

## SUPPLY RESPONSE OF SMALLHOLDER HOUSEHOLDS IN ETHIOPIA

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A large proportion of the poor in Africa south of the Sahara (SSA) reside in rural areas where smallholder agriculture is the dominant activity. Smallholder farms account for more than 90 percent of the cultivated area and output in Ethiopia, with about 80 percent of the total population living in rural areas (Bachewe et al. 2015). Smallholder farmer-focused policies, which derive from the Agricultural Development Led Industrialization (ADLI) framework, were predominant in Ethiopia over the past two decades. This includes the current Growth and Transformation Plan (GTP). Furthermore, considerable resources are used through a number of national and multilateral supported programs aimed at increasing smallholders' productivity and marketed supply (Ethiopia, MoA 2015). The success of such efforts crucially depends, among other factors, on how smallholders respond to changes in prices and policy interventions. This chapter examines supply responses of smallholder farmers to recent price changes.

Despite methodological differences and factors used to account for supply responses, a number of studies find that farmers in SSA respond inelastically to changes in market incentives, such as prices, and market liberalization policies.<sup>1</sup> The fact that the majority of smallholders in SSA produce little marketed surplus is cited as the most important factor contributing to low supply elasticities. However, Schiff and Montenegro (1997) indicate that methodological issues may have led to misleading conclusions. In the same vein, Binswanger (1990) points to the natural gestation period and the resulting fixity of inputs as an explanation for the consequent low short-run agricultural supply responses obtained in a number of studies. He also emphasized

1 Bond (1983) finds a low agricultural supply response to changes in prices in nine countries in Africa south of the Sahara. Similarly, Muchapondwa (2009) finds inelastic aggregate agricultural supply response for Zimbabwe. Studies that find low crop-specific supply responses for Africa south of the Sahara include Kavinya and Phiri (2014) and Mose, Burger, and Kuyvenhoven (2007). Furthermore, supply responses of farmers were unaffected by market liberalization policies in Uganda (Rudaheeranwa et al. 2003) and in Kenya (Mose, Burger, and Kuyvenhoven 2007).

the need for distinguishing between short-run and long-run supply responses that are crucial in agriculture. Furthermore, the most important input in crop production—land—cannot be made available inelastically, making the distinction between crop-specific and aggregate output supply responses particularly important in agriculture, even in the long run. This is particularly important in Africa south of the Sahara, where the application of modern inputs is relatively low and output increases largely derive from cultivation of more land (Binswanger and Pingali 1988; Headey and Jayne 2014).

Few studies investigate agricultural supply responses in Ethiopia. Unlike findings on supply responses for other SSA countries, the studies on Ethiopia find moderately elastic supply responses. Using an aggregate dataset that extends over the 1966–1994 period, Alemu, Oosthuizen, and van Schalkwyk (2003) found elastic long-run grains supply response for both price and market liberalization. However, the same study found that short-run supply was unresponsive to changes in price in most grains. Similarly, Suleiman (2004) found elastic cereals supply response using a household level dataset that covered the 1994–2000 period. Taffesse (2003) investigated the impact of government policy on the dynamics of agricultural supply in Ethiopia during the 1980s. In particular, the study indicated that teff acreage responded negatively to the level of forced grain procurement and positively to teff prices. The period to which these studies refer was notable for the command economic system, which was replaced in the early 1990s by policies that liberalized markets. The effect on supply response of policy changes since the mid-1990s aimed at increasing smallholder farmers' productivity, and the more recent focus to increase marketed supply and value-added, as well as the fast growth in physical and communication infrastructure, have not been studied. This study attempts to fill some of this evidence gap.

This study measures output supply response to changes in crop prices and costs of production using a dataset that covers the 2004/2005–2012/2013 period. The analysis focuses on grain crops from four of the eleven regions in Ethiopia. During the period covered, grain accounted for 96 percent and 86 percent of total agricultural area and output in the country, while the four regions accounted for more than 90 percent of both area and output (Ethiopia, CSA 2005–2013). To achieve the objective stated above, a simple dynamic farm household model is developed.<sup>2</sup> The estimable acreage demand

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2 The model is a variant of the linear rational expectations model (Sargent [1987]; Hansen and Sargent [1980]) as applied to agricultural supply response analysis (Eckstein [1984, 1985]; Tegene, Huffman, and Miranowski [1988]; and Taffesse [2003]).

equation is derived and estimated using zone-level aggregated input-output data. Estimates of acreage demand elasticities together with demand elasticities of other inputs, such as labor and fertilizer, will provide information on the importance of cultivated area vis-à-vis other inputs in output increases or supply responses—that is, whether increases in output resulted from an extensive or intensive margin. The latter, in turn, provides information not only on how farm households in Ethiopia had been coping with land scarcity in the recent past, but also indicates the extent to which efforts aimed at increasing smallholders' productivity through intensive application of modern inputs has succeeded.

There are four sections in the remainder of this chapter. Next, the empirical acreage demand equation is specified, and the long- and short-run acreage demand elasticities with respect to changes in prices and opportunity cost of teff acreage are derived. Then, the zone-level input use, output, and prices data used in the analysis are described. The subsequent section discusses the results of the analyses, and the last section concludes.

## Empirical Analysis

The simple dynamic farm household model used in this study assumes that the household allocates its land to the production of two crops or groups of crops. The acreage shares of the two crops amount to 1 in each period. The production function of each crop  $k$  expresses output ( $Q_{k,t+j}$ ) as a linear function of [lagged] acreage ( $A_{k,t+j-1}$ ) as:  $Q_{k,t+j} = y_k A_{k,t+j-1} + \varepsilon_{k,t+j}$ , where  $k = 1, 2$  denotes crops 1 and 2 and  $y_k$  is a constant. We use the quadratic cost function:  $C_{k,t+j} = c_{k,t+j} A_{k,t+j-1} + \frac{b_k}{2} A_{k,t+j-1}^2 + d_k A_{k,t+j-1} A_{k,t+j-2}$ , where  $c_{k,t+j}$  is nonland costs of production while  $b_k$  and  $d_k$  are constants. The profit function of the household is:  $\pi_{t+j} = (P_{1,t+j} Q_{1,t+j} - C_{1,t+j}) + (P_{2,t+j} Q_{2,t+j} - C_{2,t+j})$ , where  $P_{k,t+j}$  is the price of crop  $k$ . The household first maximizes its discounted expected profits,  $\pi_{t+j}$ , and subsequently chooses the level of consumption and savings, subject to a budget that constrains the sum of consumption and savings in each period to be equal with the sum of profits and previous period savings augmented by interest earned (see Bachewe and Taffesse [2015] and Taffesse [2003] for further details). The profit maximization stage generates the farm household's acreage demand for crop 1. Next, the empirical acreage demand equation is derived from that, along with the implied long- and short-run acreage elasticities. The required empirical price equation is specified and the estimation procedure is described in the Appendix.

## Empirical Specification

This study adopts the following acreage demand equation as the primary specification used to capture the supply response of smallholder teff producers.<sup>3</sup>

$$A_{1,t} = \kappa_0 + \kappa_1 A_{1,t-1} + \kappa_2 A_{1,t-2} + \kappa_3 P_{1,t} + \kappa_4 P_{1,t-1} + \kappa_5 R_{1,t} + \kappa_6 R_{1,t-1} + \varepsilon_t \quad (1)$$

Equation (1) states that current period teff acreage ( $A_{1,t}$ ) depends on teff acreage used in the last two periods ( $A_{1,t-1}$  and  $A_{1,t-2}$ ), current and last period's teff price ( $P_{1,t}$  and  $P_{1,t-1}$ ), and current and last period's opportunity costs of cultivating teff ( $R_{1,t}$  and  $R_{1,t-1}$ ). These costs are measured as the sum of average value products of non-teff grain with yields standing for average value products. Finally,  $\varepsilon_t$  represents shocks to nonland costs of producing teff. These shocks can also be used as a means of including random errors of optimization and errors in data (Epstein and Yatchew 1985). Equation (1) is directly estimated to obtain coefficients of the acreage demand equation. The estimates are then used to compute the acreage demand elasticities, which is the primary objective of this study.

## Elasticities

Equation (1) is used to derive the long- and short-run elasticities of acreage demand with respect to the market prices of teff and the opportunity costs of teff production. Accordingly, the long-run acreage demand elasticity is derived by differentiating the unconditional expectation of acreage demand,  $E(A_1)$ , with respect to  $E(P_1)$ , and weighting the result by the ratio of the unconditional means  $E(P_1)$ , and  $E(A_1)$ . That is:

$$\xi_{A_1, P_1}^L = \left( \frac{\kappa_3 + \kappa_4}{1 - \kappa_1 - \kappa_2} \right) \frac{E(P_1)}{E(A_1)} \geq 0 \quad (2a)$$

The short-run elasticity of acreage demand with respect to period  $t$  teff price is given as:

$$\xi_{A_1, P_1}^S = \kappa_3 \frac{E(P_1)}{E(A_1)} \geq 0 \quad (2b)$$

3 Equation (1) represents the empirical analogue to the optimal acreage allocation rule derived from a dynamic optimization procedure. The procedure, which we briefly describe in the introduction to this section, links teff output to acreage allocation via production technology and prices in such a way that equation (1) can serve as a vehicle for analyzing the supply response of smallholder teff producers. See Bachewe and Taffesse (2015) and Taffesse (2003) for details.

Equation (2a) indicates that long-run teff acreage demand increases with a permanent increase in teff price. This is implied by the optimal acreage demand equation derived from the optimization problem (see Bachewe and Taffesse [2015] for signs of this and the remaining elasticities given by equations [2b] though [2d]). The corresponding long- and short-run acreage demand elasticities with respect to the opportunity cost of teff production are:

$$\xi_{A_1, R_1}^L = \left( \frac{\kappa_5 + \kappa_6}{1 - \kappa_1 - \kappa_2} \right) \frac{E(R_1)}{E(A_1)} \leq 0 \tag{2c}$$

$$\xi_{A_1, R_1}^S = \kappa_5 \frac{E(R_1)}{E(A_1)} \geq 0 \tag{2d}$$

Note that the acreage demand elasticities given in equations (2a)–(2d) are also equal to the elasticities of teff supply with respect to teff price and opportunity cost of teff production.<sup>4</sup>

### The Data

The data on inputs, outputs, and prices used in the econometric analysis were collected by Ethiopia’s Central Statistical Agency (CSA) through its Annual Agricultural Sample Surveys (AgSS).<sup>5</sup> Although the AgSS collects data at household level, the households sampled change from year to year. Similarly, woredas covered by the survey are also changed. However, AgSS is required to generate zonal-level representative data. It does so by selecting a representative sample of households for each zone and by covering almost all zones every year. Since this study demands observations from the same unit of analysis repeated over time, AgSS’s zonal-level data are used. As the objective of the study is to look at the supply response of smallholders in Ethiopia, the AgSS data were the only data suitable for the purpose and consistently available over a long period.

Estimating acreage demand and price equations using zonally aggregated data may appear to violate the assumption that producers take market prices

4 This is a consequence of the linear relationship between teff acreage and teff supply,  $Q_{1,t+j} = \gamma_1 A_{1,t+j} + \epsilon_{1,t+j}$ . That the teff acreage and supply elasticities are equal can be shown for the long-run teff supply elasticity as:

$$\xi_{Q_1, P_1}^L = \frac{dQ_1}{dP_1} \frac{E(P_1)}{E(Q_1)} = \frac{\gamma_1 dA_1}{dP_1} \frac{E(P_1)}{\gamma_1 E(A_1)} = \left( \frac{\kappa_5 + \kappa_4}{1 - \kappa_1 - \kappa_2} \right) \frac{E(P_1)}{E(A_1)} = \xi_{A_1, P_1}^L.$$

5 In the CSA’s annual AgSS enumeration areas and farming households are taken to be the primary and secondary sampling units, respectively. CSA defines an enumeration area as a geographic area with 150–200 resident households. Kebeles constitute the smallest administrative units. The hierarchy of governance proceeds with woredas (composed of a number of kebeles), zones, regional states, and the federal government.

as given. The assumption will not hold if zones are production units because zonal supply of a given crop will influence its price. However, despite the data being zonally aggregated, the actual production units are competitive farm households, which, among other things, form expectations on prices and use the information to make production decisions. Moreover, to avoid inconsistent results, we conduct pairwise Granger causality tests between prices and outputs of teff and non-teff grains.

The results of testing the null hypothesis that output does not Granger cause prices are provided in [Table 8.1](#). They indicate that the null hypothesis is not rejected for both teff and non-teff grains. In addition to Granger causality tests, a method proposed by Geweke (1982) for infrequent data, such as annual data, is used to test the null hypothesis: output and prices do not have instantaneous feedback. The null hypothesis is not rejected in both crop types. Given these results, we proceed with the presumption that teff and non-teff grain outputs do not affect corresponding current prices of the respective crops.

The dataset includes 21 types of grain crops, with data collected during 2004/2005–2012/2013 (1997–2005 EC) from the four major cereal-producing regions in Ethiopia.<sup>6</sup> The data encompassed the main agricultural season, locally known as meher. The following specific considerations influenced the choices about data. During the 2004/2005–2012/2013 period, grain accounted for an average of 82 percent of the total crop output and 93.5 percent of the area, out of which teff accounted for 21 percent ([Figure 8.1](#)). In addition to the sheer importance of grain to output and area, two more reasons justify the use of grain in the analysis. First, grain (unlike other crop categories) is cultivated in all of the administrative zones of the four regions included in the analyses. Second, nongrain crops, including fruits and other tree crops, are agroecology specific and mostly permanent crops. Supply responses of perennial crops is likely to be different to that of temporary crops.

The four important regions for crop agriculture (Amhara, Oromiya, Southern Nations, Nationalities, and Peoples' [SNNP] region, and Tigray) represent most of the country's crop agriculture. These regions on average accounted for more than 90 percent of crop output and cultivated area during the period studied. Moreover, the remaining regions lack data essential for

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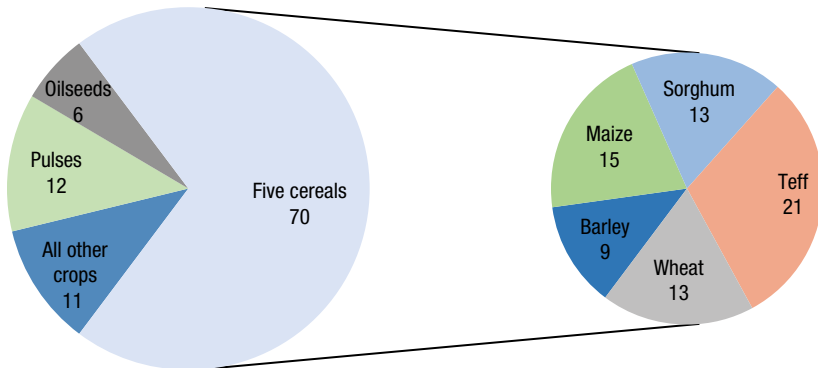
6 The Ethiopian calendar (EC) lags seven years and eight months behind the Gregorian calendar, with Ethiopian New Year occurring in the second week of September of the latter calendar.

**TABLE 8.1** Results of pairwise Granger causality and instantaneous feedback tests of zonal crop output and prices of grains

| Crop                                  | Output does not Granger cause price | Output and price do not have instantaneous feedback |
|---------------------------------------|-------------------------------------|---|
| Teff                                  | 1.41                                | 0.002   |
| Non-teff grains (area weighted price) | 2.56                                | 0.35  |
| Non-teff grains (mean price)          | 0.13                                | 0.59  |

**Source:** Authors' analyses using Ethiopia, CSA (2005–2013) and Ethiopia, CSA (2014a, 2014b).

**Note:** All estimates are not significant at 10% level of significance.

**FIGURE 8.1** Acreage share (%) of major crop categories, 2004/2005–2012/2013

**Source:** Authors' computation using zone-level aggregated Ethiopia, CSA data, 2004–2012.

the analysis. Accordingly, the data used in this study covered 10, 17, 21, and 5 administrative zones from Amhara, Oromiya, SNNP, and Tigray, respectively.

## Teff and Grain Acreage, Output, and Yields

In Table 8.2 the acreage shares of cereals, pulses, and oilseeds, which constitute grain crops, are summarized. In Ethiopia, cereals are the most important temporary crops followed by pulses and oilseeds. During the 2004/2005–2012/2013 period, cereals accounted for about 81 percent of the area cultivated with grain, of which 77 percent comprised the five major cereals of teff, maize, wheat, sorghum, and barley. Moreover, the area under these cereals varied only slightly between the regions, ranging from 72 percent in Tigray to

79 percent in SNNP. Although there was regional variation in acreage shares of different crops, the share of teff was the highest in Amhara and the second highest in the remaining three regions, making teff the most important crop in terms of area cultivated. During the same period, teff accounted for 23 percent and 21.5 percent of the area under grain and all crops, respectively.

Table 8.3 provides a summary of total teff output and area as well as average teff yields and prices. Accordingly, in an average year of the period covered, 2.9 million metric tons of teff was produced in the four regions, and this increased at an average annual rate of 8.3 percent. In an average year, 2.5 million hectares of land was sown with teff and growth in cultivated area averaged 3.2 percent. Teff yields averaged about 11 quintals per hectare and grew at an average annual rate of 5.3 percent.

## Crop Prices

CSA collected data on monthly producer prices of about 130 items since 1995/1996 from almost all zones in the country. Figure 8.2 shows average monthly nominal and real teff prices.<sup>7</sup> Table 8.3 and Figure 8.2 indicate that nominal teff prices averaged about 6 birr per kilogram and grew at average monthly and annual rates of 1.7 percent and 24.4 percent respectively during the September 2004–August 2013 period. Real teff prices averaged 3.6 birr in December 2006 prices, while growth in real teff prices averaged 0.2 percent per month and 3.6 percent per year. Nominal teff prices were the highest at the end of the period considered, with the August 2013 price at approximately 12 birr per kilogram. Real prices of teff were the highest in May 2008.

Table 8.4 summarizes the data on monthly prices of all grain. Since weights or information on relative importance of crops, such as volumes of sales, are not available, the summary uses simple averages of monthly prices. Table 8.4 indicates that, on average, oilseeds sold for the highest price, with pulses second, then followed by teff as highly priced crops. Approximately half of the oilseeds produced are sold, mostly exported, which partly explains their relatively higher price. Among the cereals, teff is the most widely marketed, with 27 percent of teff output sold (Ethiopia, CSA 2014b).

7 Note that all real prices are computed as nominal prices deflated by the corresponding regional general price index.

**TABLE 8.2** Mean regional acreage shares, 2004/2005–2012/2013 (%)

| Crop and crop group | National    | Tigray      | Amhara      | Oromiya     | SNNP        |
|---------------------|-------------|-------------|-------------|-------------|-------------|
| Five cereals        | 76.7 (10.7) | 71.7 (16.7) | 73.5 (8.3)  | 77.8 (8.3)  | 78.6 (11.1) |
| Barley              | 11.1 (10.0) | 16 (15.5)   | 12.0 (6.8)  | 10.8 (10.4) | 9.7 (9.0)   |
| Maize               | 24.9 (16.3) | 9.9 (6.0)   | 13.8 (13.2) | 28.6 (14.6) | 31.1 (15.6) |
| Sorghum             | 21.9 (20.9) | 35.7 (26.6) | 27.3 (22.9) | 18.8 (18.4) | 18.3 (18.4) |
| Teff                | 28.2 (15.1) | 23.1 (11.1) | 33.0 (9.9)  | 25.5 (15.8) | 29.0 (16.6) |
| Wheat               | 14.2 (12.4) | 15.4 (14.5) | 13.8 (8.9)  | 16.7 (14)   | 12.0 (11.6) |
| Other cereals       | 3.4 (5.4)   | 8.1 (7.7)   | 5.4 (6.5)   | 3.3 (4.9)   | 0.9 (1.5)   |
| Pulses              | 15.0 (9.9)  | 7.2 (4.0)   | 15.0 (6.8)  | 12.0 (7.8)  | 20.0 (11.6) |
| Oilseeds            | 6.0 (8.3)   | 12.3 (16.8) | 7.0 (4.8)   | 8.2 (7.6)   | 0.8 (2.3)   |

**Source:** Authors' computation using zone-level aggregated Ethiopia, CSA data, 2005–2013.

**Notes:** Figures in parentheses are standard deviations. Acreage shares of the groups of five cereals, other cereals, pulses, and oilseed are calculated out of the total area under grain crops, while acreage shares of barley, maize, sorghum, teff, and wheat are calculated out of the total area under the five cereals.

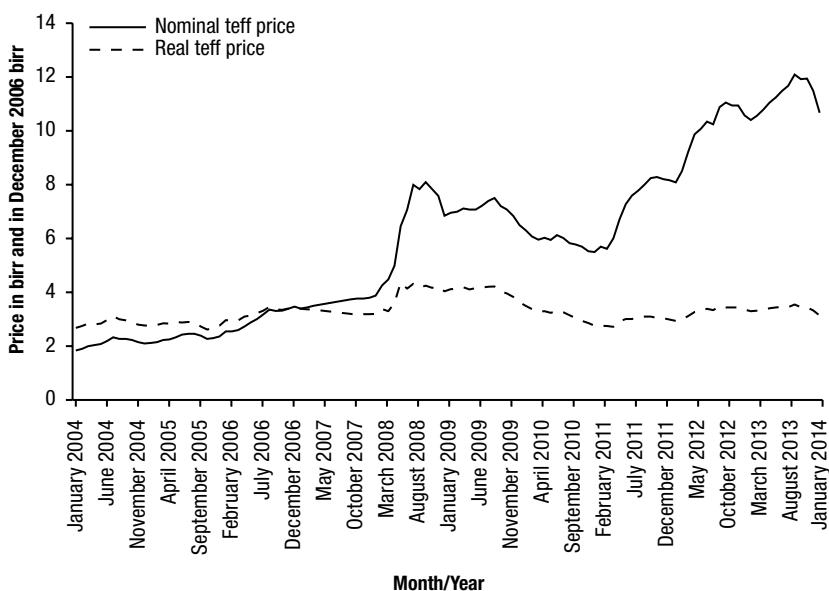
**TABLE 8.3** Total teff output and area, and average yields and prices, 2004/2005–2012/2013

| Year           | Output<br>(thousand<br>metric tons) | Area<br>(thousand<br>hectares) | Yields<br>(quintals per<br>hectare) | Nominal price<br>(birr per<br>kilogram) | Real Price<br>(December 2006<br>birr per kilogram) |
|----------------|-------------------------------------|--------------------------------|-------------------------------------|---|--|
| 2004/2005      | 2,008                               | 2,116                          | 8.7                                 | 2.2                                     | 2.9  |
| 2005/2006      | 2,168                               | 2,232                          | 8.3                                 | 2.6                                     | 3.2  |
| 2006/2007      | 2,413                               | 2,371                          | 8.7                                 | 3.5                                     | 3.7  |
| 2007/2008      | 2,970                               | 2,543                          | 11.5                                | 4.9                                     | 4.2  |
| 2008/2009      | 3,010                               | 2,464                          | 11.5                                | 7.1                                     | 4.7  |
| 2009/2010      | 3,161                               | 2,569                          | 11.5                                | 6.1                                     | 3.5  |
| 2010/2011      | 3,457                               | 2,735                          | 11.9                                | 6.4                                     | 3.3  |
| 2011/2012      | 3,473                               | 2,706                          | 12.1                                | 9.2                                     | 3.7  |
| 2012/2013      | 3,746                               | 2,711                          | 12.6                                | 11.0                                    | 3.6  |
| <b>Average</b> | <b>2,934</b>                        | <b>2,494</b>                   | <b>10.8</b>                         | <b>5.9</b>                              | <b>3.6</b>   |

**Source:** Authors' computation using zone-level aggregated Ethiopia, CSA data: Ethiopia, CSA 2005–2013; Ethiopia, CSA 2014a and 2014b.

## The Opportunity Cost of Teff Production

Table 8.5 reports estimates of the opportunity cost of teff acreage. This cost, represented by  $R_1$  in equation (1), is calculated by summing the average value products of all grain crops except teff. That is,

**FIGURE 8.2** Average nominal and real price of teff, 2004–2014

**Source:** Authors' computation using monthly price data (Ethiopia, CSA 2014b).

**TABLE 8.4** Mean regional crop prices 2004/2005–2012/2013 (birr per kilogram)

| Crop and crop group | National  | Tigray    | Amhara    | Oromiya   | SNNP      |
|---------------------|-----------|-----------|-----------|-----------|-----------|
| Barley              | 2.4 (0.6) | 3.0 (0.7) | 2.7 (0.5) | 2.2 (0.4) | 2.2 (0.4) |
| Maize               | 1.7 (0.5) | 2.2 (0.5) | 2.0 (0.4) | 1.7 (0.4) | 1.6 (0.4) |
| Sorghum             | 1.9 (0.6) | 2.4 (0.6) | 2.5 (0.5) | 1.8 (0.5) | 1.6 (0.4) |
| Teff                | 3.6 (0.7) | 3.9 (0.7) | 3.9 (0.6) | 3.5 (0.6) | 3.6 (0.6) |
| Wheat               | 2.6 (0.5) | 3.0 (0.6) | 2.8 (0.4) | 2.5 (0.5) | 2.5 (0.5) |
| Other cereals       | 2.3 (0.8) | 2.9 (1.0) | 3.0 (0.8) | 2.0 (0.5) | 2.2 (0.6) |
| Pulses              | 3.8 (1.9) | 4.2 (1.2) | 3.4 (1.1) | 3.6 (1.4) | 4.0 (2.6) |
| Oilseeds            | 4.2 (1.6) | 4.5 (1.9) | 4.5 (1.6) | 4.1 (1.4) | 4.0 (1.6) |

**Source:** Authors' computation using monthly price data (Ethiopia, CSA 2014b).

**Note:** Figures in parentheses are standard deviations.

$$R_1 = \sum_{g=2}^{21} P_g y_g A_g$$

where  $g$  stands for the 21 grain types, and  $P_g$  and  $y_g$  for corresponding prices and average products of land, respectively ( $g = 1$  represents teff and is not included in the summation). The respective zonal average yields are used as the measure of the average product of land. In the summation, the acreage share of crop  $g$  in total area under grains other than teff,  $A_g$ , is used to capture the relative importance of the crop in the opportunity cost of teff acreage.

During the period of study, on average, the opportunity cost of a hectare of land used in teff production was about 3,660 birr in December 2006 prices. The opportunity cost of teff acreage grew at an average annual rate of 8.5 percent. The latter includes a 37 percent rise during 2009/2010–2010/2011 and a 56 percent increase between 2005/2006 and 2006/2007. In contrast, the opportunity cost declined by 14 percent and 205 percent in the two years during 2006/2007–2008/2009, respectively. The opportunity cost of teff acreage was the highest in Tigray on average in all the years except 2005/2006 and 2006/2007, with the regional average ranging from about 4,600 birr in Tigray to the significantly lower average of about 3,100 birr in SNNP. These high opportunity costs of teff acreage in Tigray are likely to have arisen because of the high price of oilseeds and their greater acreage share in Tigray.

## Results

This section covers the main findings of the analysis. Given that time-series variables were used, particularly those of price series, the first test applied is for stationarity to avoid misleading conclusions that may arise from spurious regression, which is a major concern with this type of data. Results of panel unit-root tests are given in [Table 8.6](#). In [Table 8.7](#) the estimated coefficients of teff price and opportunity cost equations are reported. Moreover, estimates of the teff acreage demand equation (equation [1] above) are provided in [Table 8.8](#), while [Table 8.9](#) summarizes the long- and short-run elasticities of acreage demand calculated using equations (2a)–(2d).

In addition to the coefficient estimates obtained from the econometric analyses, [Table 8.7](#) and [Table 8.8](#) report results of tests of the joint significance of all variables ( $\chi^2$ -equation), the regressors excluding time dummies ( $\chi^2$ -regressors), and only time-dummies ( $\chi^2$ -time dummies). Under the null hypotheses the test statistics are asymptotically distributed  $\chi^2(p)$ , where the degrees of freedom  $p$  is equal to the number of variables whose joint significance is being tested. Also reported are the statistics from first- and

**TABLE 8.5** Average regional real opportunity costs of teff acreage, 2004/2005–2012/2013

| Region      | 2004/<br>2005  | 2005/<br>2006  | 2006/<br>2007  | 2007/<br>2008    | 2008/<br>2009  | 2009/<br>2010  | 2010/<br>2011    | 2011/<br>2012    | 2012/<br>2013  | Average          |
|-------------|----------------|----------------|----------------|------------------|----------------|----------------|------------------|------------------|----------------|------------------|
| All regions | 2,510<br>(739) | 3,086<br>(784) | 3,016<br>(928) | 4,715<br>(1,032) | 3,758<br>(818) | 3,227<br>(928) | 4,421<br>(1,078) | 4,281<br>(1,049) | 3,929<br>(921) | 3,660<br>(1,156) |
| Tigray      | 2,951<br>(620) | 3,297<br>(438) | 3,321<br>(605) | 5,656<br>(781)   | 4,939<br>(447) | 4,666<br>(540) | 5,951<br>(462)   | 5,403<br>(402)   | 5,229<br>(314) | 4,601<br>(1,325) |
| Amhara      | 2,707<br>(620) | 3,299<br>(438) | 3,604<br>(605) | 5,088<br>(781)   | 4,161<br>(447) | 3,710<br>(540) | 4,937<br>(462)   | 4,755<br>(402)   | 4,510<br>(314) | 4,086<br>(919)   |
| Oromiya     | 2,685<br>(533) | 3,318<br>(606) | 3,389<br>(778) | 5,122<br>(746)   | 3,881<br>(500) | 3,215<br>(638) | 4,407<br>(860)   | 4,608<br>(727)   | 4,028<br>(471) | 3,850<br>(976)   |
| SNNP        | 2,171<br>(798) | 2,747<br>(974) | 2,360<br>(890) | 3,984<br>(980)   | 3,185<br>(796) | 2,666<br>(819) | 3,822<br>(918)   | 3,524<br>(1,075) | 3,263<br>(794) | 3,080<br>(1,065) |

**Source:** Analyses using Ethiopia, CSA data (2005–2013).

**Note:** Figures in parentheses are standard deviations.

second-order serial correlation tests of residuals in the respective equations, which are given in m1 and m2 rows of the tables. The last value reported in the tables is the Sargan test of the overidentifying (moment) restrictions. Under the null hypothesis of optimal instruments the Sargan test statistic, which tests whether the overidentifying instruments are exogenous as a group, is asymptotically  $\chi^2(r)$  distributed with as many degrees of freedom  $r$  as overidentifying restrictions. In the presence of heteroscedasticity, Arellano and Bond (1991) show that the one-step Sargan test overrejects the null hypotheses. As a result, the Hansen (1982) J statistic, which tests the same null hypotheses using a consistent weighting matrix, is reported. In [Table 8.7](#) and [Table 8.8](#) this statistic is reported as  $\chi^2$ -Sargan/Hansen test.

## Results of Stationarity Tests

Panel unit-root tests devised by Harris and Tzavalis (1999) and Im, Pesaran, and Shin (2003) were used as they are considered appropriate for panel data covering a short time and with a large number of observations. [Table 8.6](#) shows the results obtained using the two panel unit-root tests with the data in levels and differences. The results provide strong evidence in favor of stationarity of teff acreage, teff price, and the opportunity cost of teff acreage. The only exception is the null hypothesis that the real teff prices series has a unit-root that is not rejected by the Harris-Tzavalis test when a trend term is

**TABLE 8.6** Results of panel unit-root tests

| Variable                 | Specification | Im, Pesaran, and Shin |            | Harris and Tzavalis |            |
|--------------------------|---------------|-----------------------|------------|---------------------|------------|
|                          |               | Level                 | Difference | Level               | Difference |
| Teff acreage             | Standard      | -4.6                  | -9.3       | -17.0               | -28.1      |
|                          | Demeaned      | -5.1                  | -9.7       | -16.3               | -27.8      |
|                          | With trend    | -6.5                  | -9.3       | -8.8                | -14.8      |
| Teff price               | Standard      | -4.5                  | -6.9       | -11.3               | -21.3      |
|                          | Demeaned      | -4.6                  | -9.7       | -15.4               | -29.1      |
|                          | With trend    | -3.2                  | -8.4       | -0.9*               | -11.4      |
| Opportunity cost of teff | Standard      | -6.1                  | -9.8       | -12.9               | -27.3      |
|                          | Demeaned      | -4.5                  | -9.7       | -14.4               | -28.6      |
|                          | With trend    | -6.6                  | -10.2      | -8.1                | -15.0      |

**Source:** Authors' analysis using CSA AgSS and prices data (Ethiopia, CSA 2005–2013).

**Note:** All coefficients are significant at 1 percent level of significance except that with \*, which is not significant.

included. Given these results, it is unlikely that the relationship between the variables will be spurious.

## Teff Price Equation Estimates

The results in [Table 8.7](#) indicate that the estimate of lagged teff price satisfies the stability condition of teff price equation associated with equation (4), as discussed in the appendix to this chapter. Moreover, the positive estimate of the lagged teff price indicates that current and lagged teff prices are positively related. All three groups of variables tested for joint significance: all variables, regressors without time dummies, and time dummies, are significant. Since the first-differenced residuals are MA(1) processes, the null hypothesis of first-order serial correlation, which is shown in the m1 row, is not rejected. However, the null hypothesis of second-order serial correlation is rejected, as reported in the m2 row. The latter indicates that the estimates are consistent. The two-step Hansen test statistics is given in the  $\chi^2$ -Sargan/Hansen row. The null hypothesis that the overidentifying restrictions are valid is not rejected.

## Opportunity Cost of Teff Acreage

The results in [Table 8.7](#) indicate that the estimated coefficient of lagged teff opportunity cost satisfies the stability condition of teff opportunity cost

equation.<sup>8</sup> Moreover, the estimated coefficient implies that current and lagged teff opportunity costs are positively related. Results of tests of the joint significance of three sets of variables, serial correlation, and overidentifying restrictions of teff opportunity cost equation are qualitatively similar with that discussed above for teff price equation.

### **Teff Acreage Demand Equation Estimates**

Parameter estimates of the teff acreage demand equation (1) are given in [Table 8.8](#). The results indicate that the sets of variables included are jointly significant at 1 percent. Moreover, the null hypothesis that the overidentifying instruments are valid is not rejected while the null hypothesis of second-order serial correlation is rejected.

Estimated coefficients of lagged and twice lagged acreage demand variables satisfy the conditions for stationarity of the AR(2) process. Moreover, both contemporaneous and lagged teff prices are significant and positive. The estimated coefficient of lagged teff prices (Teff price<sub>t-1</sub>) is lower than the estimate of current price (Teff price<sub>t</sub>). This indicates that acreage responses of households to price changes decline through time. This is because previous decisions incorporate effects of price changes that already occurred, whereby acreage demand decisions in period  $t-1$  incorporate effects of teff price in period  $t-1$ . Consistent with the theoretical model, the estimated coefficient of opportunity cost of acreage used in teff production is negative, although the estimate of its lagged term is positive.

### **Teff Acreage Demand Elasticities**

In [Table 8.9](#) the long- and short-run teff acreage demand elasticities with respect to (WRT) teff prices and the opportunity cost of acreage used in teff production are provided. The teff acreage demand elasticities WRT teff price in the table imply that teff acreage increases with teff price, while the elasticities WRT opportunity cost imply that teff acreage declines with an increase in teff opportunity cost. These results conform to predictions of the theoretical model.

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8 The specification of empirical teff opportunity cost equation and its stability conditions are similar to the teff price equation (4) given in the appendix (see also Bachewe and Taffesse [2015]).

**TABLE 8.7** Dynamic panel data estimates of teff price and opportunity cost equations

| Teff price                   |                                  | Teff opportunity cost                   |                                  |
|------------------------------|----------------------------------|---|----------------------------------|
| Variables                    | Coefficient<br>(standard errors) | Variables                               | Coefficient<br>(standard errors) |
| Teff price <sub>t-1</sub>    | 0.417***<br>(0.014)              | Opportunity cost of teff <sub>t-1</sub> | 0.413***<br>(0.012)              |
| Constant                     | 2.001***<br>(0.049)              | Constant                                | 20.7***<br>(0.383)               |
| $\chi^2$ -equation           | 13,284***                        | $\chi^2$ -equation                      | 12,564***                        |
| $\chi^2$ -regressors         | 881***                           | $\chi^2$ -regressors                    | 1,275***                         |
| $\chi^2$ -time dummies       | 5,848***                         | $\chi^2$ -time dummies                  | 6,799***                         |
| m1                           | -4.96***                         | m1                                      | -4.43***                         |
| m2                           | 0.94                             | m2                                      | -0.43                            |
| $\chi^2$ -Sargan/Hansen test | 44                               | $\chi^2$ -Sargan/Hansen test            | 45                               |
| Number of observations       | 424                              | Number of observations                  | 424                              |

**Source:** Authors' analysis using CSA prices data (Ethiopia, CSA 2005–2013).

**Note:** Coefficients with \*\*\* are significant at 1 percent.

**TABLE 8.8** Dynamic panel data estimates of teff acreage demand equation

| Variable                                | Coefficient | Standard error |
|---|-------------|----------------|
| Teff acreage <sub>t-1</sub>             | 0.481***    | 0.032          |
| Teff acreage <sub>t-2</sub>             | -0.096***   | 0.034          |
| Teff price <sub>t</sub>                 | 0.022***    | 0.007          |
| Teff price <sub>t-1</sub>               | 0.017**     | 0.008          |
| Opportunity cost of teff <sub>t</sub>   | -0.0051***  | 0.0004         |
| Opportunity cost of teff <sub>t-1</sub> | 0.0034***   | 0.0003         |
| Constant                                | 0.060'      | 0.031          |
| $\chi^2$ -equation                      | 3,708***    |                |
| $\chi^2$ -regressors                    | 1,038***    |                |
| $\chi^2$ -time dummies                  | 424***      |                |
| m1                                      | -4.29***    |                |
| m2                                      | -0.98       |                |
| $\chi^2$ -Sargan/Hansen test            | 36          |                |

**Source:** Authors' analysis using CSA AgSS and prices data (Ethiopia, CSA 2005–2013).

**Note:** Coefficients with \*\*\*, \*\*, and \* are significant at 1, 5, and 10 percent, respectively.

**TABLE 8.9** Long-run and short-run elasticity of teff acreage demand

| Elasticity                        | Teff price | Teff opportunity cost |
|-----------------------------------|------------|-----------------------|
| Long-run teff acreage elasticity  | 1.067      | -0.484                |
| Short-run teff acreage elasticity | 0.368      | -0.871                |

**Source:** Authors' analysis using CSA AgSS and prices data (Ethiopia, CSA 2005–2013).

As expected, the long-run elasticity of acreage demand WRT teff price, about 1.07, is higher than its short-run counterpart, 0.37. The long-run teff supply elasticity implies that farmers' teff supply response increases slightly faster than a permanent growth in real teff price. Growth in teff acreage is also reinforced by the relatively slow growth in the opportunity cost of teff. Particularly, the data indicate that real teff prices grew faster than prices of 14 of the 20 non-teff grain crops. More importantly, prices grew faster in teff than in the four other cereals, which, along with teff, dominate the nationwide cultivated area. Accordingly, real teff price growth was over 2.2, 1.3, 1.4, and 2.1 times faster than growth in barley, maize, sorghum, and wheat prices, respectively.

Teff is not only a staple crop in large parts of Ethiopia; it also has been increasingly adopted in parts of the country where it was not previously cultivated, as well as in other countries. This may have contributed to the higher growth in teff price and thus for the faster growth in teff supply response. The share of teff in food expenditure is highest in urban areas and increased by 3.4 percent nationwide between 2005 and 2011, while the corresponding share of all other cereals declined (see Chapter 2). Finally, the fast growth in teff demand, combined with the limited research on teff hitherto (research that was conducted almost exclusively in Ethiopia), may have induced the recent efforts of the Ethiopian government to increase teff productivity through dissemination of high-yielding teff varieties and production methods (Bachewe et al. 2015). The resultant increases in teff productivity affect teff supply response and acreage demand positively.

The long-run and short-run acreage demand elasticities WRT teff price obtained in this study are higher than the corresponding corn acreage elasticities of 0.2 and 0.011 that Tegene, Huffman, and Miranowski (1988) compute for Iowa, US. The elasticities are close to the respective grain acreage elasticity of 0.808 and 0.274 obtained in Yu, Liu, and You (2010) for Henan province

in China. In contrast, the elasticities are lower than those in Ahouissoussi, McIntosh, and Wetzstein (1995) with long- and short-run soybean acreage demand elasticity of 1.98 and 1.21 computed for Georgia, US. Moreover, the long-run and short-run soybean acreage elasticity WRT wheat price, a proxy for the opportunity cost of soybean acreage, was  $-1.57$  and  $-2.11$  in the latter study. In contrast, the long-run and short-run cotton acreage demand elasticities WRT the opportunity cost of cotton production in Egypt obtained in Eckstein (1984) are lower at  $-0.13$  and  $-0.11$ , respectively.<sup>9</sup>

The current study employs similar theoretical and econometric methods to the work by Taffesse (2003), making comparison of results of the two studies free from methodological differences. Relative to the long-run acreage demand elasticity WRT teff price of 0.48 (Taffesse [2003]), the result from this study is considerably higher, while the short-run elasticities in the respective studies, 0.37 and 0.31, are similar. Moreover, the elasticity of acreage WRT the opportunity cost of teff acreage, again from the study by Taffesse (2003), was  $-0.93$ . This is about twice the elasticity obtained in this study, which is  $-0.48$ , whereas the short-run elasticity is considerably higher than the elasticity,  $-0.13$ , obtained in the latter study.

Unlike the period studied in this chapter, Taffesse (2003) examined the 1974–1991 period that was marked in Ethiopia with the command economic system. Consequently, the difference in the results is largely a result of the distinct economic environments that prevailed during these specific periods of study.<sup>10</sup> Among these differences included the abolition of the proportion/quota of grain output that farmers were required to deliver to a government agency at fixed prices. However, the difference in long-run acreage demand elasticities obtained in the two studies is large, even after accounting for the negative acreage demand elasticity of compulsorily delivered grain quota Taffesse (2003) obtained,  $-0.04$ .

The period covered witnessed more changes that positively affected agricultural supply response. Among such changes was the abolition in the early 1990s of government control of inputs and output markets. Moreover, since the mid-1990s the Ethiopian government implemented a number of

9 Three of the four studies referred to in this paragraph use the rational expectations hypothesis, as does this study, and generally use similar empirical models, particularly Eckstein (1984) and Tegene, Huffman, and Miranowski (1988). The fourth study—Yu, Liu, and You (2010)—uses a Nerlovian adaptive expectations model.

10 Indeed, Taffesse (2003) indicates that “it is reasonable to expect that the process of market liberalization, which began with the abolition of CGD (compulsory grain delivery) in 1990, stimulates greater supply responsiveness.”

policy packages targeted at increasing the productivity of smallholder farmers. Agricultural supply response is also likely to be affected positively by improved integration of farmers with markets, consequential to increased road, telephone, and other infrastructure that had occurred since the mid-1990s (Bachewe et al. 2015). The country suffered frequent droughts and famines during the 1974–1991 period. More favorable weather in most surplus-producing areas of the country during most of the latter period has likely impacted supply response positively. Finally, the government’s decision to allow a limited renting-in and -out of land and the consequently greater flexibility of access to cultivable land may also have boosted acreage demand elasticity.

## Conclusion

Agriculture in Ethiopia is dominated by smallholder grain producers who consume most of what they produce. This study investigates the parallel characterization that smallholders respond little to changes in economic incentives, such as prices, focusing on the specific case of the responsiveness of teff supply. For this purpose, a simple dynamic model of input demand choices of a representative farm household producing two types or groups of crops under rational expectations hypothesis is developed. In the model, teff supply is a linear function of teff acreage demand. An acreage demand equation is derived and estimated using zone-level aggregated data. In addition, farmers’ long- and short-run teff supply responses or acreage demand elasticities for changes in teff prices and opportunity cost of teff production are calculated.

The results indicate that teff acreage demand increases slightly faster than the permanent increase, by 100 percent, in its price that triggered the response. The acreage demand increase corresponding to an analogous change in the temporary (short-run) real teff price is lower at about 37 percent. Moreover, the results indicate that increases in the opportunity cost of teff acreage, gauged by revenue obtainable from other crops, leads to a fall in teff acreage. Teff acreage demand declines by about 50 percent and 90 percent for a 100 percent permanent and temporary increase in the real revenue per hectare obtainable in the production of non-teff grains crops, respectively. The faster growth in teff supply response that resulted from a direct impact of growth in teff price was also likely to have been reinforced by a relatively slower growth in prices of non-teff grains.

Studies of supply response in other countries obtain higher short- and long-run crop supply response elasticities than those obtained in this study.

The long-run acreage demand elasticities obtained in this study are considerably higher than that obtained by Taffesse (2003) for Ethiopia. This difference is attributable to the different economic policy regimes that prevailed in the periods of these two studies, in addition to the relatively faster growth in teff price that occurred during this same period. Moreover, policies aimed at increasing agricultural and particularly teff productivity, infrastructural development, and favorable weather are likely contributors to the faster growth in overall agricultural supply response.

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## Appendix

### Estimation Procedure

The empirical teff acreage demand equation given in equation (1) and teff price equation are estimated using available data on the variables. Zone-level aggregated annual panel data are used, which extend over the nine-year period of 2003/2004–2011/2012. Equation (1) is restated below by introducing zone-specific effects. The resulting teff acreage demand equation is:

$$A_{1i,t} = \kappa_1 A_{1i,t-1} + \kappa_2 A_{1i,t-2} + \kappa_3 P_{1i,t-1} + \kappa_5 R_{1i,t} + \kappa_6 R_{1i,t-1} + \eta_i^A + v_{i,t}^A \quad t \geq 3 \quad (3)$$

In equation (3)  $i = 1, \dots, 53$  identifies the 53 administrative zones and  $t$  denotes the years covered in the dataset.<sup>11</sup> The term  $\eta_i^A$  stands for unobserved zone-specific effects of acreage demand. To ensure stationarity in equation (3), it is also assumed that,  $\kappa_1 + \kappa_2 < 1$ ,  $\kappa_2 - \kappa_1 < 1$ , and  $\kappa_2 > -1$ .<sup>12</sup>

The following teff price equation is similarly obtained from  $P_{1,t} = \Theta P_{1,t-1} + u_t^P$  with  $|\Theta| < 1$ :

$$P_{1i,t} = \Theta P_{1i,t-1} + \eta_i^P + v_{i,t}^P \quad |\Theta| < 1, t \geq 2 \quad (4)$$

Note that,  $\eta_i^A + v_{i,t}^A = \varepsilon_t$  and  $\eta_i^P + v_{i,t}^P = u_t^P$  represent the “fixed effects” decomposition of the disturbance terms commonly adopted in panel data models, with  $v_{i,t}^A$  and  $v_{i,t}^P$  assumed to be white noise.

Equations (3) and (4) are estimated using techniques applicable to such models. Given the equations include the levels for past one or two periods (once or twice lagged levels) of the dependent variable, they must be estimated using dynamic panel data (DPD) models. Estimating the equations using ordinary least squares (OLS) or panel data methods, such as the within-groups estimator, result in biased parameter estimates (Nickell [1981] and Hsiao [1986]). OLS estimates are biased because  $J_{1i,t-k}$  is correlated with  $v_{i,t}^J$  through the individual specific effect,  $\eta_i^J$ , for  $J \in (A, P)$  and  $k = 1, 2$ . The within-groups estimator, in which the variables are transformed by subtracting their time-means, the cause is the correlation between  $J_{1i,t-k}$  and the time-mean of  $v_{i,t}^J$ .

11 Although the data extends for the 2004/2005–2012/2013 period the first two years of data are lost due to twice lagged acreage variables used in equation (3).

12 These conditions define the triangle that ensures the stationarity of an AR(2) process (Davidson and MacKinnon [1993], 343). In this regard, recall that in the present case,  $|\kappa_1| = |\lambda_1 + \rho| < 2$ , and  $|\kappa_2| = |\rho \lambda_1| < 1$ , since  $|\lambda_1| < 1$  and  $|\rho| < 1$ .

Among methods developed to estimate the parameters of such models, two standard DPD models are used. The first is the linear dynamic panel-data method developed by Arellano and Bond (1991). The second method is the systems estimator that uses additional moment conditions than those used in the first.<sup>13</sup> This was developed by Arellano and Bover (1995) and Blundell and Bond (1995).

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13 References on theoretical underpinnings of single equation dynamic panel data models include Anderson and Hsiao (1982), Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (1995).

