency because it is producing Q_j using smaller aggregate input, $\bar{I}_j \leq I_j$. Then an input-oriented technical efficiency (ITE) of A, relative to B, is:

$$ITE_j = \frac{Q_j/I_j}{Q_j/\bar{I}_j} = \frac{TFP_j}{TFP_B} = \frac{\bar{I}_j}{I_j} = D_I^j(X_j, Y_j)^{-1} \leq 1 \quad (8)$$

$\overline{Q}_j^I$ denotes the potential output the household at A can produce if it were input-efficient or, equivalently, the aggregate output the household at B can produce if it were using I_j and operating at a point such as F. This is given as:

$$\bar{Q}_j^I = TFP_B * I_j \tag{9}$$

Note that in Figure 7.1 the slope of the line that connects the origin with each point on or under the production frontier provides the TFP of the household that operates at that point. This implies that although the households at points B and C are superior to that at A, they have lower TFP relative to the household at point D, which has the maximum TFP of Q^*/I^* or the line that is tangent to point D has the maximum slope. D is superior relative to C due to output oriented scale efficiency (OSE) and relative to B in input-oriented scale efficiency (ISE).[3]

Performance in OSE and ISE of the households at C and B is given by:

$$OSE_j = \frac{\bar{Q}_j/I_j}{Q^*/I^*} = \frac{TFP_C}{TFP^*} \leq 1 \quad \text{and} \quad ISE_j = \frac{Q_j/\bar{I}_j}{Q^*/I^*} = \frac{TFP_B}{TFP^*} \leq 1 \tag{10}$$

Equation (5) can be used to compute, $\overline{Q}_j^*$, which denotes the aggregate output j could produce, if it were as productive as k, as:[4]

$$Q_j^* = TFP_k^* * I_j \tag{11}$$

The hypothetical optimal outputs given by equations (7), (9), and (11) are aggregate units. This study computes the optimal teff output in two steps. First, the factor by which aggregate output increases is computed as a ratio of optimal aggregate output and actual aggregate output. In the second step the optimal teff output is obtained by multiplying the factor calculated in the first step and household j's actual teff output. The method is justified because the output aggregator function is nondecreasing and linearly homogenous or increases at the same rate teff output increases.

3 The TFP of households are defined relative to technically and scale-efficient household(s) operating on production frontiers constructed from the dataset. Such comparisons can also be made relative to households that operate on mix-unrestricted production frontier lying above the current frontier (see O'Donnell 2008 and 2011b). The objective of comparing households within the current production possibility frontier justifies the approach used in this study.

4 Equation (11) implicitly assumes that j becomes both scale and technically efficient as k. The latter may not hold if the scale of operation of inefficient households differs from the scale at which optimal households operate. However, the assumption and consequently the computation can be justified for an average household, if increases in scale required for small inefficient farms to be optimal are equivalent to decreases in scales required for larger farms to become optimal. In this dataset aggregate input ranges between 0.76 and 14.71 for all observations, while the 35 all-rounded efficient households have aggregate inputs ranging from 1.108 to 14.34 and are well distributed across this range.

Factors Explaining Efficiency and Productivity

We use a Tobit model to study factors that are associated with teff productivity and efficiency. The empirical equation used for this purpose is given as:

$$\begin{aligned} Efficiency_j = \delta_0 + \textstyle\sum_{i=1}^{4} \delta_i\, HH\ demography_{ij} + \delta_5\, Teff\ area_j + \delta_6\, Teff\ area_j^2 + \\ \delta_7\, Land\ owned\ by\ HH_j + \delta_8\, Crop\ damage_j + \delta_9\, Partial\ Spec_j + \delta_{10}\, Full\ Spec_j + \\ \delta_{11}\, Numb\ cash\ crops_j + \delta_{12}\, Off\_farm\ work_j + \delta_{13}\, TLU_j + \delta_{14}\, Production\ info_j + \\ \delta_{15}\, HH\ participation_j + \delta_{16}\, Fert\ users\ in\ FA_j + \delta_{17}\, Imp\ seeds\ users\ in\ FA_j + \\ \delta_{18}\, DA\ center\ in\ FA_j + \delta_{19}\, PAs\ in\ FA_j + \delta_{20}\, Distance\ to\ mkt_j + \delta_{21}\, red\ teff_j + \\ \textstyle\sum_{r=A,O,S} \beta_r\ Region\ dummy_{rj} + \delta_{25}\, AGP_j + \textstyle\sum_{z=WD,D} \delta_z AEZ_{zj} + e_j \end{aligned} \quad (12)$$

In equation (12) $Efficiency_j$ stands for RTFP, OTE, OSE, ITE, and ISE, which are associated with crop-, household-, and location-specific factors. The first summation on the right includes four demographic variables: age, gender, and education of the household head, and household size. About 53 percent of the households cultivated red teff variety, which is represented by the $red\ teff_j$ dummy, while white teff is the omitted category. $Region\ dummy_{rj}$ are region dummies where r ∈ [Amhara (A), Oromiya (O), and SNNP (S)] and Tigray is omitted. Similarly, AGPj takes a value of 1 if household *j* resided in one of the 62 AGP woredas (districts). Included in the last summation are agroecologic zone (AEZ) dummies. The households surveyed lived in AEZs, locally known as Kolla, which is omitted, and Woina Dega (WD), and Dega (D).[5] The error term, e_j, is assumed to be distributed as: $e_j \sim N(0,\sigma_e^2)$. The remaining variables are defined in Table 7.2.

Data

The dataset used in this work was collected in the AGP Baseline Survey. The survey covered 93 woredas (districts) in four regions in Ethiopia: Tigray, Amhara, Oromiya, and Southern Nations, Nationalities, and Peoples' (SNNP) region (see Berhane et al. 2013 for a detailed description of the dataset). The four regions accounted for more than 90 percent of the nation's agricultural output and area during 2004 through 2013 (Ethiopia, CSA 2005a–2014a). Out of 7,928 households covered in the AGP Baseline Survey, 2,942 teff-producing households are included in this study. The data pertains to the 2010/2011 main agricultural season. We decided to rely on these AGP survey

5 This classification divides Ethiopia into five agroecologic zones (AEZs). In general, the Wurch AEZ has the highest altitude and precipitation, followed respectively by Dega, Woina Dega, Kolla, and Berha (see Ethiopia, MoA 2000). About 59 percent of households resided in Woina Dega, 25 percent in Dega, and 15 percent in Kolla; the Wurch dummy was excluded because only 1.1 percent of households resided in that AEZ.

TABLE 7.2 Definition of variables used in the econometric analyses

Variables	Definition	Aggregation
HH demography$_1$	Head gender; dummy = 1 if male	HH
HH demography$_2$	Head age in years	HH
HH demography$_3$	Head education; dummy = 1 if educated in grades 4 or higher	HH
HH demography$_4$	Household size; number of members	HH
Teff area	Teff area (hectares)	Crop
Land owned by HH	Dummy = 1 if cropland is allocated to HH by authorities, purchased, or inherited; and = 0 if rented or sharecropped	Crop
Crop damage	Total crop damage suffered due to different causes (%)	Crop
Partial spec	HH partially specializing, dummy = 1 if HH cultivates two crops	HH
Full spec	HH fully specializes, dummy = 1 if HH cultivates one crop	HH
Numb cash crops	Cash crop types grown (pulses, oilseeds, vegetables, fruits, chat, and coffee)	HH
Off-farm work	Dummy = 1 if at least one HH member is off-farm/nonfarm employed	HH
TLU	Tropical livestock units, number of livestock normalized in cattle units	HH
HH participation	Dummy = 1 if HH member/s visited DA centers, farmers' training centers, or attended community meetings	HH
Production info	Dummy = 1 if HH head obtained production information from radio, newspaper, or information board	HH
Fert users in FA	Percent in FA that use fertilizer	FA
Imp seeds users in FA	Percent in FA that use improved seeds	FA
DA center in FA	Dummy = 1 if FA has extension center where DAs provide services	FA
PAs in FA	Dummy = 1 if one or more active producers' associations in FA	FA
FIs in FA	Dummy = 1 if there exist financial institutions in FA (saving and credit or saving and loan cooperatives and banks and small microfinance institutions)	FA
Distance to market	Distance in kilometers to closest market	FA

Source: Authors.

Notes: HH = household; DA = development agents; FA = farmers' association; PA = producers' association.

data given the large sample, the geographical coverage (as a large number of teff producers were part of the sample), the detailed agricultural information, and the good quality of the data. Table 7.3 summarizes the data used in the analyses.

An average household used 0.5 hectares to grow teff and produced 3.2 quintals, and yields averaged 7.7 quintals per hectare. An average household head was 43 years old in May 2011, and about 77 percent of the households have male heads. About 43 percent of household heads are literate, and 29 percent attended grade 4 or higher. In the econometric analyses, household

TABLE 7.3 Mean value of variables

Variable	Mean	Standard deviation	Variable	Mean	Standard deviation
Output (kilograms)	320	372	Gender of head	0.77	0.42
Yields (kilograms per hectare)	769	624	Head age (years)	43	15
Teff area (hectares)	0.50	0.47	Head literate (%)	43	49
Total household area (hectares)	1.58	1.27	Head in grades 4 or higher (%)	29	46
Land owned (%)	75.1	43.3	Household size (number)	5.0	2.2
Labor (working days)	55	107	HHs with member/s employed off/nonfarm (%)	40	49
Oxen (number)	1.4	1.4	Tropical livestock units	3.7	3.9
Fertilizer (kilograms)	31	52	Obtained production information (%)	26	44
Improved seeds (kilograms)	1.0	6.5	Household member participation (%)	55	50
Pesticides (% using)	35	48	Percent in FA using fertilizer	68	33
Percentage of area irrigated	1.9	13.5	Percent in FA using improved seeds	52	32
Land quality index	6.5	2.3	FAs with extension centers (%)	90	30
Percentage of crop damaged	11	20	FAs with producers' associations (%)	24	43
Percent partially specializing	13	34	FAs with financial institutions (%)	48	50
Percent fully specializing	3.3	17.9	Distance to market (kilometers)	11.1	10.0
Cash crops cultivated (number)	1.0	1.1	Total crop season rainfall	1,497	609

Source: The authors made the calculations directly using the 2011 Agricultural Growth Program Baseline Survey data.
Note: HHs = households; FA = farmers' associations, which are the smallest administrative unit in rural Ethiopia.

heads that attended grade 4 or higher are assigned a value of 1. This follows Wier's (1999) finding that four years of schooling is the minimum threshold for education to meaningfully affect productivity.

Results and Discussion

In the first part of this section, performance in relative TFP (RTFP) and efficiency of teff producers obtained from DEA are discussed. The discussion focuses on performances of households cultivating different teff area. This is followed by a discussion of optimal output and yields computed using the performance indexes together with the assumption that all households are optimal and partially or fully specialized in teff production. DPIN 3.0, a program designed to decompose productivity and index numbers (O'Donnell 2011b), is used to compute relative TFP and efficiency indexes. Finally, results of the econometric analyses conducted to indicate the associates of relative TFP and efficiency are discussed.

Relative TFP and Efficiency

Average performance in RTFP, output-oriented technical and scale efficiency (OTE and OSE), and corresponding input-oriented measures (ITE and ISE) are summarized in Table 7.4. Average RTFP of teff production is 0.344. That is, average RTFP can potentially increase by 191 percent (= (1−0.344)/0.344). However, improvements in RTFP computed at household level indicate a potential growth of about 400 percent. The latter indicates that RTFP is skewed to lower values, which is corroborated by normality tests of RTFP. OTE and ITE averaged 0.39 and 0.64, while OSE and ISE averaged 0.91 and 0.52, respectively.

Table 7.4 also summarizes the performance indexes across three levels of specialization (measured by number of crops cultivated) and proportion of household area allocated to teff. About 77 percent of the households allocate less than half of their landholdings to grow teff, while about 84 percent grow three or more crops. About 13 percent grow two crops, 20 percent use at least half of their landholdings in teff production, and 3.2 percent specialize in teff or use all their land to grow teff.

Performance in all productivity indexes, except OSE, improves with specialization and household area sown to teff. Household landholdings are largest among those households that specialize least and smallest among those that are fully specialized. This implies that there is considerable room to increase the scale of operation as well as to specialize in fewer crops. Moreover, households that allocate half or more of their landholdings for teff, 57 percent of which grow three or more crops, cultivate larger teff area (0.77 hectares) but perform poorer in RTFP, OTE, and ITE relative to households that fully specialize in teff. The latter suggests that performance in teff productivity improves if households both specialize in fewer crops and increase their scale of teff production.

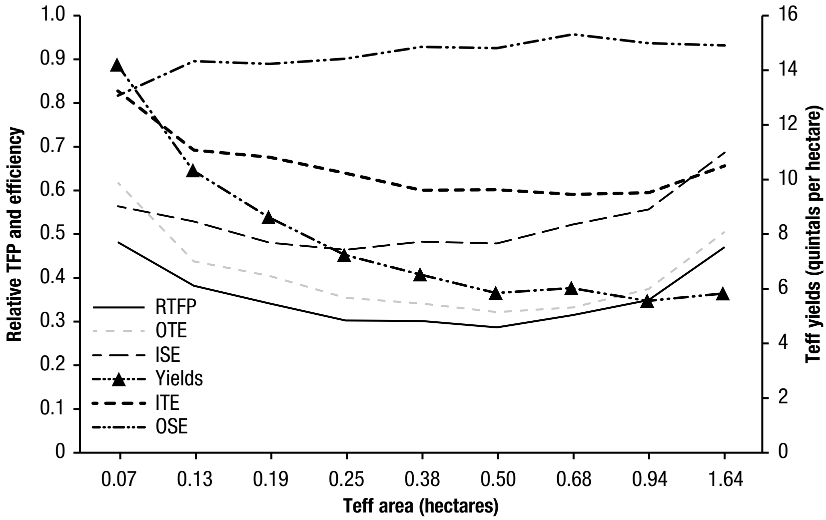
TABLE 7.4 Summary of DEA predicted relative TFP and efficiency across scale of operation and specialization

Household category (%)	Statistics	Performance in productivity/ efficiency					Land management characteristics			
		RTFP	OTE	OSE	ITE	ISE	Teff area (hectares)	Number of crops	Average area per crop (hectares)	Total household area (hectares)
All households (100)	Mean	0.34	0.39	0.91	0.64	0.52	0.50	4.22	0.40	1.58
	Standard deviation	0.23	0.27	0.15	0.19	0.26	0.47	1.85	0.31	1.27
Household area in teff										
Less than half (77.1%)	Mean	0.33	0.38	0.91	0.64	0.51	0.42	4.65	0.39	1.70
	Standard deviation	0.23	0.27	0.15	0.19	0.26	0.38	1.75	0.29	1.33
At least half (19.7%)	Mean	0.37	0.41	0.93	0.64	0.56	0.77	3.06	0.42	1.24
	Standard deviation	0.24	0.26	0.12	0.19	0.26	0.64	1.25	0.33	0.99
Number of crops cultivated										
Three or more (83.7%)	Mean	0.33	0.38	0.92	0.63	0.51	0.49	4.69	0.38	1.70
	Standard deviation	0.23	0.26	0.14	0.19	0.26	0.47	1.64	0.29	1.32
Two (13.1%)	Mean	0.39	0.45	0.89	0.72	0.53	0.52	2.0	0.51	1.02
	Standard deviation	0.24	0.27	0.16	0.20	0.25	0.44	0.00	0.36	0.73
All area in teff/ single crop (3.2%)	Mean	0.39	0.46	0.89	0.70	0.55	0.69	1.0	0.69	0.69
	Standard deviation	0.26	0.29	0.18	0.21	0.26	0.52	0.00	0.51	0.51

Source: The authors made the calculations directly using the 2011 Agricultural Growth Program Baseline Survey data.
Note: DEA = data envelopment analyses; RTFP = relative total factor productivity; OTE and OSE = output-oriented technical and scale efficiency; and ITE and ISE = input-oriented technical and scale efficiency, respectively.

Figure 7.2 depicts the productivity indexes across average teff area of nine groups of households. Seven of the nine groups constitute about 10 percent or a decile of the 2,942 observations, while households that cultivate 0.25 hectares and 0.5 hectares accounted for 18 percent and 14 percent of the total, respectively. The figure indicates that RTFP, OTE, and ISE decline with teff area up to about 0.5 hectares and increase thereafter. OSE increases up to 0.68 hectares and then declines, while the reverse holds for ITE. It appears that households gain in productivity if they allocate at least about 0.5 hectares of their landholdings for teff. In this dataset, less than 30 percent allocate half a hectare or more for teff production.

FIGURE 7.2 **Relationship between teff area and relative TFP and efficiency**



Source: The authors made the calculations directly using the 2011 Agricultural Growth Program Baseline Survey data.
Note: TFP = total factor productivity; RTFP = relative total factor productivity; OTE and OSE = output oriented technical and scale efficiency; and ITE and ISE = input oriented technical and scale efficiency, respectively.

Note that the results on teff productivity are only a partial picture of performance in overall crop productivity of the households studied, nearly 97 percent of which grow at least one other crop than teff. This implies that production decisions targeted at maximizing overall crop productivity may impact teff productivity negatively. However, Bachewe et al. (2015) find productivity levels similar to those obtained in this study using households in the AGP baseline dataset that cultivate the five most important cereal crops in Ethiopia, in terms of cropped area and number of households cultivating the crops.

Optimal Teff Output Yields

The discussion in the previous section indicates that relative TFP of an average household can potentially increase by nearly threefold if all households were optimal in RTFP, or if average RTFP equals 1. The discussion also indicates that performance in RTFP declines until about 0.5 hectares and then increases, implying that teff productivity could increase in households that use larger areas to produce teff. This study computes output and yield levels that each household could produce at hypothetically optimal levels of RTFP, OTE, and ITE—the results of which are discussed in the first part of this section. The second part discusses outputs and yields computed under the assumption that households allocate half or all of their landholdings to produce teff and become as productive as an average household that is currently using similar area to produce teff.

Scenario 1: Current Input Use and Inefficiencies Removed

Equations (11), (7), and (9) are used to compute optimal outputs that households could produce using current inputs, if inefficiencies implied by RTFP, OTE, and ITE were removed, respectively. Optimal outputs so computed are divided by teff area cultivated to obtain optimal yields. Yields and output levels computed under those assumptions are summarized in the third column of Table 7.5 ("Yields and output if fully optimal"). The first panel of the table summarizes yields. Optimal outputs of an average household are summarized in the second panel. The 2,942 households included in this study represent 3.6 million teff-producing households that resided in the districts covered by the AGP Baseline Survey. These 3.6 million households are computed using sampling weights of households included in that baseline survey. In the third panel, total teff output of the 3.6 million households is summarized.

Optimal teff yields implied by RTFP and OTE are higher than 2 metric tons per hectare or nearly three times actual yields. Optimal yields implied by ITE are lower, at about 1.2 metric tons per hectare, because households perform relatively well in ITE. Teff output could be potentially higher than 0.9 metric tons per household if all households were both technically and scale efficient. OTE and ITE implied optimal teff output averaged about 0.86 metric tons and 0.5 metric tons, respectively. The 3.6 million households in the districts surveyed cultivated 1.6 million hectares of land and produced about 1.1 million metric tons of teff. If all households were optimal in RTFP, output could increase to 3.2 million metric tons. Similarly, if output and input technical inefficiencies were removed, output could increase to 3.1 million metric tons and 1.8 million metric tons, respectively.

Scenario 2: Partial or Full Specialization in Teff Production

Gains in output that could result if households partially specialize in teff production are computed by assuming households use half of their total landholdings to produce teff.[6] Similarly, gains in output due to fully specializing

6 Households that use half of their landholdings to produce teff and the second half to grow one other crop can accurately be described as partially specializing in teff. The term describes households that use the second half of their land to grow multiple crops only loosely and can only be justified because such households use a larger proportion of their landholdings to grow teff.

TABLE 7.5 Teff output and yield at optimal productivity and at partial and full specialization in teff

Variable	Efficiency index or indicator	Yields and output if fully optimal (index = 1)	Yields and output due to: Partial specialization (teff area = half household area)	Yields and output due to: Full specialization (teff area = household area)
			First Panel	
Average teff area (hectares)	Actual or with specialization	0.50	0.79	1.58
Yields (kilograms per hectare)	Actual (current productivity)	769	769	769
	RTFP	2,259	953	1,032
	OTE	2,070	961	1,034
	ITE	1,163	825	836
			Second Panel	
Output (kilograms)	Actual or with specialization	320	554	1,058
	RTFP	925	730	1,521
	OTE	863	734	1,527
	ITE	504	608	1,182
			Third Panel	
Total area (million hectares)	Actual or with specialization	1.63	2.61	5.22
Total weighted output of 3.6 million households (thousand metric tons)	Actual or with specialization	1,099	1,933	3,745
	RTFP	3,230	2,489	5,296
	OTE	3,070	2,531	5,383
	ITE	1,825	2,155	4,264

Source: The authors made the calculations directly using the 2011 Agricultural Growth Program Baseline Survey data.

Note: RTFP = relative total factor productivity; OTE = output-oriented technical efficiency; and ITE = input-oriented technical efficiency. Output levels are computed for each household as the product of area and yields with area measured as "actual area," "area with partial specialization in teff," and "area with full specialization in teff," respectively. The figures in the Second Panel are the averages corresponding to each of these products.

in teff production are computed by assuming households use their total landholdings to produce teff.[7] These computations also use the teff area deciles described in the last section and used in Figure 7.2. Accordingly, households in the first to eighth teff area deciles are assumed to move into one of the

7 Households that currently use at least half or all of their landholdings to produce teff are considered as partially or fully specializing in teff and hence not included in computations that consider these respective scenarios.

higher (second to ninth) teff area deciles when they allocate half or all of their landholdings to produce teff. Then, gains in partial or full specialization are computed by assuming that the households:

1. Use average levels of nonland inputs used by households in the new teff area decile that they move into, and
2. Become as productive as an average household in the new area decile (in RTFP, OTE, and ITE).

Equations (11), (7), and (9) are then used to compute the new output levels implied by the new input use and RTFP, OTE, and ITE levels in the higher teff area deciles, respectively. Moreover, output levels at initial values of productivity indexes and new input use levels are also computed. The difference in the two output levels is then taken as the gain in output that results from improvements in the respective productivity index or due to partially or fully specializing in teff. Results of these computations are provided in the last two columns of Table 7.5. These computations consider only improvements in productivity that result from partially or fully specializing in teff production. The latter considerations abstract from the fact that households' current scale of production and diversification are part of the overall production decision made under existing resource constraints as well as intended to mitigate production and price shocks associated with cultivating a single or a few types of crop (Barrett, Bellemare, and Hou 2010). Nevertheless, the simple and partial exercise is worth pursuing as it adds insights into the positive relationship between productivity and teff area pointed to in the last section and further explored in the econometric analyses that follow. Furthermore, in economies with more developed markets, production and price risks are better mitigated through other tools than diversification.

The results in the fourth column of Table 7.5 indicate that average teff area will increase to nearly 0.8 hectares if all households were to use at least half of their landholdings to produce teff. At current levels of productivity, an average household could produce 5.5 quintals of teff using half of its landholdings. Teff output and yields could increase to about 7.3 quintals and 9.5 quintals per hectare due to gains in RTFP and OTE when partially specializing in teff. That is, teff output could potentially increase by over 1.7 quintals and yields by 1.8 quintals per hectare due to improvements in RTFP and OTE when partially specializing in teff. Gains implied by ITE increases are lower, at about 50 kilograms for both output and yield per hectare. The 3.6 million households in the districts surveyed would allocate 2.6 million hectares, if all of them were to partially specialize in teff. Teff output would then grow to 1.93 million metric tons at current levels of productivity. Improvements in RTFP and OTE when partially specializing in teff would increase teff output of the districts surveyed by at least 0.56 million metric tons.

If all households used their total landholdings, which averaged 1.58 hectares, to produce teff, an average household could produce 10.6 quintals at current productivity levels. Teff output of an average household could increase by at least 4.6 quintals and yields by at least 2.6 quintals per hectare due to improvements in RTFP or OTE when fully specializing in teff production. The latter implies that teff yields grow faster at full specialization than at partial specialization. If all 5.2 million hectares of land used in the main agricultural season of 2010/2011 in the districts surveyed were used to produce teff, output could increase to 3.8 million metric tons at current productivity levels. Full specialization induced improvements of RTFP and OTE could increase teff output of households in the districts surveyed by least 1.6 million metric tons, while improvements in ITE could increase teff output by 0.5 million metric tons.

Factors Associated with Efficiency and Productivity

In this section estimates of equation (12) obtained using a Tobit model are discussed. Results of the econometric analyses, which are given in Table 7.6, indicate that household size and age of the household head are not associated with teff productivity. Male headed households, which on average cultivate larger teff area, have higher scale efficiency. The education level of household heads is positively associated with performance in RTFP, OTE, and ISE.

Access to Information on Production and Services

Access to information on production from media sources is positively correlated with all productivity indexes, except OSE. Performance in most indexes is higher among households residing in kebeles (subdistricts), where government offices provide extension services and also where a higher proportion of households use improved seeds. This may indicate that households benefit from direct exposure to extension and indirect information on modern production methods. Studies that find similar results include Ajewole and Folayan (2008); Binam, Gockowski, and Nkamleu (2008); Helfand and Levine (2004); and Solís, Bravo-Ureta, and Quiroga (2007). Productivity was expected to be positively associated with attending meetings and/or visiting

TABLE 7.6 Tobit model estimates of factors associated with relative TFP and efficiency

	Dependent variable[a]				
		Output oriented		Input oriented	
Variables	Relative TFP	Technical efficiency	Scale efficiency	Technical efficiency	Scale efficiency
Household characteristics					
Gender of household head	0.424	–0.924	1.151*	–0.772	1.162
	(1.075)	(1.305)	(0.667)	(0.839)	(1.179)
Age of household head	–0.000	0.026	–0.029	0.018	–0.006
	(0.029)	(0.036)	(0.018)	(0.023)	(0.032)
Head education	1.60*	3.31***	–1.39**	0.819	2.32**
	(0.934)	(1.134)	(0.578)	(0.727)	(1.024)
Household size	0.260	0.204	0.079	–0.092	0.335
	(0.214)	(0.259)	(0.132)	(0.166)	(0.234)
Land management and risk					
Crop area	–3.14**	–9.55**	6.71**	–14.86**	7.50**
	(1.590)	(1.931)	(0.985)	(1.235)	(1.745)
Crop area squared	3.24***	4.92***	–1.49***	4.59***	0.910*
	(0.493)	(0.600)	(0.305)	(0.382)	(0.545)
Proportion of land owned	–0.479	–1.196	0.649	–1.054	–0.105
	(1.001)	(1.215)	(0.620)	(0.780)	(1.098)
Total crop damage (%)	–12.8***	–12.6***	–2.36*	–1.385	–18.4***
	(2.006)	(2.433)	(1.241)	(1.563)	(2.20)
Partially specialized	5.44***	4.12***	2.54***	1.73*	6.08***
	(1.310)	(1.594)	(0.812)	(1.031)	(1.437)
Fully specialized	7.49***	7.74***	1.55	3.54*	7.56***
	(2.345)	(2.854)	(1.459)	(1.857)	(2.576)
Number of cash crops cultivated	0.021	–0.533	1.01***	–1.21***	0.696
	(0.421)	(0.510)	(0.261)	(0.326)	(0.461)
HH member works off-farm	–0.330	–0.065	–0.668***	0.652**	–0.950**
	(0.409)	(0.497)	(0.254)	(0.319)	(0.449)
Tropical livestock units	0.123	-0.006	0.180**	–0.117	0.262**
	(0.118)	(0.144)	(0.074)	(0.092)	(0.131)
Access to information and services					
Production information	2.65***	2.91***	–0.214	1.60**	2.82**
	(0.978)	(1.188)	(0.607)	(0.763)	(1.073)

(continued)

TABLE 7.6 Continued

	Dependent variable[a]				
		Output oriented		Input oriented	
Variables	Relative TFP	Technical efficiency	Scale efficiency	Technical efficiency	Scale efficiency
Access to information and services (continued)					
Household member participation	–2.160**	–1.378	–0.505	–1.337*	–1.837*
	(0.880)	(1.068)	(0.545)	(0.685)	(0.965)
Fertilizer users in FA	0.006	–0.001	0.003	0.014	0.013
	(0.016)	(0.019)	(0.010)	(0.012)	(0.017)
Improved seeds users in FA	0.060***	0.086***	–0.013	–0.003	0.089***
	(0.017)	(0.020)	(0.010)	(0.013)	(0.018)
DA center available in FA	4.75***	4.44**	0.644	3.02***	4.10**
	(1.497)	(1.813)	(0.930)	(1.155)	(1.641)
PAs available in FA	–1.860*	–1.740	0.462	–0.544	–2.687**
	(1.010)	(1.227)	(0.626)	(0.790)	(1.107)
FIs available in FA	1.97**	2.20**	0.277	–2.34***	4.10***
	(0.894)	(1.084)	(0.553)	(0.695)	(0.980)
Distance to closest market	0.071*	0.173***	–0.116***	0.081**	0.033
	(0.043)	(0.053)	(0.027)	(0.034)	(0.048)
Constant	14.3***	29.1***	75.0***	84.8***	15.3***
	(3.468)	(4.209)	(2.148)	(2.698)	(3.804)
Log likelihood	–13,149	–13,143	–11,311	–11,437	–13,289
Number of observations	2,942				

Source: The authors made the calculations directly using the 2011 Agricultural Growth Program Baseline Survey data.
Note: Coefficients with ***, **, and * are significant at 1, 5, and 10 percent level of significance, respectively. The equations estimated are specified in equation (12) above and include region and agroecologic zone dummies. The estimates are omitted to avoid clutter. [a] The dependent variables are DEA productivity indexes expressed in percent and thus have an upper limit of 100.

farmers' training centers. Despite this expectation, households with members that participated in such events have lower RTFP and input-oriented efficiencies.

Performance in productivity was expected to be positively associated with proximity to markets, as the latter generally improves access to marketed inputs and outlets to marketed surplus. However, RTFP, OTE, and ITE of households farther from markets is higher while the reverse holds in OSE. This result is similar to the finding in Nisrane et al. (2011). The latter study argues that villages close to markets are often early-settled areas where the production potential may have diminished from years of cultivation (Nisrane et al. 2011). Moreover, households in areas closer to markets have a higher likelihood of engaging in nonfarming activities and thus less productive in teff. Relative TFP and ISE of households residing in FAs with active producers' associations are lower. This is contrary to the positive association of efficiency and membership in cooperatives that Helfand and Levine (2004) found. Households in FAs with financial institutions have higher RTFP, OTE, and ISE and lower ITE. This is similar to the findings by Solís, Bravo-Ureta, and Quiroga (2007) and Helfand and Levine (2004), which argue that access to credits impacts efficiency positively.

Land Management and Risk

The description in the previous two sections indicate that productivity generally improves with specializing in fewer crops. However, the dataset used indicates that households lack specialization. An average household cultivated 4.2 crops. Only 3 percent and 13 percent cultivated one and two crops, while 21 percent and 23 percent cultivated three and four crops, respectively. Results of the econometric analyses indicate partially specializing in teff is positively associated with performance in all five indexes, while fully specializing in teff is positively associated with four of the indexes. Moreover, where significant, estimates of the effect of full specialization are statistically significantly higher than those of partial specialization. These findings are similar to Sherlund, Barrett, and Adesina (2002), where a negative relationship between performance in efficiency and number of crops cultivated is found.

Households reported that 11 percent of their teff output was lost to damages such as bad weather, diseases, and pests (Table 7.3). The econometric analysis also indicates that households that suffered crop damages have lower productivity in all indexes, except input-technical efficiency. Households cope with variability of income generated from teff production by engaging in non-teff-production activities, such as livestock production and off-farm employment. Coelli and Fleming (2004) argue that cost efficiency improves due to gains in diversifying economies, resulting from the production of subsistence and cash crops. The results in this study indicate that both output and input scale efficiency are positively associated with the number of livestock households own, which increases households' access to plowing power. Households with members that participate in off-farm/nonfarm activities are likely to face labor constraints relative to those with no such member. Our results indicate that participation in off- or nonfarm activity is negatively associated with scale efficiency. This result is similar to the negative relationship between off-farm work and efficiency found by Coelli, Rahman, and Thirtle (2002). Moreover, Mariano, Villano, and Fleming (2011) found that efficiency of rice farmers in the Philippines declined with an increase in income generated through nonrice farming and nonfarming activities.

This study examines whether scale of operation, defined in the teff area cultivated, is related with productivity. Estimated coefficients of area and its square term imply that output and input technical efficiency decline until about 1 hectare and 1.6 hectares, respectively, and then increase. Moreover, output scale efficiency increases until 2.3 hectares before declining. Consequently, RTFP declines until 0.48 hectares and increases thereafter. The econometric analyses, which consider the effects of a number of factors other than area, implies that RTFP starts to increase at the same teff area size as implied in the descriptive analyses (Figure 7.2).

The inverse farm size–productivity relationship has been documented in a large number of studies (Barrett, Bellemare, and Hou 2010). However, most studies establish the relationship using "partial measures of productivity such as yield" and such a relationship may not hold "if a measure of total factor productivity (TFP) were used instead" (Helfand and Levine 2004, 241). The latter observation is corroborated by a number of works that study diverse countries and crop systems, which indicate a positive relationship between farm size and productivity, more specifically, between farm size and multifactor productivity measures. This includes, among others, Padilla-Fernandez and Nuthall (2012), Rios and Shively (2005), Hadley (2006), and Coelli, Rahman, and Thirtle (2002). In particular, the u-shaped efficiency-area relationship implied in the econometric analyses and depicted in Figure 7.2 is similar to that obtained in Helfand and Levine (2004) and Latruffe et al. (2005).

Bachewe et al. (2015) used the AGP Baseline Survey data to show that productivity improves with farm size among cereals producers in Ethiopia. Moreover, an inverse relationship between cereals yields and farm size was found. The data used in the current study also indicates that teff yield generally declines with cultivated area (see Figure 7.2). Bachewe et al. (2015) examine application levels and partial productivities of labor, fertilizer, and improved seeds to explain the apparently contradictory inverse farm size–yield relationship on the one hand and positive farm size–multifactor productivity relationship on the other. The study attributes the apparent contradiction, among others, to per hectare application of the three inputs, which is relatively higher among smallholders and declines with area, consequently leading to lower partial productivity of the inputs at smaller scales of operation.

This study further investigates the farm size–productivity relationship and examines whether the association of factors with productivity and efficiency differs across farm size. For this purpose the econometric analysis applied to all households and presented in Table 7.6 is conducted by dividing the households in the dataset into two groups: smallholders and medium- to largeholders (henceforth "largeholders"). Households cultivating the median teff area of 0.375 hectares or less, which constitute 51.5 percent of the total, are categorized as smallholders. Results of this analysis are provided in Appendix Table 7.A1.

When significant, almost all estimates in Appendix Table 7.A1 have implications similar to those in Table 7.6. There are two exceptions, however. Age of the household head and household size are associated with smallholders' efficiency negatively and positively, respectively, and OSE of both smallholders and largeholders is positively associated with proximity to markets. Despite the similarity in their implications, a number of the variables are associated with the productivity of either smallholders or largeholders. This includes access to media information on production, which is positively correlated with four productivity indexes of only largeholders. Similarly, off-farm employment is negatively correlated with scale efficiency of only smallholders. Four of the five performance indexes of only largeholders are negatively associated with availability of producers' associations, while only RTFP of largeholders is negatively associated with participation in meetings or visits to farmers' training centers.

The relationship between area and productivity, implied by estimates of area and area-squared, is shown to be distinct for smallholders when compared to largeholders. Accordingly, input- and output-oriented technical efficiency of largeholders increase linearly and quadratically, respectively. ISE increases until 6.25 hectares and then declines. Consequently, relative TFP of largeholders increases linearly in all teff areas. In contrast, all indexes of smallholders, except OSE, decline until teff areas ranging between 0.3 hectares and 0.38 hectares before increasing, and the reverse is true for OSE. In particular, relative TFP of smallholders declines until 0.33 hectares and increases thereafter.

Key Findings and Policy Implications

Data envelopment analysis (DEA) is employed on input-output data of teff-producing households in Ethiopia. The data used in the analyses is part of a larger dataset collected in the baseline survey of the Agricultural Growth Program and pertains to the 2010/2011 main agricultural season. The results of the DEA indicate that current relative total factor productivity levels can nearly triple with removal of inefficiencies. Performance in output-oriented technical efficiency was also considerably low. Despite differences in magnitudes, the performance measures imply a significant potential for increases in output produced on current acreage, if inefficiencies were removed. Moreover, the analyses in the chapter reveal that considerable gains in teff yields and output could be achieved by partially or fully specializing in teff production.

The econometric analyses conducted in the study indicate that relative productivity is positively associated with education, and with access to financial institutions, production information, and extension services. Off-farm income-generation activities that help reduce income variability are negatively correlated with scale efficiency. Productivity of households that specialize fully or partially in teff is higher, relative to productivity of nonspecializing households. The results also indicate that gains in scale efficiency improve productivity at lower scales of operation, while gains in technical efficiency improve productivity at larger scales. This, unlike the inverse farm size–productivity hypotheses, implies that largeholders are as productive as smallholders. The results also indicate that largeholders' productivity increases linearly with cultivated area, while smallholders' productivity first declines and then increases.

Many factors that are associated with productivity are amenable to policy targeting. These include improving access to formal education, possibly through training programs that are delivered during the off-season. Also, improved access to information on production methods and extension services are shown to be positively correlated with productivity. The decision on the type and number of crops households cultivate, and consequently the tendency to specialize depends, among others, on their subsistence requirements, profitability of the crops, risks associated with cultivating few crop types, and the size of their total land holdings. Further research is required on factors that determine levels of specialization and scale of operation in order to make more precise recommendations. However, the results in this study indicate that productivity is positively associated with both scale of operation and level of specialization. Furthermore, well-established findings in international trade and development economics imply that access to and participation in markets, along with low crop failure risks, help farmers specialize.

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Appendix

TABLE 7.A1 Tobit model estimates of factors associated with TFP and efficiency of smallholders and medium- to largeholders

	Smallholders (0.38 hectares)					Largeholders (0.40 hectares)				
		Output oriented		Input oriented			Output oriented		Input oriented	
Variables	Relative TFP	Technical efficiency	Scale efficiency	Technical efficiency	Scale efficiency	Relative TFP	Technical efficiency	Scale efficiency	Technical efficiency	Scale efficiency
Household characteristics										
Gender of household head	–0.144	–2.297	1.770*	–1.507	0.165	0.890	0.863	0.006	0.057	2.276
Age of household head	–0.006	0.027	–0.054**	0.021	–0.009	0.005	0.020	–0.006	–0.002	0.006
Head education	2.162	4.016**	–0.935	0.968	2.699*	–0.038	0.548	–0.759	–0.572	1.313
Household size	0.544*	0.515	0.077	–0.070	0.782**	0.019	–0.050	0.069	–0.030	–0.109
Land management and risk										
Crop area	–167***	–280***	72.9***	–178***	–107***	14.6***	15.4***	–0.987	1.559	19.6***
Crop area squared	254***	444***	–109***	237***	185***	–0.370	–0.278	0.166	1.20***	–1.57**
Proportion of land owned	–0.944	–1.827	1.734*	–1.291	–1.391	–0.199	–0.727	–0.058	–0.791	0.811
Percent of crop damaged	–15.5***	–14.2***	–4.36**	–3.45*	–20.1***	–8.43***	–9.24***	–0.288	1.697	–15.5***
Partially specialized	6.8***	7.4***	0.335	3.55***	6.47***	3.84**	1.249	4.20***	–0.117	5.44***
Fully specialized	7.372*	10.517**	–0.058	5.046*	6.650	5.86**	3.987	2.851**	1.630	6.52**
Number of cash crops cultivated	0.310	–0.316	1.25***	–0.918**	0.799	0.054	–0.368	0.718**	–1.29***	0.825
Household member works off-farm	–0.810	–0.638	–1.16***	0.546	–1.37**	–0.043	0.233	–0.203	0.510	–0.618
Tropical livestock units	0.243	–0.051	0.441***	–0.092	0.270	0.087	0.050	0.043	–0.119	0.280*

Access to information and services										
Production information	1.130	1.377	0.047	0.912	1.061	4.64***	4.76***	−0.226	2.48**	5.01***
Household member participation	−1.340	−0.161	−1.085	−0.871	−1.065	−2.24*	−2.065	0.255	−1.065	−2.064
Fertilizer users in FA	−0.005	−0.032	0.019	−0.022	0.015	0.016	0.002	0.016	0.044***	0.009
Improved seeds users in FA	0.076***	0.112***	−0.012	0.035**	0.081***	0.034	0.048*	−0.009	−0.044***	0.081***
DA center available in FA	4.16**	4.45*	0.118	3.245**	2.377	4.182*	3.344	1.815*	1.241	4.85**
PAs available in FA	0.868	1.208	0.755	0.578	0.278	−5.92***	−5.80***	−0.263	−2.339**	−6.58***
FIs available in FA	−1.067	−2.478	2.09**	−3.90***	0.138	5.09***	6.74***	−1.452**	−0.759	8.09***
Distance to closest market	0.034	0.107	−0.097***	0.052	0.015	−0.016	0.065	−0.090**	−0.003	−0.041
Constant	38.2***	72.0***	59.8***	108.1***	35.8***	10.4**	18.6***	82.2***	81.8***	9.85*
Log likelihood	−6,765	−6,672	−5,947	−5,704	−6,860	−6,269	−6,299	−5,156	−5,545	−6,376
Number of observations			1,516					1,426		

Source: The authors made the calculations directly using the 2011 Agricultural Growth Program Baseline Survey data.

Note: Coefficients with ***, **, and * are significant at 1, 5, and 10 percent level of significance, respectively. The dependent variables are DEA productivity indexes expressed in percent and thus have an upper limit of 100. Equations estimated including region and agroecologic zone dummies specified in equation (12). The estimates are omitted to avoid clutter.