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Growth in Total Factor Productivity in the Ethiopian Agriculture Sector: Growth Accounting and Econometric Assessments of Sources of Growth

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Abstract

During the 2003/04–2008/09 period agricultural production in Ethiopia grew annually at 9.3 percent while cultivated area expanded at 4.7 percent. The remaining growth resulted from intensive use of other inputs, increased productivity, increased efficiency, or a combination of these factors. This study applies growth accounting and two econometric approaches on sector and administrative zone level data to investigate the issue.

The baseline three-factor growth accounting specification applied to sector level data covering the 2004/05–2009/2010 period implies an average year-to-year change in total factor productivity (TFP) of 4.5 percent. The five-factor specification that includes the effects of intermediate manufacturing and services inputs implies that out of the 8.4 percent average, annual growth in real value of output TFP growth accounted for 4 percent. Out of the remaining 4.4 percent growth in output, increased application of labor accounted for 2.7 percent, land and capital for 1 percent, and intermediate inputs for 0.7 percent. A modification of the growth accounting model, to take into account factors that indirectly affect TFP, resulted in an average annual growth in TFP of 2.7 percent. I applied the Cobb-Douglas and stochastic production frontiers on zone level data of four agriculturally important regions. The results of the Cobb-Douglas production function (CDPF) imply that TFP grew at an average annual rate of 5.6 percent. Growth in cultivated area and employment of labor accounted for 3.6 and 1.0 percent of the growth in output. Similarly, results of the stochastic production frontier model imply that growth in labor and cultivated area accounted for 0.6 and 3.7, respectively, of the growth in output. Changes in TFP and gains in efficiency accounted for 3.9 and 0.5 percent of the growth in output. A typical farmer in these regions had an average level of efficiency of 0.73, which implies that output can be increased by about 37 percent from its current level without increased application of inputs.

During the same period, efficiency improved as the proportion of literate farmers grew. It also improved with the application of the extension package, and as the number of farmers who receive advisory services grew. The fact that growth in efficiency between 2003/04 and 2005/06 represents about 84 percent of the average annual change in TFP, which mainly occurred between 2003/04 and 2005/06, has an important policy implication. This result, together with the sources of growth in efficiency, implies that the Ethiopian government's efforts to educate farmers and expand modern production practices—efforts that have been going on for well over a decade—are starting to pay off. .

Keywords: Growth accounting; Total factor productivity; Production efficiency; Sources of agricultural growth; Stochastic production frontier; Ethiopia

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1. Introduction

The 2004/05–2008/09 period was marked with a remarkable growth in total Ethiopian agricultural production. This work investigates whether the growth resulted from increased application of inputs, or from gains in total factor productivity, or from efficiency, or both. The Agricultural Sample Survey data of the Central Statistical Agency (several CSA publications) indicate that total agricultural output grew consistently between 2004/05 and 2008/09, from 14.2 million metric tons in 2004/05 to 20.2 million metric tons in 2008/09, averaging 17.4 million metric tons during the period.[1] This is a 42.4 percent growth between 2004/05 and 2008/09, or an average annual growth rate of 9.3 percent.

Growth in total agricultural production was largely driven by expansion in grains production, which on average accounted for 84 percent of total volume of agricultural production and grew at an average annual rate of 9.5 percent. Total cultivated area averaged 11.1 million hectares during the period and grew at an average annual rate of 4.7 percent, from 10.1 million hectares in 2004/05 to 12.1 in 2008/09. On average, 95 percent of the total cultivated area was under grains. However, growth in area under grains averaged 3.4 percent, visibly lower relative to growth in total cultivated area.

About half of the increase in total agricultural production was attained by bringing more land into cultivation. [2] The ratio of growth in area to growth in output averaged 0.51 during the period under consideration. Therefore, the remaining increase in output must have resulted from intensive use of other inputs, or from increased productivity, or from increased efficiency, or both. On average, farmers harvested 13.9 and 15 quintals of grains and cereals per hectare during the period. Yields of these crops consistently grew during this period, at an average annual rate of 5.9 percent.

Data corroborates the claim that the part of growth that is not accounted for by growth in cultivated area is the result of growth in yields.[3] The difference between average annual growth rates of production and cultivated area closely resembles average annual growth rate in yields. On average, the ratio of average annual growth in yields and the difference between average annual growth in output and cultivated area of the crop categories considered is 0.97.[4] It is logical then to ask what explains this increase in yield. Did the increase in yield result from intensive use of other inputs, such as labor, fertilizer, improved seeds, and pesticides? Did it result from improved production technology that changed the production structure? Or was it the reduced inefficiency that increased yields, thereby bringing farmers closer to the production frontier? If it was a combination of these factors, which were the factors in play? And how important were they in explaining growth in output?

This work is part of a project that aims to investigate: (1) what were the important factors that explain the growth in output and yields? (2) was there any increase in efficiency and what was the magnitude of its contribution? (3) was there any technical change in production leading to increased total factor productivity (TFP) and how large was its contribution? and

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[1] All input use and output levels refer to the meher agricultural season in Ethiopia, unless otherwise stated. Meher is the agricultural season associated with the major rain season. Defined in terms of harvesting, it runs from September to December.
[2] Note that this assertion assumes that the additional land brought into cultivation yielded the same or a lower amount as average yield levels of previously cultivated land.
[3] Nisrane et. al. (2011), Taffesse (2009), and Yu, Nin-pratt, and Funes (2011) complement this study in providing analytical treatments of sources of growth in output during this period.
[4] This ratio is: percentage change in yield/{(percentage change in output)-(percentage change in area)}

lastly, (4) what is the policy implication of the findings if growth in agricultural production is to be sustained? Among the studies that analyzed the period, there is a lack of consensus on the sources of growth in output. Nisrane et al. (2011), using household level panel data collected between 1994 and 2009, found that farmers benefited from increased efficiency between 2004 and 2009. However, that study implies a decline in TFP during the same period. Yu, Nin-pratt, and Funes (2011), on the other hand, using enumeration area level official data of three important crops, found that TFP grew annually by at least 9 percent.

This work studies trends in total factor productivity and sources of growth in output during the 2004/05–2009/10 period using two data sets and analytic methods. The growth accounting approach is applied on sector level data covering the 2004/05–2009/10 period. To check the robustness of results from the growth accounting exercise and to study trends in efficiency, I applied the Cobb-Douglas production function and stochastic production frontier on zone level data covering the 2003/04–2008/09 period.

The remainder of this study is divided into three major sections. Section 2, which has four subsections, presents two versions of the growth accounting model in the first subsection. The second subsection describes sector level data used in the analyses and considers alternative scenarios. The third subsection presents results of the growth accounting analysis, while the last subsection summarizes the key findings of growth accounting analyses. Section 3 has three subsections. The first describes the zone level input and output data used in the econometric analysis and the empirical models I used. The second subsection presents results obtained from the analyses and the third subsection summarizes the key findings of the econometric analyses. The fourth major section summarizes the key findings of the study.

2. Trends in TFP: A growth accounting approach

The basic growth accounting model used in this section derives mainly from Solow (1957). The approach employs an aggregate production function that makes it possible to apply production theory to economic growth and macroeconomic theory. According to this approach, growth in total factor productivity (TFP), which is considered equivalent to growth in technical change, is meant to represent any kind of shift in the production function. I describe the approach here.

2.1. A model of growth accounting

To apply the growth accounting method of measuring changes in TFP, let us assume that agricultural production can be represented by an aggregate production function of the form:

$$Q = F(K, L, T; t) \qquad (1)$$

Where Q is the real value of agricultural output at a given period t, and K, L, and T respectively represent the real value of capital, labor, and land services put into the production of Q during the same period. In this equation, t accounts for the effect of technical change occurring through time. Although I consider only the three primary inputs in (1), for simplicity, I discuss results from a generalized version of (1) that accounts for contributions made by intermediate inputs in section 2.3. Assuming neutral technical change that leaves marginal rates of substitution constant, it is possible to write the production function given by equation (1) as,

$$Q = A(t) f(K, L, T) \quad (2)$$

whereby *A(t)* measures the cumulative change in TFP that occurred over time. Differentiating equation (2) with respect to time and rearranging,

$$\frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - w_K \frac{\dot{K}}{K} - w_L \frac{\dot{L}}{L} - w_T \frac{\dot{T}}{T} \quad (3)$$

where w_K, w_L, and w_T are shares of capital, labor, and land inputs in total agricultural output, respectively, and the upper dots indicate time derivatives. Here the assumption is that factors are paid their contribution to total product. That is, $w_J = (\partial Q / \partial J)(J / Q)$, where *J = K, L, T*. In equation (3) $\dot{A}/A$ represents the rate of change in TFP. It is the remainder of change in total output after taking into account changes in application rate of inputs, which earned it the name 'Solow Residual'. Given this equation and data on its components, the time series of $\dot{A}/A$ and hence of A can be calculated. Since availability of data on sector level input use and output is limited to a given period, often annual, I can only calculate the discrete version of $\dot{A}/A$, which I denote by $\Delta A/A$. The series of $\Delta A/A$ is then used to construct the series of TFP indices using $A_{t+1} = A_t(1 + \Delta A_t / A_t)$.

Among the criticisms against using equation (3) to compute changes in TFP are the assumption of an aggregate production function and the aggregation into a single factor of factors that may qualitatively differ. This is particularly problematic for analyzing a relatively dynamic sector and a longer time period. I make these assumptions for several reasons. The most important are the absence of relevant data and the brevity of the period analyzed. Moreover, the oxen-plough technology that dominates Ethiopian agriculture has changed little except for the push for increased application of modern inputs and methods in the past two decades. However, this specification and the other two alternatives can accommodate this specification. Moreover, as long as the qualitative composition of factors has not changed in this period, the aggregation will not affect the results. I also make this assumption for the same reasons listed above, some aspects of which are supported by the data presented in section 2.2.

In addition to the all-pervasive issue of measurement errors, other criticisms of the model given by (3) include that it fails to account for factors other than those included in the function but that contribute toward production increases. Among others, this list includes public and private infrastructural and institutional improvements, and changes in returns to scale that may result in increases in output larger than the corresponding growth in inputs applied. Failure to account for such factors results in an overstatement of TFP (Griliches 1996). Given the conceptual and empirical concerns against using the basic specification, and due to the unique characteristics of the sector, I consider the following factors to subsequently modify the basic model: 1) errors in measurement of inputs, 2) errors in weights associated with factors of production, 3) gains from changes in returns to scale, and 4) factors that contribute to increases in production but unaccounted for by those included in the basic model, such as infrastructure. Carlaw and Lipsey (2003) present Griliches' (1987) model that takes into account these factors, which I modified for my purposes as,

$$\Delta TFP = \frac{\dot{A}}{A} = w_K(\frac{\dot{K}^*}{K} - \frac{\dot{K}}{K}) + w_L(\frac{\dot{L}^*}{L} - \frac{\dot{L}}{L}) + w_T(\frac{\dot{T}^*}{T} - \frac{\dot{T}}{T}) + [(w_K^* - w_K)(\frac{\dot{K}^*}{K} - \frac{\dot{T}^*}{T}) + (w_L^* - w_L)(\frac{\dot{L}^*}{L} - \frac{\dot{T}^*}{T})] + h\left(w_K^* \frac{\dot{K}^*}{K} + w_L^* \frac{\dot{L}^*}{L} + w_T^* \frac{\dot{T}^*}{T} - f \right) + \alpha z + t \quad (4)$$

where $h = w_K + w_L + w_T - 1$, f stands for the expansion rate of agricultural activities. z is the growth rate in infrastructure while α is TFP elasticity with respect to infrastructure. Symbols with asterisks denote correctly measured magnitudes while those without asterisks may involve errors in measurement. The rest were defined earlier.

Note that in equation (4), the term $\dot{A}/A$ represents the rate of change in TFP equal in value to the left hand side of equation (3). The first three terms after the second equal sign account for measurement errors in growth rates of capital, labor, and land inputs. The fourth term in square brackets accounts for errors in the importance of inputs arising from errors in measuring factor shares. The fifth term in the parentheses accounts for growth in output that may have resulted from gains in economies of scale and the sixth term, αz, accounts for the contribution of infrastructure. The last term, t, captures changes in output net of changes in factor inputs less those captured by terms 1 through 6.

Using equation (3) in (4) and then rearranging simplifies equation (4) to:

$$\Delta TFP = t = \frac{\dot{Q}}{Q} - w_K^* \frac{\dot{K}^*}{K} - w_L^* \frac{\dot{L}^*}{L} - w_T^* \frac{\dot{T}^*}{T} - h\left(w_K^* \frac{\dot{K}^*}{K} + w_L^* \frac{\dot{L}^*}{L} + w_T^* \frac{\dot{T}^*}{T} - f \right) - \alpha z \quad (5)$$

Equation (5) addresses the four concerns listed above. In equation (5) t is the remaining change in output after having accounted for increased application of inputs, based on correctly measured factor shares and services; gains in output due to factors external to production; and changes in returns to scale. While this may provide a more precise measure of TFP relative to the baseline model given by equation (3), my application of the latter and the five-factor specifications will leave out only the latter two factors. In the following section I describe the data and scenarios used to conduct the growth accounting exercise.

2.2. Scenarios considered and data used in growth accounting

I use three specifications of the growth accounting model. The specification given by equation (3), which aggregates all inputs into the three primary inputs, is used as a baseline. The second, dubbed the five-factor specification, treats intermediate manufacturing and services inputs as distinct. [5] This specification uses relatively disaggregated data and helps investigate the effects of changes in application rates of intermediate inputs of the two sectors on agricultural TFP (AgTFP). Importantly, it allows for changes in fertilizer application rates, which represented 81 percent of intermediate manufacturing inputs in 2004/05 that affected AgTFP. The third modified specification is provided by equation (5).

[5] That is, under the baseline specification intermediate manufacturing and services sectors inputs are disaggregated into the respective sector's primary input content and added to the primary inputs used in agriculture. Intermediate agricultural inputs used in agriculture are treated similarly under both baseline and five-factor specifications.

2.2.1. Scenarios considered

Output shares of factor inputs for 2004/05, which I derive from the 2005/06 Ethiopian Social Accounting Matrix (SAM) developed by the Ethiopian Development Research Institute (EDRI 2009), serve as the starting point for my computations of changes in TFP.[6] Shares of the respective factors of labor, capital, and land out of total agricultural output, w_L, w_K, and w_T were calculated using $w_L = W * L/Q$, $w_K = rK/Q$, and $w_T = \pi T/Q = 1 - w_L - w_K$. In the last expressions, *W* represents real wage of labor service and *L* the total flow of labor services; *r* stands for real rental rates of capital and *K* the total flow of capital services; and p represents real rental rate of land while T is the flow of land services.[7] Starting from the 2004/05 factor prices (W, r, and p) and flow of factor services (L, K, and T), I consider different scenarios about their rates of change in the subsequent years. This is necessitated because although I have data on real value of agricultural output, I do not have corresponding information on factor prices and flow of factor services for the years 2005/06 through 2009/10.

I considered three scenarios for changes in real wages and rental rate of land. Real wages and rental rates of land are assumed to:

- i) remain constant at 2004/05 levels;
- ii) grow at the rate of real agricultural valued added per worker and real value added per hectare under temporary and permanent crops, respectively; and
- iii) grow at an average of rates in i) and ii). [8]

I proxy the rates of growth in the flow of factor services by growth rates of variables that closely mimic growth rates of interest. Accordingly:

1) The flow of labor services was alternatively assumed to change at rates of growth in:
   - i) the number of private holders;
   - ii) employment in agriculture; and
   - iii) the average of rates in i) and ii).
2) The flow of land services was assumed to change at the rate of growth in total area under temporary and permanent crops.
3) The rate of change in capital services was approximated by:
   - i) the rate of change in the number of draft animals;[9]
   - ii) growth in aggregate gross fixed capital formation;
   - iii) total private investment in agriculture; and
   - i) at an average of the rates in i), ii), and iii).

I calculated labor services of each year from 2005/06–2009/10 using the formula $L_{t+1} = L_t(1 + \Delta L_t / L_t)$, where $\Delta L_t / L_t$ is given by assumed growth rates. I computed the flow of services of other inputs similarly.[10] Permuting the three scenarios I assumed about the flow

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[6] We use factor shares derived from the 2005/06 SAM for 2004/05 and to derive values of factor services and shares for other years. This allowed us to use one more year of data without affecting the analysis that assumed constant factor shares while the analyses that assumed changing factor shares were affected little.

[7] One of the criticisms of this approach that we simply assumed away in the current analysis is the assumption that each factor is paid its marginal contribution, which implicitly assumes markets are competitive. We also made this assumption although we are aware that factor markets are far from competitive in Ethiopia, particularly in the agriculture sector.

[8] Changes in real rental rates of capital were not considered because almost all data sources implied constant or slightly declining real interest rates.

[9] Oxen used for farming constitute almost all of the non-land agricultural capital in Ethiopia, while in the 2004/05 SAM, oxen constitute the entire non-land capital.

[10] Under each scenario factor shares are then calculated as: $w_J = R * J/Q$, where *J = K, L, T* and R =*W, r,* p .

of labor services across the four scenarios for capital services, I got 12 scenarios for each of the three assumptions about growth rates of factor prices. I will discuss here only the scenarios with significantly different results.

To apply the five-factor specification I proxied changes in the flow of the two intermediate inputs, in addition to those made for primary inputs. Changes in the flow of manufacturing intermediate inputs were assumed to grow at fertilizer application rates. Intermediate services inputs were assumed to grow at the rate of growth in:

i) real value of services sector output;
ii) real agricultural output; and
iii) the average of growth rates in i) and ii).

The 12 baseline scenarios under each of the three assumptions made about growth rates of wages and rental rates of land were permuted across the three growth rates assumed for intermediate services inputs. That is, I considered 36 scenarios using the five-factor specification. However, results of the analysis are affected little by these assumptions, owing to the unimportance of intermediate services inputs, which represent less than 1 percent of the total value of agriculture. I will discuss only three sets of results that represent scenarios with significantly different results.

I use current and lagged expansions in rural roads and electrification to account for contributions of infrastructure when using the modified specification. I use lagged values of such improvements because infrastructure made available at a given period takes some time to fully integrate with production activities. The response of agricultural output/TFP for changes in infrastructure was taken from three studies that analyzed these relationships. These are:

i) Binswanger et al.'s (1989) elasticity of crop output with respect to rural roads of 0.201;
ii) Zhang and Fan's (2004) elasticity of TFP with respect to rural roads of 0.042;
iii) the average elasticity of agricultural output with respect to rural roads of 0.29 that Fan et al. (2002) calculate for 13 Indian provinces; and
iv) the average of the elasticities in i) through iii).

Moreover, I used the average elasticity of agricultural output with respect to electrification of 0.143, obtained in Fan et al. (2002) for 13 Indian provinces, to calculate the contribution of electrification.[11] In the modified specification, the 12 baseline scenarios were permuted across the four scenarios assumed about the elasticity of TFP with respect to rural roads. These resulted in 48 measures of changes in TFP under each of the assumptions made about factor price growth rates. However, I will discuss only a small proportion of the results, summarizing across scenarios that resulted in important differences.

2.2.2. Data used in growth accounting

The 2004/05 SAM indicates that 65.5 billion birr worth of agricultural commodities were produced (in 2006 prices). Labor, land, and capital services accounted for 68.3, 13.0, and 9.2 percent, respectively, of the 65.5 billion birr (Table 2.1). Intermediate agricultural, manufacturing, and services sectors inputs constituted 4.2, 3.7, and 1.5 percent,

[11] We calculated average elasticities of agricultural output with respect to rural roads and electrification from Fan et al. (2002) first by dropping negative estimates and then dropping the top and bottom elasticities.

respectively, of the aggregate. Aggregation of the 9.4 percent share of intermediate inputs into primary inputs using factor shares in each sector raises shares of labor and capital to 73.5 and 13.5 percents. The last two shares, together with the share of land of 13 percent, are used in the three-factor and modified specifications. Total payments for these inputs were calculated using these technology coefficients in conjunction with assumed rates of growth and real value of agricultural output reported by the Ministry of Finance and Economic Development (MoFED) for the 2004/05–2009/10 period.

Table 2.1—Share and total value of factor inputs in agricultural production, 2004/05

Commodity and factor inputs	Share and value of primary inputs (baseline model)		Share and value of primary and intermediate inputs	
	Share (%)	Value (billion birr)	Share (%)	Value (billion birr)
Total Factor Inputs			**90.50**	**59.29**
Labor	73.46	48.12	68.30	44.74
Land	13.02	8.53	13.00	8.52
Capital	13.52	8.86	9.20	6.03
Total Intermediate Demand			**9.50**	**6.22**
Primary Agricultural Products			4.20	2.75
Manufactured Goods			3.70	2.42
Fertilizer			3.00	1.97
Utilities & Other services			1.50	0.98
Transport Services			0.40	0.26
Financial Services			0.20	0.13
Other Services			0.90	0.59
Total Inputs = Gross output	100.00	65.51	100.00	65.51

Source: Ethiopian Development research Institute (2009)

Annual growth in AgGDP, which ranged from the slowest rate of 6.4 percent in 2007/08–2008/09 to 10.9 percent during 2004/05–2005/06, averaged 8.4 percent (see Appendix Table A.1 for details and data sources). Total agricultural employment and the number of private holders grew at an average annual rate of 3.6 and 3.3 percent, respectively. Agricultural value added per agricultural worker grew at an average annual rate of 7.1 percent. The number of draft livestock grew at an average annual rate of 5.8 percent. On average, the difference between growth in real AgGDP and the 2004/05 factor share weighted sum of growth rates of labor, capital, and land inputs, was 4.7 percent. The last computation basically measures the average change in TFP using equation (3) under constant rental rate and flow of services scenarios (not considered in this study). As a result the 4.7 percent difference in growth rates of outputs and inputs roughly foretells a positive average annual rate of growth in TFP.

CSA data indicate that rural roads expanded at an average annual rate of 10 percent, while EEPCo data reveal an average annual growth in electrification of 9 percent (EEPCo 2011). I calculated gains from returns to scale from the difference between factor share weighted payments and primary inputs and changes in the scale of agricultural activities for each of the scenarios considered. That is, if the factor share weighted sum of payments exceeds changes in the level of agricultural activities $(w_K^* (\dot{K}^*/K) + w_L^* (\dot{L}^*/L) + w_T^* (\dot{T}^*/T) > f)$ it implies that there were gains in returns to scale. In the following section I present results of analyses obtained by applying the three specifications of the growth accounting model on the data and scenarios discussed above.

2.3. Results and discussion

Results of analyses obtained from the 12, 36, and 48 scenarios considered under the baseline, five-factor, and modified specifications that assume average growth rates in wage and land rental rates are provided in Appendix Tables A.2, A.3 and A.4, respectively.[12]

As can be seen from Appendix Table A.2 and Table A.3, results of analyses obtained from the three and five-factor specifications change mainly with assumptions about the flow of labor services.[13] As a result, for these two specifications, I present and discuss results that are summarized across the three flows of labor service assumed.

Moreover, results of the 48 scenarios of the modified specification in Appendix Table A.4 indicate that elasticities of TFP with respect to infrastructure affect the results more than assumptions made about the flow of labor services do; as a result, I present 16 results from this specification. Twelve of these permute the three labor flow scenarios across the four elasticities of infrastructure assumed. The remaining four summarize the results across the four elasticities.

Averaging across all scenarios considered in the baseline and five-factor specifications, annual TFP growth rates averaged 4.5 and 4.0 percent during the 2004/05–2009/10 period (Table 2.2). Analyses using the modified specification result in an average annual change in TFP of 1.4 percent. Results of the three and five-factor specifications vary only moderately owing to the relatively small role of intermediate inputs.

Table 2.2—Annual changes in TFP and levels of TFP under average real wage and land rental scenario, 2004/05–2009/10

Specification	Annual change in TFP					
	2004/05–2005/06	2005/06–2006/07	2006/07–2007/08	2007/08–2008/09	2008/09–2009/10	Average change
Baseline specification	0.073	0.049	-0.007	0.057	0.050	0.045
Five-factor specification	0.055	0.048	-0.013	0.058	0.049	0.040
Modified specification	0.042	-0.002	-0.016	0.019	0.029	0.014
	Level of TFP					
	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Baseline specification	1.0	1.073	1.126	1.118	1.181	1.240
Five-factor specification	1.0	1.055	1.106	1.091	1.155	1.211
Modified specification	1.0	1.042	1.040	1.023	1.043	1.073

Source: Calculated from changes in TFP resulting from using three-factor specification

TFP growth rates obtained from the modified specification were significantly lower than the first two and vary significantly among themselves as they assume elasticities of TFP with respect to infrastructure that range from 4 to 29 percent. Periods of largest increase and decline in TFP match in all three specifications. Under all specifications, growth in TFP was the fastest between 2004/05 and 2005/06. The largest decline in TFP occurred during the 2006/07–2007/08 period; as a result, cumulative levels of TFP were lower in 2007/08 than in 2006/07 in all 3 specifications. Next I discuss results obtained using each specification.[14]

[12] The remaining 24, 72, and 96 sets of results obtained using the three specifications under each of constant and growing wage and rental rates of land, (which differ little from those in Appendix Tables A.2, A.3, and A.4) can be obtained on request.
[13] As labor constitutes the largest share of output—more than fivefold of each of capital and land,—the results change more with assumptions made about this factor.
[14] Unless stated otherwise in the remaining discussion, we refer to results of analysis that assume real wages and rental rates of land obtained by averaging the levels in 2004/05 and those that assume wages and rental rates of land grew at the rate of agricultural value added per agricultural worker and per hectare of cultivated land, respectively.

2.3.1. Baseline specification

Averaging through the 12 scenarios in the baseline specification annual TFP growth were 7.3, 5.0, -0.7, 5.7, and 5.0 percent during the respective five one-year periods between 2004/05 and 2009/10, which averaged 4.5 percent across the period. The standard deviation of growth rates of the 12 scenarios was 1.1, 1.0, 2.7, 2.4, and 1.5 percent in each of these five one-year periods. Normalizing TFP level of the initial year, 2004/05, at 1 and using the formula $A_{t+1} = A_t(1 + \Delta A_t / A_t)$, cumulative levels of TFP were 1.07, 1.13, 1.12, 1.18, and 1.24 in the years 2005/06 through 2009/10. That is, the cumulative level of TFP was 24 percent larger in 2009/10 than the level in 2004/05 (Table 2.3).

Calculated changes in TFP under a given scenario, viewed together with the rate of growth of the flow of assumed inputs, indicate consistency in the estimated results. For instance, the fastest annual growth in TFP of 8.9 percent (Scenario number 1.1.3 in Appendix Table A.2) was recorded in 2004/05–2005/06 under the scenario that assumed the slowest growth rate in agricultural employment, of 2.1 percent, and the fastest decline in capital services, of about 70 percent of agricultural investment. Similarly, the worst decline in TFP, of 5 percent, was recorded during 2006/07–2007/08 (Appendix Table A.2, Scenario number 2.1.2). This resulted from the scenario in which both labor and capital services were assumed to have grown at the fastest rates of about 11 and 18 percent, proxied using growth in the number of farm holders and gross fixed capital formation. Similar comparisons of assumptions made about the flow of inputs, with resultant changes in TFP, reveal consistent results across this and the other two specifications.

The sum of contributions made by factor inputs and changes in TFP accounted for the entire change in output during each of the five one-year periods. The 4.5 percent average annual growth in TFP is the largest contributor to the growth in real output. Growth in labor, land, and capital services, on average, accounted for 2.8, 0.5, and 0.6, respectively, of the 8.4 percent growth in real agricultural output. Expressing the contributions of TFP and factor inputs just mentioned as a ratio of growth in real output implies that growth in TFP accounted for 54 percent of the growth in output; that is, (4.5/8.4)*100%=54. Similarly, growth in labor employment, land, and capital services respectively accounted for 34, 6, and 7 percent of the total growth in output. In addition, the contribution of factor inputs relative to TFP varied across the period. The three inputs made the largest contribution between 2006/07 and 2007/08, during which they accounted for 100 percent of the growth in output while TFP stagnated. But between 2007/08 and 2008/09, growth in the three inputs accounted for only 11 percent of the growth in output.

Table 2.3—Annual changes and levels of TFP, baseline specification 2004/05–2009/10

Growth in labor use assumed	Annual change in TFP					
	2004/05-2005/06	2005/06-2006/07	2006/07-2007/08	2007/08-2008/09	2008/09-2009/10	Average growth
Agricultural employment	0.085	0.044	0.023	0.030	0.034	0.043
Private holders	0.061	0.054	-0.036	0.085	0.066	0.046
Average of the two	0.073	0.050	-0.008	0.056	0.050	0.044
Average change in TFP across 12 scenarios	0.073	0.049	-0.007	0.057	0.050	0.045
	Level of TFP					
	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Agricultural employment	1.0	1.09	1.13	1.16	1.19	1.23
Private holders	1.0	1.06	1.12	1.08	1.17	1.25
Average of the two	1.0	1.07	1.13	1.12	1.18	1.24
Average level of TFP across 12 scenarios	1.0	1.07	1.13	1.12	1.18	1.24

Source: Calculated from changes in TFP.

To summarize, the baseline specification results in close average annual changes in TFP across the three labor service flow scenarios I considered. However, measured changes in TFP may be significantly different in some periods, depending on the combined effect of assumptions made about the growth rates in the flow of factor inputs, as can be seen in Table 2.3 above, particularly for 2006/07–2007/08. Despite this, the finding is particularly important for two reasons. First, the assumed rates of growth in labor services comprise two different parameters derived from two different sources. Data on the number of private holders, which is derived from CSA publications, includes mostly household heads who traditionally own land. By contrast, total employment data from World Development Indicators (WDI) (World Bank 2009) includes family members engaged in farming, in addition to those who own land. Secondly, change in TFP during a given period is calculated by considering changes in output and input during the given one-year period without any feedback from changes in TFP from previous periods. Given these, the similarity in average annual changes in TFP across the considered scenarios is remarkable.

2.3.2. Five-factor specification

Just as in the case of the baseline specification, annual changes in TFP that resulted from the 36 scenarios of the five-factor specification vary only with growth rates of labor services flow assumed. This is because the flow of intermediate service inputs, about which three growth rates were assumed, play little role in agriculture. The little inter-sectoral linkage also goes for the manufacturing sector, with the exception of the one-way link through fertilizer.

Results of the 36 scenarios aggregated across the three growth rates assumed about labor services are listed in Table 2.4. Averaging through all scenarios, annual changes in TFP were 5.5, 4.8, -1.4, 5.9, and 4.9 percent during the consecutive five one-year periods between 2004/05 and 2009/10. Changes in TFP averaged about 4 percent, 11 percent lower than the 4.5 percent in the baseline specification. As the five-factor specification incorporates the effect of growth in fertilizer application rates, an important agricultural input, I feel it provides a relatively reliable measure of the first two specifications. TFP levels of the five years that followed 2004/05 averaged 1.06, 1.11, 1.09, 1.16, and 1.21. Standard deviations of changes in TFP across the 36 scenarios were lower than those in the 12 scenarios of the three-factor specification in all periods except 2008/09–2009/10.

Again, growth in labor services was important, accounting on average for 32 percent of the total growth in output. While land and capital services accounted, respectively, for 6.1 and 5.6 percent of the growth in output, intermediate manufacturing and service sector inputs contributed, respectively, 5 and 3 percent. Just as in the baseline case, changes in TFP were important, with TFP accounting on average for 47 percent for the total growth in output.

Table 2.4—Average change and levels of TFP, five-factor specification 2004/05–2009/10

	Average annual changes in TFP					
Assumed growth in labor use	2004/05-2005/06	2005/06-2006/07	2006/07-2007/08	2007/08-2008/09	2008/09-2009/10	Average growth
Agricultural employment	0.067	0.043	0.018	0.033	0.033	0.039
Private holders	0.044	0.053	-0.044	0.084	0.065	0.040
Average of the two	0.056	0.048	-0.012	0.058	0.049	0.040
Average change in TFP across 36 scenarios	0.055	0.048	-0.013	0.058	0.049	0.040
	Level of TFP (2004/05 = 1)					
	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Agricultural employment	1.0	1.07	1.11	1.13	1.17	1.21
Private holders	1.0	1.04	1.10	1.05	1.14	1.21
Average of the two	1.0	1.06	1.11	1.09	1.16	1.21
Average level of TFP across 36 scenarios	1.0	1.06	1.11	1.09	1.16	1.21

Source: Calculated from changes in TFP resulting from using 5-factor specification

2.3.3. Modified specification

The first panel of Table 2.5 contains 16 rows that summarize the results of using the modified specification. The first four rows average the 48 scenarios across the four elasticities, while the remaining 12 rows summarize them across the three scenarios of the flow of labor services and the four elasticities I adopted. The first four rows imply that the 2006/07–2007/08 period was accompanied with a decline in TFP as in the previous specifications, although the decline in TFP, which ranged from 1.3 to 2.3 percent, was relatively large. Unlike the previous two specifications, which had 2005/06–2006/07 as a period of growth in TFP, the largest two of the three unique elasticities imply a decline in TFP. The remaining 12 rows clearly indicate that growth in TFP varied, depending mainly on the elasticity of TFP with respect to the infrastructure assumed.

The modified specification implies an average annual growth in TFP of 1.4 percent and cumulative level of TFP of 1.07 by 2009/10. Given that the modified specification accounts for more factors that affect TFP changes, in theory it is preferable over the baseline specification. However, the average growth from the modified specification sets it apart from the last two specifications. Further unpacking of the factors in the modified model implies an average annual change in TFP of 4.4 percent when considering the effect only of gains in returns to scale, and 1.5 percent when considering the effect only of infrastructure. That is, the baseline specification overstates the average annual changes in TFP by 3 percent by not accounting for contributions made by infrastructure. This again implies that the level of TFP in 2009/10 obtained from the three-factor specification is 240 percent larger than that which resulted from the modified specification (Figure 2.1).

Table 2.5—Changes in TFP using modified model averaged across different criterion

Assumed effect of change in infrastructure on TFP	Starting baseline scenario	Average annual changes in TFP					
		2004/05-2005/06	2005/06-2006/07	2006/07-2007/08	2007/08-2008/09	2008/09-2009/10	Average growth
Zhang and Fan (0.042)	Averaged across all 12 baseline scenarios	0.053	0.021	-0.023	0.042	0.039	0.027
Binswanger et al. (0.201)		0.039	-0.007	-0.016	0.016	0.026	0.012
Fan et al. (0.29)		0.032	-0.022	-0.013	0.002	0.020	0.004
Average of 3 studies (0.18)		0.041	-0.002	-0.017	0.020	0.028	0.014
Zhang and Fan (0.042)	Agricultural employment	0.065	0.016	0.011	0.013	0.021	0.025
	Private holders	0.041	0.026	-0.057	0.073	0.057	0.028
	Average of the two	0.053	0.022	-0.023	0.041	0.039	0.026
Binswanger et al. (0.201)	Agricultural employment	0.052	-0.012	0.018	-0.013	0.008	0.011
	Private holders	0.027	-0.002	-0.050	0.047	0.044	0.013
	Average of the two	0.040	-0.006	-0.016	0.015	0.027	0.012
Fan et al. (0.2896)	Agricultural employment	0.044	-0.027	0.021	-0.028	0.001	0.002
	Private holders	0.019	-0.017	-0.047	0.032	0.037	0.005
	Average of the two	0.032	-0.022	-0.013	0.001	0.020	0.004
Average of three studies (0.178)	Agricultural employment	0.054	-0.008	0.017	-0.009	0.010	0.013
	Private holders	0.029	0.003	-0.051	0.050	0.046	0.015
	Average of the two	0.042	-0.002	-0.017	0.019	0.028	0.014

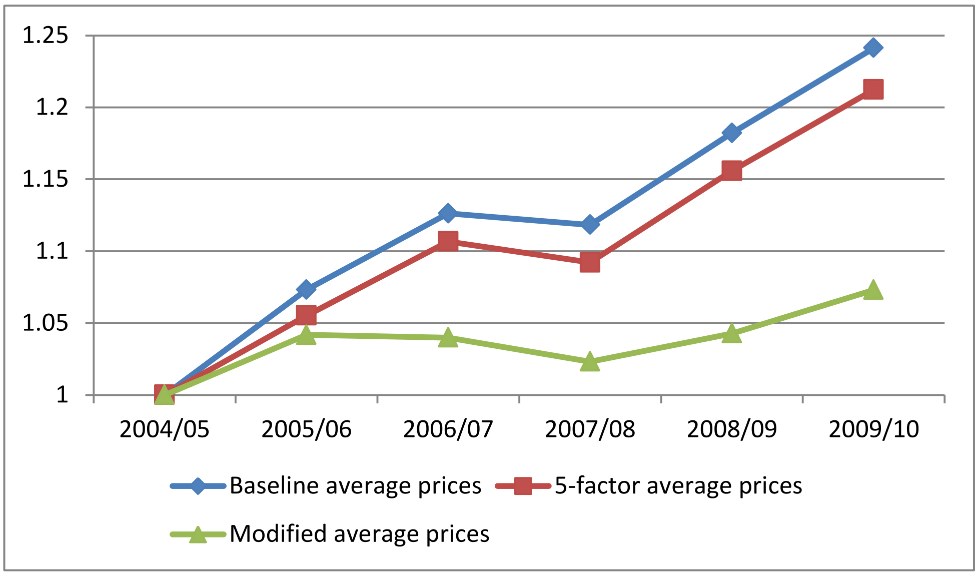
Assumed effect of change in infrastructure on TFP	Starting baseline scenario	Level of TFP (2004/05 = 1)					
		2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Zhang and Fan (0.042)	Averaged across all 12 baseline scenarios	1.0	1.053	1.076	1.051	1.096	1.138
Binswanger et al. (0.201)		1.0	1.039	1.033	1.016	1.032	1.059
Fan et al. (0.29)		1.0	1.032	1.009	0.996	0.998	1.017
Average of 3 studies (0.18)		1.0	1.041	1.039	1.021	1.041	1.071
Zhang and Fan (0.042)	Agricultural employment	1.0	1.065	1.083	1.095	1.109	1.132
	Private holders	1.0	1.041	1.068	1.008	1.081	1.142
	Average of the two	1.0	1.053	1.076	1.051	1.095	1.137
Binswanger et al. (0.201)	Agricultural employment	1.0	1.052	1.039	1.058	1.044	1.052
	Private holders	1.0	1.027	1.025	0.974	1.019	1.064
	Average of the two	1.0	1.040	1.033	1.016	1.031	1.059
Fan et al. (0.2896)	Agricultural employment	1.0	1.044	1.015	1.037	1.008	1.010
	Private holders	1.0	1.019	1.002	0.955	0.986	1.023
	Average of the two	1.0	1.032	1.009	0.996	0.997	1.017
Average of three studies (0.178)	Agricultural employment	1.0	1.054	1.046	1.063	1.053	1.064
	Private holders	1.0	1.029	1.032	0.979	1.028	1.076
	Average of the two	1.0	1.042	1.039	1.021	1.041	1.070

Source: Calculated from results using the modified model.

I obtained the elasticities I used from thorough studies that analyzed rural India at different periods. I used these elasticities for lack of ones pertaining to Ethiopia. But I am aware that India's relatively commercialized agricultural production responds more to infrastructure improvements than does Ethiopia's. Moreover, the difference is largest for the two elasticities obtained from studies that cover the relatively recent period, 0.042 from Zhang and Fan (2004) and 0.29 from Fan et al. (2002).

According to the results of the modified specification, the three primary inputs account for 47 percent of the total growth in output and changes in TFP account for 17 percent. Improvements in infrastructure contribute to 36 percent of the total, or 3 percent of the 8.4 percent. However, I feel that the 3 percent average contribution of infrastructure, which is larger than the 2.8 and 0.5 percent average contribution of labor and land, appears to be an overestimate of infrastructure's contribution in such traditional agriculture, where land and labor are the important inputs. Moreover, the 2.7 average annual change in TFP I obtained using the lowest elasticity of 0.042, implies a 1.8 percent average contribution of infrastructure, larger than the combined contribution of land and capital. As a result, I would like to caution the reader about interpreting the results.

Figure 2.1—Level of agricultural TFP, 2004/05–2009/10



Source: Growth accounting calculations.
Note: 2004/05=1

2.4. Summary and key findings

In conclusion, averaging across the 12 scenarios obtained from the baseline specification that used the three primary inputs, annual changes in TFP averaged 4.5 percent during the five one year periods of 2004/05–2005/06 through 2008/09–2009/10. Accordingly, the cumulative level of TFP in 2009/10 was 1.24, 24 percent larger than the level in 2004/05. The relatively disaggregated five-factor specification—which treats intermediate manufacturing and services inputs as distinct—resulted in an average annual 4 percent growth in TFP. According to this specification, the cumulative TFP level in 2009/10 was 21 percent larger than the level in 2004/05. The modified specification that accounted for factors that contribute to increased agricultural output—but that are not included in measured factors of production—implied an average annual TFP growth of 1.4 percent and a cumulative TFP level of 1.07 at the end of the period. However, given the circumstance discussed in the last paragraph, I believe the 2.7 percent average annual growth in TFP and a cumulative level of TFP of 1.14 implied by one of the elasticities of TFP with respect to infrastructure seems an understatement of changes in TFP.

3. Trends in agricultural total factor productivity: econometric analysis of zone level data

This section continues from the last and will strive to pinpoint and quantify factors that contribute to Ethiopia's remarkable growth in agricultural output in recent years. For that purpose I use zone level output and input data obtained from Central Statistical Authority (CSA) publications covering the 2003/04–2008/09 period. The sampling frame used by CSA evolved over the years. The last survey used in this study was conducted in 2,242 enumeration areas (EAs) across all regions of the country that practice sedentary agriculture. From each EA, 20 households were selected. Data were collected from 44,922 households, or 98 percent of those selected. Since 1995, the collected data have been published at various levels of aggregation. Starting from 1997/98, the publications consisted of zone and regional level input-output data with more details added from 2003/04 onwards. In this section I use zone level data covering the 2003/04–2008/09 period.[15] I consider administrative zones in Tigray, Amhara, Oromia, and SNNP (Southern Nations, Nationalities and Peoples) regions, which respectively include 5, 10, 12, and 21 zones. These regions together account for more than 90 percent of the country's crop production (Seyoum Taffesse forthcoming).The data pertaining to other regions is mostly incomplete.

To pinpoint the sources of growth in output, and to study trends in TFP and efficiency, I apply the Cobb-Douglas production function and stochastic production frontier analysis on zone level input-output data. The following subsection provides a brief description of input and output trends in the four regions and briefly discusses the empirical models used in the analyses. In subsection 3.2 I present the results obtained using the two analytic tools. In addition to take advantage of the disaggregated data, additional features of the analytical tools I used helped to check whether the previous section's results are robust. I summarize the key findings in subsection 3.3.

3.1. Data description and empirical models

3.1.1. Data description

During the 2003/04–2008/09 period, cultivated area weighted total agricultural output was 0.22, 0.63, 0.69, and 0.22 million metric tons, respectively, in an average zone of Tigray, Amhara, Oromia, and SNNP regions (Table 3.1).[16] Although zone level output in these regions grew at average annual rates of 12, 11, 5.6, and 13 percent, respectively, there were large variations in growth rates with standard deviations of 12, 4, 11, and 29. Total agricultural output in Tigray, Amhara, Oromia, and SNNP averaged 1, 5, 7, and 2.6 million metric tons respectively, and grew at average annual rates of 13.6, 10.5, 6, and 11.4 percent. Considering all four regions, this averaged 8.6 percent. This average is the same as the 8.6 percent growth rate in real value of output during 2004/05–2009/10, which was used in the previous section, but slightly lower than the 9.3 nationwide average annual growth during the 2004/05–2008/09 period.

Total cultivated area in Tigray, Amhara, Oromia, and SNNP averaged 0.8, 3.6, 4.4, and 1.2 million hectares, respectively, and grew at average annual rates of 8.6, 4.8, 3.8, and 6.3

[15] Analyses in this section cover only the 2003/04–2008/09 period, as CSA publications for 2008/09-2009/10 agricultural season aggregate the data regionally making them unusable for our purposes. To have a reasonably comparable period between this and the previous sections and in other studies we begin from 2003/04.
[16] The weights are the ratio of zone level cultivated area out of regional total in each year.

percent. These averaged 5.9 percent across the four regions. Output per hectare averaged 12.6, 13, 16, and 20 quintals in an average zone in Tigray, Amhara, Oromia, and SNNP regions, respectively, and grew at average annual rates of 4, 5, 1 and 5.2 percent. Across all four regions, yields grew at an average annual rate of 4.3 percent.

Table 3.1—Area weighted zone level average output and input use, 2003/04–2008/09

Region	Variable	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	Average
Tigray	Output (1000 tons)	162	162	201	253	265	281	221
	Output per hectare (quintals)	11.9	10.4	12.3	12.7	14.1	14.2	12.6
	Number of holders (000)	140	154	158	163	193	196	167
	Number of livestock (000)	178	184	175	190	199	195	187
Amhara	Output (1000 tons)	463	527	616	665	721	784	629
	Output per hectare (quintals)	11.3	11.8	13.2	13.9	14.6	14.5	13.0
	Number of holders (000)	355	365	383	391	419	441	392
	Number of livestock (000)	389	396	415	433	468	526	438
Oromia	Output (1000 tons)	567	699	737	707	686	730	688
	Output per hectare (quintals)	15.2	14.2	16.6	17.0	17.5	17.1	16.0
	Number of holders (000)	369	402	402	359	397	383	385
	Number of livestock (000)	363	378	413	384	397	432	394
SNNP	Output (1000 tons)	155	177	282	237	224	251	221
	Output per hectare (quintals)	15.9	17.1	23.5	21.7	21.0	19.3	20.0
	Number of holders (000)	363	378	413	384	397	432	394
	Number of livestock (000)	91	100	102	102	116	112	104

		Growth rate in percent					
Region	**Variable**	2003/04-2004/05	2004/05-2005/06	2005/06-2006/07	2006/07-2007/08	2007/08-2008/09	Average
Tigray	Output	-0.5	24.5	25.8	4.7	6.0	12.1
	Output per hectare	-12.6	18.2	3.5	10.7	0.8	4.1
	Number of holders	10.1	2.3	3.0	19.0	1.1	7.1
	Number of livestock	3.4	-4.5	8.2	4.9	-1.9	2.0
Amhara	Output	13.8	17.0	7.9	8.5	8.7	11.2
	Output per hectare	4.8	12.0	4.8	5.1	-0.2	5.3
	Number of holders	3.0	4.7	2.3	7.1	5.3	4.5
	Number of livestock	1.8	4.7	4.4	8.1	12.4	6.3
Oromia	Output	23.1	5.6	-4.1	-3.0	6.5	5.6
	Output per hectare	-6.9	17.2	2.0	2.9	-1.9	2.7
	Number of holders	9.0	0.1	-10.8	10.6	-3.4	1.1
	Number of livestock	4.0	9.4	-7.1	3.4	8.8	3.7
SNNP	Output	14.1	59.5	-16.1	-5.3	12.0	12.8
	Output per hectare	7.7	37.4	-7.7	-3.5	-8.1	5.2
	Number of holders	4.0	9.4	-7.1	3.4	8.8	3.7
	Number of livestock	8.9	2.2	0.6	13.7	-3.9	4.3

Source: CSA Report on Area and Production for Major Crops Volume I 2003–2004 through 2008–2009. SNNP = Southern Nations, Nationalities and Peoples Region

Cultivated area weighted number of farm holders grew at average annual rates of 7.0, 4.5, 1.1 and 3.7 percent, respectively, in an average zone of Tigray, Amhara, Oromia, and SNNP regions. Moreover, the total number of farmers who owned land in each of the regions grew at average annual rates of 7.0, 4.3, 0.7, and 3.2 percent, respectively. In Ethiopia, livestock for plowing make up—almost entirely—what is called “non-land capital”. Cultivated area weighted stock of draft animals grew at average annual rates of 2.0, 6.3, 3.7 and 4.3 percent in an average zone of the respective regions. Growth in draft livestock was on average slow relative to growth in number of holders and cultivated area. Averaging across all zones in the four regions, the number of draft livestock per farm holder declined from 1.15 in 2003/04 to 1 in 2008/09, or at an average annual rate of 1.2 percent. In relation to that, the area cultivated by a pair of oxen increased from 1.9 hectares in 2003/04 to 2 hectares in 2008/09, which grew at an average annual rate of about 2 percent.

The zonal average proportion of literate farmers, application rate of modern inputs, and other variables used in the analysis are provided in Appendix Tables A.5 and A.6. Averaging across the 48 zones in the four regions, about 30 percent of farm holders were literate during the 2003/04–2008/09 period and this proportion grew at an average annual rate of 3.5 percent. About 0.3 kilograms per hectare of fertilizer was applied in an average zone and application grew at an average annual rate of 5.2 percent. Only 0.02 kilograms per hectare of improved seeds were used, while growth in use averaged 6.8 percent. Farmers applied pesticides to about 10 percent of the cultivated area in an average zone, while this proportion grew at an average annual rate of 18 percent. Similarly, in an average zone, the proportion of area cultivated using the extension package suggested by Ministry of Agriculture averaged about 14 percent and annual growth of this proportion averaged 0.7 percent. The proportion of farmers who received credit and advisory services averaged 27 and 51 percent, respectively, and these proportions grew at average annual rates of 58 and 28 percent. These large growth rates are mainly dominated by the large swings between 2003/04–2005/06 and also by the relatively small proportion of users of these services. Excluding growth rates in the first two years, the annual growth rate of credit and advisory services averaged 1.8 and 4.5 percent. In Tigray, more farmers used credit (47 percent) and advisory services (75 percent), while in SNNP relatively few used credit (12 percent) and advisory services (30 percent). The proportion of cultivated area that suffered damages due to one or more types of natural factors was similar across zones in each region—ranging from an average of 15 percent in SNNP to 21 percent in Tigray—and it averaged about 18 percent and remained about constant across the period.

3.1.2. Empirical model specification

I used the Cobb-Douglas production function and stochastic production frontier for this section. I specify the Cobb-Douglas production function as,

$$\ln output_{it} = \beta_0 + \beta_1 \ln labor_{it} + \beta_2 \ln livestock_{it} + \beta_3 \ln area_{it} + \beta_4 \ln fertilizer_{it} + \beta_5 \ln improved\ seed_{it} + \beta_6 \ln pesticides_{it} + \sum_{t=7}^{11} \beta_t\ year_t + \beta_{12}\text{Amhara} + \beta_{13}\text{Oromia} + \beta_{14} SNNPR + e_{it} \quad (6)$$

where ln *output*$_{it}$ is the natural logarithms of total output in zone i at period t, where $i \in (1, 2, 3, ..., 48)$ and $t \in (2003/4, ..., 2008/9)$. The variables associated with parameters β_1 through β_6 are factors of production in zone i at time t, which I discussed above. Those associated with β_7 through β_{11} are dummy variables for years 2004/05 through 2008/09, while those associated with β_{12} through β_{14} are region dummies dropping Tigray. e_{it} are error terms that are assumed to be white noise.

The stochastic production frontier differs from the model above in that it assumes e_{it} in (6) are composed of idiosyncratic and inefficiency components.[17] The crux of the assumption in the present context is that each administrative zone may differ in the amount of measured output it produces from the same given bundle of measured inputs. Such divergence could result from differences in efficiency. This in turn could result from differences in the managerial ability of farmers and zone- or region-specific factors not accounted for by measured inputs that affect what a given zone produces. The stochastic frontier model accounts for these deviations of measured output and provides a relative measure of the deviation of each zone from those efficient zones that produce at the frontier. Accordingly, the empirical stochastic production frontier is specified as

$$\begin{aligned}\ln output_{it} &= \beta_0 + \beta_1 \ln labor_{it} + \beta_2 \ln livestock_{it} + \beta_3 \ln area_{it} + \beta_4 \ln fertilizer_{it} + \\ &\beta_5 \ln improved\ seed_{it} + \beta_6 \ln pesticides_{it} + \sum_{t=7}^{11} \beta_t\ year_t + \beta_{12}\text{Amhara} + \\ &\beta_{13}\text{Oromia} + \beta_{14} SNNPR + V_{it} - U_{it} \qquad (7)\end{aligned}$$

where V_{it} and U_{it} are respectively the idiosyncratic and inefficiency components of the "composed error term", $e_{it,}$ of zone i at time period t.

Given the stochastic production frontier specified by equation (7), the level of technical efficiency (TE_{it}) of each zone i at period t is given by

$$\begin{aligned}TE_{it} &= \frac{\ln output_{it}}{f(X_{it}, \beta) * \exp(V_{it})} \\ TE_{it} &= \exp(-U_{it}) \qquad (8)\end{aligned}$$

where $f(X_{it}, \beta)$ is the deterministic component or the component without $V_{it} - U_{it}$ in the right-hand side of equation (7). An equation that associates the inefficiency component, U_{it}, of each zone i at time t with zone and region specific factors is simultaneously estimated with equation (7) using the empirical inefficiency equation,

$$\begin{aligned}U_{it} &= \delta_0 + \delta_1\ \text{literate}_{\text{it}} + \delta_2\ \text{extension}_{\text{it}} + \delta_3\ \text{credit}_{\text{it}} + \delta_4\ \text{advisory service}_{\text{it}} + \delta_5\ \text{road}_{\text{it}} \\ &\delta_6 \text{Damaged area}_{\text{it}}\ + \sum_{\text{t}=7}^{11} \delta_{\text{t}} \text{time}_{\text{t}}\ + \delta_{12} Amhara + \delta_{13} Oromia + \delta_{14} SNNP + W_{it} \qquad (9)\end{aligned}$$

In equation (9) the technical inefficiency, U_{it}, is assumed to be a function of zone and/or region specific variables. For parameters δ_1 through δ_6 I use as explanatory variables the proportion of literate farm holders, the proportion of area cultivated using the extension package, the proportion of farm holders using credit and advisory services, regional road density, and the proportion of cultivated area that suffered damages. Moreover, I use year and region dummies to investigate whether there were gains in efficiency across periods and regions. In equation (9) W_{it} is a random variable that is assumed to be distributed with mean zero and variance σ_w^2. I use the following notations when discussing results of this part of the analysis. Let us define: $\varepsilon_{it} = V_{it} - U_{it} = \ln output_{it} - f(X_{it}, \beta),\ \sigma^2 = \sigma_v^2 + \sigma_u^2,$ and

[17] Please refer to Aigner, Lovell, and Schmidt (1977), Meeusen and Van den Broeck (1977), Battese and Coelli (1995), Kumabhakar and Lovell (2000) for a further theoretical underpinning, and to Nisrane et al. (2011) for an empirical application on household level agricultural data from Ethiopia.

$\gamma = \sigma_u^2 / \sigma^2$. Note that σ^2 represents the total variation in output that is not explained by factors used in the analysis and γ represents the proportion that is due to differences in efficiency. As a result, $\gamma \in (0,1)$. If $\gamma \to 0$ then either $\sigma_u^2 \to 0$ or $\sigma_v^2 \to \infty$, which occurs if the symmetric disturbance term V_{it} dominates the truncated efficiency component U_{it} which in turn indicates that ordinary least squares is more appropriate than stochastic frontier analysis. As $\gamma \to 1$ either $\sigma_u^2 \to (\sigma_u^2 + \sigma_v^2)$ or $\sigma_v^2 \to 0$; that is, the variation in the inefficiency component increasingly dominates the variation in ε_{it}, indicating stochastic production frontier is more appropriate.

I estimated two variants of both the Cobb-Douglas production function and the stochastic production frontier that involve three-factor (baseline) and six-factor (modified) specifications, to match the analyses in the previous section. While I estimated both models using a relatively flexible year-region dummy structure, I report those pertaining to the Cobb-Douglas model, as the results are similar. I also estimated the six-factor specification of each model separately for each region.

3.2. Results and discussion

In the following subsection I present and discuss results of analyses obtained using the Cobb-Douglas production functions, while in subsection 3.2.2 results obtained using the stochastic production frontier model are discussed.

3.2.1. Cobb-Douglas production function

Parameter estimates of the three- and six-factor Cobb-Douglas production functions that aggregate all zones in the four regions are given in Table 3.2. The results of the two specifications are almost identical. These results have similar implications, with production functions estimated for each region (Table 3.3) and with the specification using flexible year-region dummies (Appendix Table A.7). Moreover, the implications of these results are similar to findings in other studies that use different approaches or data sets or both (see Taffesse (2009); Yu, Nin-pratt, and Funes (2011); Nisrane et al. (2011); and Nisrane (2009)).

The results indicate that growth in the size of cultivated area and labor are among the factors that make the largest contribution to changes in output. Labor is significant in all specifications.[18] Elasticity of output with respect to labor is about 0.35. Labor's contribution was important in SNNP, and slightly less so in Amhara and Oromia. Labor did not affect output in Tigray (Table 3.3). Moreover, the estimated elasticity of labor in the aggregate production function and calculations mimicking those in the growth accounting model indicate that growth in labor accounted for 1 percent of the 8.6 percent growth in output. The number of zones weighted average elasticity of labor of the separate production functions obtained by setting the elasticity of Tigray to zero is 0.35, which is the same as the one obtained using the entire panel data. The share of labor in the six-factor specification, 0.35, is about one-half of the corresponding share used in the growth accounting model, 0.68. This is mainly because the government, which owns all land, distributes land to farmers at next-to-free rental rates and these rental rates are among the components used to construct factor shares in the Social Accounting Matrix (SAM). As a result, factor shares derived from

[18] Since results of the three and six-factor specifications using three regional and five year dummies are mostly similar to those using 23 (4x6-1) region-year dummies, the descriptions apply to both. We will be specific when needed.

the SAM and used in the growth accounting section grossly underestimate actual shares of land and overestimate the share of labor.

Table 3.2—OLS estimates of Cobb-Douglas production functions, baseline and modified specifications using zone level data for 2003/04–2008/09

	Baseline		Modified	
Variable	Coefficient	Standard error	Coefficient	Standard error
Constant	0.846***	0.271	0.876***	0.332
Labor	0.360***	0.048	0.351***	0.054
Drought livestock	-0.021	0.038	-0.017	0.040
Area	0.789***	0.059	0.790***	0.079
Fertilizer			0.003	0.018
Improved seeds			0.006	0.022
Pesticides			-0.006	0.015
2004/05 dummy	0.047	0.061	0.048	0.062
2005/06 dummy	0.235***	0.061	0.234***	0.062
2006/07 dummy	0.246***	0.061	0.249***	0.062
2007/08 dummy	0.242***	0.061	0.245***	0.062
2008/09 dummy	0.253***	0.061	0.255***	0.062
Amhara dummy	-0.039	0.068	-0.040	0.071
Oromia dummy	0.130*	0.067	0.135**	0.068
SNNP dummy	0.274***	0.073	0.280***	0.083
R-squared	0.954		0.954	

Source: Analysis conducted using CSA data.
Note: coefficients with *** , **, and * are significant at 1, 5, and 10 percent significance levels. SNNP = Southern Nations, Nationalities and Peoples Region

Table 3.3—OLS estimates of regionally separate Cobb-Douglas production functions, 2003/04–2008/09

	Region			
Variable	Tigray	Amhara	Oromia	SNNP
Constant	3.434***	2.653***	3.667***	0.637
Labor	-0.124	0.323**	0.334***	0.453***
Drought livestock	0.095	0.068	-0.051	0.011
Area	0.913***	0.505***	0.537***	0.718***
Fertilizer	-0.005	-0.024	0.048	0.038
Improved seeds	0.042	0.087***	0.054*	-0.063
Pesticides	0.017	0.076***	0.028	-0.023
2004/05 dummy	-0.127*	0.034	-0.002	0.184
2005/06 dummy	0.037	0.165**	0.089	0.433***
2006/07 dummy	0.083	0.225***	0.185***	0.376***
2007/08 dummy	0.192**	0.235***	0.169**	0.326**
2008/09 dummy	0.206**	0.247***	0.202***	0.372***
Number of observations	30	60	72	126
R-squared	0.97	0.98	0.96	0.91

Source: Analysis conducted using CSA data.
Note: coefficients with ***, **, and * are significant at 1, 5, and 10 percent significance levels. SNNP = Southern Nations, Nationalities and Peoples Region

Elasticity of output with respect to cultivated area is about 0.79 across the specifications excepting the six-factor flexible dummy specification, which has a slightly larger estimate. While cultivated area is the most important input in all regions, the degree of its importance varies. Elasticity of land is lower at about 0.5 in both Amhara and Oromia while it is more important in Tigray at 0.9 and about average in SNNP. The aggregate panel data implies that 3.6 percent of the 8.6 percent average growth in output was accounted for by an increase in cultivated area. While the importance of land cannot be overemphasized in Ethiopia, in a sector that uses little modern inputs, the fact that it is the single most important factor driving growth in output makes the sustainability of output growth questionable. This is particularly so given the limited availability of land and the fast population growth in the country, especially in rural areas where most people are engaged in agriculture.

The effect of change in the number of livestock used to plow land is statistically not different from zero across all specifications and levels of aggregations. Given that draft cattle represent the major source of plowing power in Ethiopia together with the slow growth in draft cattle relative to area and labor, which implied growth in the marginal product of draft cattle, I expected a significant effect. I obtained the same result using the cattle per area variable in both aggregate and regional panels. This finding is important as many anecdotal findings mention shortage of draft cattle as an important constraint of many farmers. One plausible explanation for the results contradicting the expectation would have been that the SNNP region, in which 21 of the 48 zones are located and where hoe-culture—which uses less draft power—dominates, would have the largest proportion of draft cattle. However, as expected because of the hoe-culture, SNNP accounted for only 14 percent of the total draft cattle population in an average year. Given this fact, both the aggregate and the regional regressions should have indicated a significant effect of cattle.

Parameter estimates associated with fertilizer, improved seeds, and pesticides used in the six-factor specification indicate that these factors did not have a significant effect on output. Regional production functions provide similar implications about fertilizer, while improved seeds contributed significantly in Amhara and Oromia and pesticides made a positive contribution in Amhara. However, where significant, the elasticities associated with these inputs are small, leading to non-significant estimates in the aggregate production function. Application of improved seeds accounted for only 0.6 and 0.7 percent, respectively of growth in output in Amhara and Oromia. Pesticides accounted for another 1.6 percent of Amhara's growth in output. The relatively large effect of pesticides is due to the 21 percent average annual growth in pesticide application in Amhara. In addition to the importance of land and labor discussed above, the low importance of modern inputs implied by these results is consistent with results obtained elsewhere.

Estimates of time dummies for specifications that differ in time-region dummy structure compare the TFP level of each period and region with the Tigray region in 2003/04.[19] Those in the regionally separate production functions compare each region's performance during the 2004/05–2008/09 period with its own performance in 2003/04. The general implications of these three sets of estimates are similar. Estimated coefficients of regional dummy variables imply that while Amhara and Tigray regions were not significantly different from each other, Oromia and SNNP performed better. The specifications differ slightly in magnitudes and in the implications of the results. Particularly, the specification that uses a flexible year-region dummy structure implies that zones in Amhara were essentially indistinguishable from Tigray zones in 2003/04 for the entire period. Tigray performed relatively better in 2007/08 and 2008/09, and SNNP performed better not only during 2004/05–2008/09 but also in 2003/04.

[19] Note that in the growth accounting model we calculate TFP levels from annual changes in TFP while we do the reverse in both the Cobb-Douglas production function and the stochastic production frontier analyses.

Results of the three- and six-factor specifications, which are close to each other, indicate that total factor productivity was not different in 2004/05 relative to 2003/04, while it was larger from 2005/06 onwards. The level of TFP in 2005/06 was about 26 percent larger than the level in 2003/04. It was about 28, 28, and 29 percent larger in the respective years of 2006/07, 2007/08, and 2008/09.[20] Since estimated coefficients of the 2005/06–2008/09 dummies are not significantly different from each other, I averaged the level of TFP across the years in which the estimates were significant. This indicated that relative to 2003/04 the TFP level was 28 percent larger in an average year in both three- and six-factor specifications. This is similar to the finding from the baseline growth accounting model in which the level of TFP in 2009/10 was 24 percent larger than the level in 2004/05. However, there are two differences between the findings of the two approaches. While TFP gains were well distributed across periods in the growth accounting model, the results in Table 3.2 imply that almost all TFP gains were made between 2003/04 and 2005/06. Moreover, the average annual change in TFP of 5.6 percent implied by the Cobb-Douglas model is significantly larger than the 4.5 and 4.0 percent growth rates obtained from the three- and five-factor growth accounting specifications.

Results of the regionally separate production functions have similar implications with some exceptions: relative to 2003/04, Tigray's TFP level was lower in 2004/05 and was no different in 2005/06 and 2006/07 and Oromia's TFP levels were similar during 2003/04 and 2005/06. As expected, gains in TFP varied across regions. Averaged across the period, Tigray had the lowest TFP level—only 10 percent larger than the level in 2003/04—and Amhara and Oromia had slightly lower TFP levels than the average at 24 and 20 percent, respectively. The average TFP level in SNNP, 46 percent, was about twice as large as the second largest regional average. Averaging TFP levels obtained from regional production functions across periods, the annual levels were similar to those in the aggregate production function, with the exception of the negative value in 2004/05. Ignoring this negative value, number of zones weighted average levels of TFP were similar in each year and the average TFP level was 0.3, which is close to the 0.28 obtained from the aggregate panel data.

In summary, estimated elasticities of factors employed in the six-factor production function and calculations similar to those used in the growth accounting exercise imply that about 1.0 and 3.6 percent of the 8.6 percent growth in output was obtained from increased employment of labor and cultivation of land, respectively. According to the results, at the end of the 2003/04–2008/09 period, TFP level was about 28 percent larger than the level in 2003/04, which implied an average annual TFP growth rate of 5.6 percent. Together, growth in factors applied in production and TFP changes imply an average annual growth in output of about 10 percent, significantly larger than the 8.6 percent average growth in total output. Similarly, the regional production functions imply that out of the 13.6 percent average annual growth in Tigray, 7.9 percent was accounted for by growth in area and 1.8 percent by growth in TFP, which totals 9.7 percent. Out of the 10.5 average annual growth in output in Amhara, 2.4 percent resulted from expansion in area, 1.4 percent from growth in labor, 4.4 percent from growth in TFP and the remaining 2.2 percent from increased application of improved seeds and pesticides. Oromia experienced an average annual growth in output of 6 percent. Growth in area, labor, improved seeds, and an increase in TFP accounted for 2.0, 0.2, 0.7, and 3.7 percent, respectively of this growth. Finally, increases in cultivated area, labor, and

[20] This calculation involves first converting the estimated coefficients of time dummies into elasticities using the formula $E_{YX_{Dl}} = Exp(\beta_{Dl}) - 1$, where X_{Dl} is the dummy variable, β_{Dl} is its estimated coefficient, and Y is log of output (Halvorson and Palmquist 1980).

growth in TFP that respectively contributed 4.5, 1.5, and 7.5 percent to growth in output in SNNP imply a total growth in output of 13.5 percent. The implied contribution of these factors is about 18 percent larger than the average growth in output that occurred in both SNNP and nationwide.

The factors considered in the analyses account for all the growth in output in the aggregate panel and in all regions except Tigray. However, further explanations are needed about the sources of the implied growth in TFP, particularly the large growth between 2003/04 and 2005/06. Whether it was the more-than-a-decade-long government effort to expand extension and farmer training finally taking effect or other factors producing these changes—or maybe the government efforts plus the other factors—remains to be investigated, possibly by using more detailed data. I tried to partly answer this question by considering one more source of growth in output and gains in efficiency using the stochastic production frontier analyses. As we shall see in the next section, there were gains in efficiency between 2003/04 and 2005/06 that explain 84 percent of the TFP increase during the same period. Government efforts on behalf of farmers—advisory services provided by agricultural agents and the application of the extension package recommended by the Ministry of Agriculture—were important in explaining efficiency gains. Therefore, the findings in this and the next sections entail that the growth in TFP implied by estimated coefficients of the Cobb-Douglas production functions also carry the effect of efficiency gains achieved during the period. This is in line with some authors who define TFP as a sum of the effects of purely technical changes and gains in efficiency. Next, I present results obtained by applying the stochastic frontier analyses (SFA) on the same data set. I will also study factors affecting efficiency and its patterns.

3.2.2. Stochastic production frontier analyses

To take advantage of the features unique to SFA, I present analyses conducted using this model in two subsections. In the first, I briefly discuss the results of estimated production frontiers. In the second, I discuss factors affecting efficiency and patterns in efficiency for the period analyzed. Recall that I defined $\sigma^2 = \sigma_v^2 + \sigma_u^2$ as the total variation in output that is not explained by factors used in analysis, and $\gamma = \sigma_u^2 / \sigma^2$ as the proportion explained by differences in efficiency. The estimated results of these variables are listed in the rows named "sigma squared" and "gamma" in Table 3.4 below. The results indicate that differences in efficiency explain about 87 percent of this total variation. Moreover, the null hypothesis that there exist only idiosyncratic error terms is tested. This hypothesis is rejected at all levels of significance, underscoring the existence of significant differences in efficiency.

a. Determinants of output growth and patterns in TFP

Parameter estimates of stochastic production frontiers (SPF) using the three- and six-factor specifications provided in Table 3.4 are similar. These estimates differ slightly from the corresponding Cobb-Douglas estimates. In particular, the estimated elasticity of output with respect to land area of the three- and six-factor specifications are 5.0 and 2.7 percent larger, respectively, and those pertaining to labor are 16 and 14 percent smaller, respectively, than the corresponding Cobb-Douglas production function (CDPF) estimates. Moreover, estimated time dummies of the SPF are smaller, which, as I indicated previously, was expected given that SPF distinguishes between the effects of TFP and efficiency. With the exception of these differences, all implications of the previous results hold. Area of cultivated land is the most important factor affecting growth in output, followed by labor. Draft livestock continue to have no effect on output, and neither do fertilizers, pesticides, or improved seeds. I made one change when estimating Tigray region's SPF. Given that the number of total observations of this region is too few (five zones observed in six years), I estimated different versions for this region. I used goodness-of-fit criteria to choose the one for which we would use the dummy variable for the 2006/07–2008/09 period over the other two versions. The regionally separate production frontiers are mostly similar to CDPF estimates except that now fertilizer is significant in Oromia and SNNP while the coefficient on pesticides is negative in SNNP.

Applying growth accounting-type decomposition to the results of the six-factor specification implies that growth in labor and expansion of area accounted for about 0.6 and 3.7 percent, respectively, of the average growth in output of 8.6 percent. Regionally, increases in cultivated area accounted for 7.3, 2.6, 1.3, and 3.0 percent of the growth in output in Tigray, Amhara, Oromia, and SNNP, respectively. Growth in labor accounted for about 2.0 percent of output growth in Amhara, 0.3 percent in Oromia, and 1.4 percent in SNNP. All of the results listed so far are strikingly similar to those obtained from the CDPF, with the exception that increases in area contributed more in SNNP (4.5 percent) when using the CDPF. As with the Cobb-Douglas production function, both improved seeds and pesticides affect output in Amhara, although the effects are smaller, accounting for only 0.4 and 0.9 percent of growth in output, respectively. Unlike the results obtained from the CDPF, fertilizer contributed positively in the SPF in Oromia and SNNP although its contribution to growth in output—0.4 percent in both regions—is small. Again, in contrast to what happened with the CDPF, pesticides negatively affect output in SNNP with an elasticity of -0.03 percent. While the last result is counterintuitive, it may have resulted from a failure to apply sufficient insecticide on fields that suffered from crop diseases. This supposition is also corroborated by the large estimated coefficient of the proportion of damaged crop area variable that resulted from the inefficiency equation of SNNP.

Regional and period dummy variables used in the six-factor SPF have similar implications as those in the CDPF, although they differ in magnitudes. As with the CDPF, TFP levels were larger during the 2005/06–2008/09 period. These results imply that relative to 2003/04 TFP levels were only 10, 14, 19, and 19 percent larger in the years 2005/06 through 2008/09. Using the TFP level in 2008/09 to calculate changes in TFP provides an average annual change in TFP of 3.9 percent, close to the 4 percent implied by the five-factor growth accounting model. To strengthen the last point, let us go ahead for a moment. Nationwide average levels of efficiency were 0.70, 0.73, 0.77, 0.75, 0.72, and 0.72 in the consecutive years of 2003/04 through 2008/09 (Table 3.6). Then, between 2003/04 and 2005/06, when TFP levels changed significantly, efficiency grew by 10 percent. Similarly, considering the remaining years of 2006/07, 2007/08, and 2008/09, when TFP levels were different relative to 2003/04 efficiency levels were respectively 7, 3, and 3 percent larger than the level in 2003/04. Adding the growth in efficiency in each year to TFP levels of the four years from 2005/06 through 2008/09, I obtain total TFP levels of 20, 21, 22, and 21 percent. While these TFP levels are slightly lower than the average obtained from the CDPF, they are close. Moreover, the TFP level in 2008/09 obtained in this manner—21 percent more than the level in 2003/04—is the same as the one obtained from the five-factor growth accounting model.

Following the change I made on Tigray region's SPF, the estimated year dummy implies that the TFP level for 2006/07–2008/09 was 27 percent larger than the level during the 2003/04–2005/06 period. Accordingly, annual growth in TFP averaged 5.5 percent. Amhara and

Oromia had similar patterns of TFP in both models. TFP levels in the respective regions were on average 35 and 41 percent larger during the 2006/07–2008/09 period relative to the 2003/04 level. Using the TFP level in 2008/09, the annual change in TFP averaged 7.0 and 6.4 percent in the respective regions, larger than the 4.4 and 3.7 percent obtained from the CDPF. SNNP's level of TFP in 2005/06 was 44 percent larger than the level in 2003/04. This implies an average annual growth in TFP of 4.5 percent during the 2003/04–2008/09 period.

To summarize, the six-factor stochastic production frontier implies that growth in labor and cultivated area accounts for 0.6 and 3.7 of the 8.6 percent growth in output, while changes in TFP account for 3.9 percent of the growth. These add up to 8.2 percent. As I pointed out earlier, the SPF also accounts for the growth in output which results from efficiency gains. The growth in efficiency that occurred during this period accounts for the remaining growth in output. Moreover, the results of the regional production frontiers imply that growth in factor inputs and changes in TFP add up to about 13.0 percent in Tigray and Amhara, 9.3 percent in Oromia, and 9.0 percent in SNNP. These growth rates account for all of the growth in regional output in Amhara and Oromia and fall slightly short to account for growth in output in Tigray and fall significantly short in SNNP. I now turn to factors that account for changes in efficiency and then describe trends in efficiency.

b. Determinants and trends in efficiency

Determinants of efficiency

Parameter estimates of the inefficiency equations accompanying the production frontiers are provided in Table 3.5. I limit the discussion to those accompanying the six-factor SPF, whose results are almost the same as the three-factor SPF. The results imply that inefficiency declines with an increased proportion of literate farmers, with an estimated coefficient of -1.2.[21] While literacy significantly affects efficiency in Oromia and SNNP it does not affect efficiency in Tigray and Amhara. For that matter, none of the factors used in the equation for Tigray explain inefficiency.

With the largest estimated coefficient of -2.5, inefficiency declined with the proportion of area cultivated using the Ministry of Agriculture's recommended extension package. This result held also in Amhara and Oromia. Moreover, efficiency improved with more users of agricultural advisory services, although this effect was only significant in SNNP region. Defying our expectations, inefficiency grew with the proportion of credit recipients and the effect was rather large, with an estimated coefficient of 1.5 in Oromia and about 0.7 in Amhara. The finding obtained using the aggregate data for Amhara and Oromia may imply the effect of some unobservable factors associated with acquiring credit, such as processing costs. Or, it may mean that those in need of cash received insufficient credit while those who had sufficient funds did not use the service. In relation to the last point, the estimate may have resulted because credit was targeted toward poorly performing zones.

As expected, inefficiency grew with the proportion of cultivated area that suffered from crop damages of one or more type, which held true in Amhara and SNNP. Unlike the finding from the growth accounting model, in which infrastructure made one of the largest contributions to growth in output, the road density in a region did not affect growth in output. Total road network produced a similar result. Moreover, the effect was mixed regionally. Efficiency improved along with infrastructure in Oromia and declined in SNNP. The effect in SNNP was

[21] Recall that, since the dependent variable of these equations is the level of inefficiency, factors that have a positive effect on efficiency have negative estimates.

unexpected, given that the region had the second-longest road network, next to Oromia, and the fastest growth rate. Road network per cultivated area was by far the largest in SNNP. The only factor that may have caused this result is the direction of change in road network per cultivated area in SNNP: during the 2005/06–2008/09 period, it declined at an average annual rate of 4 percent.

Estimated coefficients of time and region dummies imply that none of the years of the 2004/05–2008/09 period was accompanied by significant gains in efficiency relative to 2003/04. Moreover, while Tigray, Amhara, and Oromia were essentially the same in terms of efficiency, SNNP performed badly, as can be seen from the significant positive SNNP dummy. Although estimated coefficients of all year dummies are not significantly different from zero, it does not mean that there were no gains in efficiency during the entire period. It is just that those gains were not large enough for year dummies to be significant. This point will become clear when studying patterns of efficiency shortly. Time dummies of the regional inefficiency equations imply that in Tigray, the 2006/07–2008/09 and 2003/04–2005/06 periods were no different from each other. Relative to 2003/04, efficiency increased in Amhara in 2005/06, declined in 2004/05 in Oromia and in 2005/06 in SNNP regions. Viewing these coefficient estimates together with average regional levels of efficiency in Table 3.6 reveals consistent results in Amhara and Oromia while efficiency levels in SNNP were essentially the same in 2003/04 and 2005/06.

Trends in efficiency

The six-factor stochastic production frontier implies an overall national average level of efficiency of 0.73. The separate production frontiers imply that the nationwide level of efficiency averaged 0.84 (Table 3.6). The latter provides larger average efficiency because it involves comparisons in efficiency levels across zones in a relatively homogenous group in a given region. Although this principle applies nationally, it may not apply for each region. In regions where an average zone performed very poorly when using aggregated data (thus using data of all 48 zones in all four regions), I found that performance improved when using only zones of a given region as efficiency levels of zones in that region are compared with each other, for example in SNNP. While the reverse case is counterintuitive, it stems from the proportion of inefficiency that is explained when the zones are aggregated nationwide relative to when they are aggregated across regional boundaries.[22]

Nationwide, the average level of efficiency grew annually at a rate of 0.5 when all zones in the four regions are aggregated, and 2.0 percent in the regionally separate panels. Tigray zones performed better than others, though levels of efficiency slightly declined in Tigray. In contrast, zones in SNNP experienced the fastest growth rate in efficiency, although their average level of efficiency was inferior in both aggregate and regional panels. Making cross regional comparisons of efficiency levels obtained from the aggregate and regional panels does not make much sense, as the last footnote explained. However, the growth rates provide equally useful insights. Accordingly, the slight decline in efficiency observed in Tigray in the aggregate panel also holds in the regional stochastic production frontier,

[22] To make this point clear, consider Tigray, which has an average efficiency of 0.94 when the data is aggregated across all zones in the four regions and 0.84 when only the zones in Tigray are compared with each other. In the aggregate panel performance of zones in Tigray was compared with the best performing zone in all four regions, which is the Borena zone in Oromia. Borena's level of efficiency was 0.97 in 2005/06. That is, 3 percent of Borena's output was attributed to stochastic factors when this zone is compared with others. Considering only the zones in Tigray, the best performing zone of North western Tigray had efficiency level of 1, making performance by each zone in Tigray relatively low when compared with Western Tigray.

Table 3.4—Parameter estimates of three-factor and six-factor stochastic production frontiers using all regions in one and regionally disaggregated panel data, 2003/04–2008/09

	All regions				Separate regional regressions							
	Baseline		Modified		Tigray		Amhara		Oromia		SNNP	
Variable	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Constant	1.702***	7.054	1.820***	6.814	3.295***	3.261	2.164***	5.008	3.052***	3.372	2.549***	7.146
Labor	0.204***	5.231	0.207***	4.315	-0.024	-0.060	0.448***	3.416	0.472***	5.621	0.433***	5.417
Draft livestock	0.008	0.229	0.014	0.377	0.036	0.054	-0.019	-0.286	0.008	0.123	0.091**	2.064
Area	0.854***	21.277	0.817***	15.748	0.849**	2.201	0.542***	4.990	0.354***	2.968	0.492***	4.550
Fertilizer			0.009	0.585	-0.008	-0.087	-0.008	-0.389	0.092***	2.684	0.039**	2.148
Improved seeds			0.019	1.438	0.054	1.186	0.059***	3.151	0.070**	2.091	0.001	0.053
Pesticides			-0.001	-0.075	0.072	1.163	0.041**	2.168	0.013	0.533	-0.035*	-1.914
2004/05 dummy	-0.032	-0.722	-0.026	-0.522			0.042	0.650	0.101	1.332	-0.048	-0.345
2005/06 dummy	0.097**	2.004	0.094*	1.856			0.106	1.631	0.076	0.816	0.369***	2.534
2006/07 dummy	0.131***	3.012	0.130***	2.721			0.183***	2.699	0.358***	3.611	0.221	1.609
2007/08 dummy	0.182***	3.718	0.177***	3.591			0.439***	4.782	0.391***	3.808	0.025	0.205
2008/09 dummy	0.179***	3.815	0.176***	3.403			0.274***	4.365	0.276***	3.296	0.002	0.019
2006/07-2008/09 dummy					0.243*	1.729						
Amhara dummy	0.058	1.215	0.044	0.785								
Oromia dummy	0.215***	5.001	0.204***	3.671								
SNNP dummy	1.104***	9.494	1.022***	8.845								
Sigma squared	0.126***	7.7	0.131***	9.8	0.014	1.573	0.01***	4.9	0.02***	4.5	0.26***	4.6
Gamma	0.870***	30.9	0.879***	33.5	0.99***	145	0.34***	2.4	0.22***	3.6	0.84***	19.0
Log-likelihood	36		38		30		65		48		16	

Source: Analysis conducted using CSA data.
Note: Coefficient estimates with ***, **, and * are significant at 1, 5, and 10 percent, respectively. SNNP = Southern Nations, Nationalities and Peoples Region

Table 3.5—Inefficiency equation parameter estimates of stochastic production frontiers using all regions in one and regionally disaggregated panel data, 2003/04–2008/09

	All regions				**Separate regional regressions**							
	Baseline		Modified		Tigray		Amhara		Oromia		SNNP	
Variable	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Constant	-1.061**	-2.293	-1.108*	-1.845	-0.046	-0.102	-0.342	-1.608	-0.179	-0.931	0.863*	1.920
Literate	-1.228***	-3.388	-1.179***	-3.044	0.137	0.145	0.258	0.423	-0.659*	-1.816	-4.308***	-3.104
Extension covered area	-2.354***	-3.938	-2.527**	-2.467	0.021	0.036	-0.403*	-1.887	-0.790*	-1.774	-4.964	-0.845
Credit users	0.667**	2.032	0.827**	2.331	-0.135	-0.379	0.671*	1.723	1.498***	3.705	0.524	1.061
Advisory service users	-0.647**	-2.247	-0.698**	-2.368	0.135	0.285	0.132	0.453	0.244	0.830	-4.889***	-3.327
Road per regional area	-0.018	-0.273	-0.027	-0.411	0.003	0.003	-0.474	-1.182	-0.263**	-2.126	0.349**	2.516
Damaged area	2.160***	4.266	2.344***	4.187	0.332	0.482	1.845***	3.402	0.465	0.918	4.027***	3.823
2004/05 dummy	-0.031	-0.263	-0.015	-0.117			-0.088	-0.866	0.355**	2.318	-0.339	-0.915
2005/06 dummy	-0.038	-0.270	-0.023	-0.164			-0.288**	-2.144	-0.103	-0.442	1.312**	2.561
2006/07 dummy	-0.041	-0.286	-0.031	-0.204			-0.139	-0.962	0.118	0.786	0.680	1.516
2007/08 dummy	0.135	0.879	0.153	1.003			0.034	0.227	0.196	1.295	0.238	0.498
2008/09 dummy	0.230	1.484	0.239	1.382			-0.169	-1.189	0.069	0.423	-0.130	-0.175
2006/07-2008/09 dummy					0.140	0.455						
Amhara dummy	0.595	1.499	0.472	0.766								
Oromia dummy	0.137	0.379	0.021	0.043								
SNNP dummy	2.196***	5.077	2.115***	3.396								
Mean efficiency	0.72		0.73		0.84		0.87		0.89		0.79	

Source: Analysis conducted using CSA data.
Note: Coefficient estimates with ***, **, and * are significant at 1, 5, and 10 percent, respectively. SNNP = Southern Nations, Nationalities and Peoples Region

as similar trends also hold for other regions, with some differences in magnitudes. The SNNP region, which had an average efficiency of 0.5 in the aggregate panel, averaged about 0.8 when considered separately, and growth rate in efficiency jumped from 1.6 percent to 6.9, dominating the relatively fast nationwide average growth in efficiency.

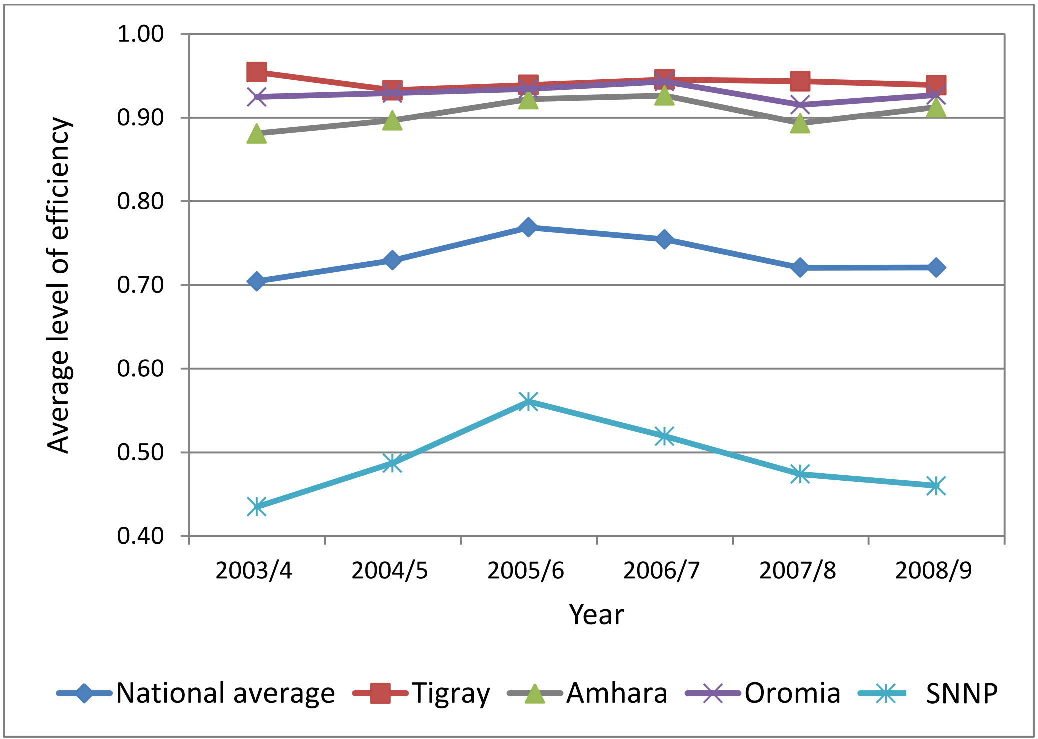
Table 3.6—Average efficiency estimates of equations using all regions in one and regionally disaggregated panel data, 2003/04–2008/09

		Average level of efficiency						
Equation	**Region**	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	Average
Modified model, aggregated panel	National average	0.70	0.73	0.77	0.75	0.72	0.72	0.73
	Tigray	0.95	0.93	0.94	0.95	0.94	0.94	0.94
	Amhara	0.88	0.90	0.92	0.93	0.89	0.91	0.91
	Oromia	0.92	0.93	0.93	0.94	0.92	0.93	0.93
	SNNP	0.44	0.49	0.56	0.52	0.47	0.46	0.49
Modified model, regionally separated regressions	National average	0.82	0.85	0.84	0.81	0.81	0.90	0.84
	Tigray	0.90	0.84	0.94	0.74	0.82	0.83	0.84
	Amhara	0.89	0.89	0.95	0.91	0.71	0.87	0.87
	Oromia	0.96	0.90	0.96	0.83	0.80	0.91	0.89
	SNNP	0.68	0.81	0.69	0.77	0.86	0.92	0.79
		Growth rate in efficiency (percent)						
Equation	**Region**		2003/04-2004/05	2004/05-2005/06	2005/06-2006/07	2006/07 - 2007/08	2007/08 - 2008/09	Average
Modified model, aggregated panel	National average		3.6	5.4	-1.9	-4.5	0.0	0.5
	Tigray		-2.3	0.7	0.7	-0.2	-0.5	-0.3
	Amhara		1.8	2.8	0.5	-3.6	2.1	0.7
	Oromia		0.5	0.5	0.9	-2.9	1.3	0.1
	SNNP		12.0	15.1	-7.4	-8.7	-3.0	1.6
Modified model, regionally separated regressions	National average		4.0	-1.5	-2.8	-0.6	10.7	2.0
	Tigray		-7.0	11.2	-20.8	10.3	1.9	-0.9
	Amhara		-0.8	6.8	-3.7	-22.0	21.6	0.4
	Oromia		-6.7	6.9	-13.2	-4.2	14.1	-0.6
	SNNP		19.1	-14.4	11.8	11.3	6.6	6.9

Source: Analysis conducted using CSA data. SNNP = Southern Nations, Nationalities and Peoples Region

The estimated levels of efficiency imply an average level of inefficiency of 0.27. That output can be increased by about 37 percent from its current level without increasing the application of inputs. However, the aggregate panel data imply that improvements in efficiency contributed only 0.5 percent to growth in output in the 2003/04–2008/09 period. Moreover, the results imply efficiency grew annually at 4.9 percent between 2003/04 and 2005/06 while it declined annually at 2.2 percent in the remaining period. The average annual growth in efficiency during the 2003/04–2005/06 period is equal to 84 percent of the average annual change in TFP obtained from the Cobb-Douglas production function, which mainly occurred between 2003/04 and 2005/06. Recall that increased application of inputs and growth in TFP accounted for 8.2 percent of the 8.6 growth in output. Adding to this the average annual growth in efficiency of 0.5 percent provides 8.7 percent, which means all growth in output is accounted for by these factors. The regional production frontiers also imply that output growth in the respective region is explained by a combination of these factors. The only exception is Tigray, in which only 88 percent of the growth in output is accounted for by these factors.

Figure 3.1—Average regional and nationwide level of efficiency of six-factor specification, 2003/04–2008/09



Source: Stochastic frontier analysis using CSA data. SNNPR = Southern Nations, Nationalities and Peoples Region

The levels of efficiency obtained in this section are significantly different from the nationwide average level of efficiency of 0.5 that Nisrane et al. (2011) obtained using Ethiopian Rural Household Survey data for the 2004–2009 period. However, these results are similar to the findings in Yu, Nin-Pratt, and Funes (2011) that found average annual growth in efficiency of 0.7, 0.4, and 0.3 percent for maize, teff, and wheat producers, respectively, for the three-year period between 2003/04 and 2006/07. On average, efficiency in the six-factor model was 37 percent more than the average efficiency of about 1,400 households that Nisrane et al. (2011) obtained. However, part of this divergence is explained by the fact that the efficient farmer, used as a reference in the latter study, may actually be far more efficient or may be using other inputs than those included in the study. Moreover, the performance of households is averaged out when using zone level data, in contrast to what happens when using household level data, as Nisrane et al. admitted in their study (2011). This aside, the level of efficiency is also close to that which Battese and Coelli obtained (1995).

3.3. Summary and key findings

For this section I estimated Cobb-Douglas production functions (CDPF) and stochastic production frontiers (SPF) using administrative zone level CSA data covering the 2003/04–2008/09 period and specifications that match the analysis in the previous section. Sources of output growth implied by the relatively inclusive six-factor specification of each model are summarized in Table 3.7 below. Three observations common to the panel data that aggregates all zones in the four regions and to the zones in each region can be made. First, among factors of production employed, growth in cultivated area made the largest contribution followed by labor. Together, cultivated area and labor explain 53 percent of the growth in output in the CDPF and 50 percent in the SPF model. Moreover, zone number weighted regional contributions of cultivated area and labor were 56 and 48 percent of the nationwide growth in output in the respective models.

Table 3.7—Contribution to growth in output of increase in application of factor inputs, TFP, and efficiency, 2003/04–2008/09

	Cobb-Douglas production function					Stochastic production frontier				
Factor	National	Tigray	Amhara	Oromia	SNNP	National	Tigray	Amhara	Oromia	SNNP
Cultivated area	3.6	7.9	2.4	2.0	4.5	3.7	7.3	2.6	1.3	3.1
Labor	1.0	_	1.4	0.2	1.5	0.6	_	1.9	0.3	1.4
Fertilizer	_	_			_	_	_	_	0.4	0.4
Improved seeds	_	_	0.6	0.7	_	_	_	0.4	0.9	_
Pesticides	_	_	1.6		_	_	_	0.9	_	-0.3
TFP	5.6	1.8	4.4	3.7	7.5	3.9	5.5	7.0	6.4	4.5
Efficiency	NA	NA	NA	NA	NA	0.5	-0.9	0.4	-0.6	6.9
Total contribution	10.1	9.6	10.4	6.7	13.5	8.7	11.9	13.1	8.7	15.9
Output growth accounted for (%)	118	71	99	111	119	101	88	125	145	140

Source: Analyses using CSA data.
Note: Since the Cobb-Douglas production function does not measure efficiency levels, the NA stands for “not applicable.” Moreover, cells with dashes indicate non-significance of the respective variables. SNNP = Southern Nations, Nationalities and Peoples Region

The second observation is that when both models are applied to the aggregate panel data, they imply that application of modern inputs made no contribution to growth in output and the contribution of modern inputs is lower than that of both area and labor. However, modern inputs made positive contributions in some of the regions. Considering only the regions in which the three modern inputs affected output provides number of zones weighted average contribution of 16 and 8 percent in the respective models of CDPF and SPF. The exceptions to the two observations are results of the CDPF for Amhara and of the SPF for Oromia. In both cases, modern inputs jointly contribute more than labor. Thirdly, using the definition of TFP as “the sum of technical change, (represented by year dummies), and changes in efficiency,” growth in TFP made the largest contribution— 51 percent—in the SPF model. Added to this, the fact that growth in TFP represented about 65 percent of growth in nationwide output implies that growth in TFP made the largest contribution to growth in output. Moreover, without even adding the effect of efficiency, TFP’s contribution was the largest in all the regions except Tigray.[23]

Additional observations from the stochastic production frontier analysis include findings that efficiency improved with literacy, with application of the extension package, and with the number of farmers who receive advisory services. Efficiency declines with the proportion of area that sustains crop damages. Efficiency also declines with increases in the number of credit recipients, perhaps due to the costs associated with processing credit, to insufficient funds, or because credit is made available to households that are inefficient to begin with.

[23] Note that total growth in output implied by growth in factor inputs, TFP, and efficiency are larger than nationwide average growth in output and are equal or larger in all regions except in Tigray. While this can be attributed to statistical and data error we acknowledge that some of the differences are rather large.

4. Conclusion

This work is part of an effort to quantify the remarkable growth in agricultural output during the 2004/05–2009/10 period. The study examined whether the growth in output resulted from intensive use of inputs, increases in total factor productivity (TFP) that resulted from changes in production technology, or from improvements in efficiency. In addition to descriptive analyses of sector and zone level data that provided important insights, I used growth accounting, Cobb-Douglas production function (CDPF), and stochastic production frontier (SPF) models. Despite the methodological difference between these approaches and the difference in the levels of aggregation of the data, there are remarkable similarities in the results.

The data indicate that during the 2004/05–2008/09 period, nationwide agricultural output and cultivated area grew at average annual rates of 9.3 and 4.7 percent, respectively. Yields of grains—grains are cultivated on 95 percent of the total cultivated area—grew at an average annual growth rate of 5.9 percent. Moreover, the ratio of annual growth in area to annual growth in output averaged 0.51, implying that about one-half of the increase in total agricultural output was attained by bringing more land into cultivation. This implied that the remaining increase in the output resulted from increases in yield. Thus, it remains to be seen whether this increase in yield resulted from intensive use of other inputs (such as labor, fertilizer, improved seeds, and pesticides), if it resulted from improved technology that changed the production structure, or from reduced inefficiency that increased yields, thereby bringing farmers closer to the production frontier. The results indicate that a combination of these factors resulted in the increase in yields.

The five-factor growth accounting model that includes the contributions made by intermediate manufacturing and services inputs, in addition to the three primary inputs, implied an average annual growth in TFP of 4 percent during the 2004/05–2009/2010 period. I expected low levels of measured changes in TFP as more factors that make a positive contribution were included in the analysis, as in the case of the modified specification. However, the average annual TFP growth of 2.7 percent obtained from one of the scenarios of the modified growth accounting model—which implied an average annual contribution of 3 percent to output growth by infrastructure improvement—seems an overstatement of its effect. This is supported also by results of the stochastic production frontier, which implied that infrastructure had no effect in improving production efficiency.

In the five-factor growth accounting model, growth in application of factor inputs accounted for the remaining growth in output. On average, increases in employment of labor accounted for 2.7 percent of the 8.4 percent growth in real value of output. Increases in cultivated area, capital, intermediate manufacturing, and services inputs respectively accounted for 0.5, 0.5, 0.3, and 0.2 percent of the remaining growth in output. The contribution of labor and of land seem to be reversed from what was obtained descriptively and in the two econometric analyses as the low rates that the government charges for land rental are used in calculating factor shares of inputs, grossly underestimating the actual contribution of land.

Results from different specifications and aggregations using the Cobb-Douglas production function and stochastic production frontiers reveal that much of the increase in agricultural output resulted from increased use of traditional inputs. These were mainly cultivated area and growth in TFP. On average, modern inputs contributed little. Regionally disaggregated results imply that improved seeds made contributions in one-half of the cases, while both fertilizer and pesticides made positive contributions in one-quarter of the analysis. The results also indicate that there was significant growth in TFP in the 2005/06–2008/09 period relative to the level in 2003/04. The contribution of growth in TFP was larger than the combined contribution of land and labor in the Cobb-Douglas production functions, while it was slightly smaller in the stochastic production frontier. Results from the SPF imply that the difference between growth in output and the sum of total contributions by factor inputs and TFP is about equal to growth in efficiency, which on average made the lowest contribution to growth in output. An average zone produced about three-quarters of the output produced in the most efficient zone, using a given bundle of inputs. In general, efficiency improved with the proportion of farmers who are literate and who received advisory services. Moreover, efficiency improved with an increased proportion of cultivated area, use of the extension package and with a decreased proportion of area that sustained crop damages.

The fact that efficiency grew annually at 4.9 percent between 2003/04 and 2005/06 and that it represented about 84 percent of the average annual change in TFP, (which mainly occurred between 2003/04 and 2005/06), has an important policy implication. This result, together with the findings that efficiency improved with literacy, with application of the extension package, and with advisory services, imply that the efforts made by the government to educate farmers and expand modern production practices may have started paying off. However, the findings that efficiency declined in the remaining period and that TFP stagnated after 2005/06 require further explanation and analysis that use detailed and longer data.

Appendix

Table A.1—Magnitude of variables used in growth accounting analyses

Variable	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10[a]	Data source
Value of agriculture and related activities at constant prices (in million birr)	39,714	44,049	48,211	51,823	55,116	59,332	MoFED
Total employment in agriculture (in 000)	26,970	27,528	28,774	29,948	31,052	32,194	WDI
Number of private holders (in 000)	10,992	11,560	11,924	13,255	12,897	12,876	CSA
Area under temporary and permanent crops (000 hectares)	10,888	11,293	11,788	12,382	12,494	12,954	CSA
Agriculture value added per worker (constant 2000 US$)	158	174	188	199	208	223	WDI
Number of draft livestock (in 000)	9,699	10,368	10,707	11,540	12,194	12,849	CSA
Gross fixed capital formation at constant prices (million birr)	18,874	19,159	22,675	26,852	26,713	29,234	WDI
Total investment in agriculture (million birr)	959	291	644	322	296	291	EIA
Rural roads (in kilometers)	17,956	22,349	20,164	23,930	25,640	28,237	CSA
Electric production (in GWH)	2,587	2,890	3,332	3,532	3,728	3,981	EEPCO

Growth rates in percentage

Variable	2004/05-2005/06	2005/06-2006/07	2006/07-2007/08	2007/08-2008/09	2008/09-2009/10[a]	Average Growth rate
Value of agriculture and related activities at constant prices	10.9	9.4	7.5	6.4	7.7	8.4
Total employment in agriculture	2.1	4.5	4.1	3.7	3.7	3.6
Number of private holders	5.2	3.2	11.2	-2.7	-0.2	3.3
Area under temporary and permanent crops	3.7	4.4	5	0.9	3.7	3.5
Agriculture value added per worker	10.1	8	5.9	4.5	7.1	7.1
Number of draft livestock	6.9	3.3	7.8	5.7	5.4	5.8
Gross fixed capital formation at constant prices	1.5	18.3	18.4	-0.5	9.4	9.4
Total investment in agriculture	-69.6	121.3	-50	-8.2	-1.6	-1.6
Rural roads	24.5	-9.8	18.7	7.1	10.1	10.1
Electric production	11.7	15.3	6	5.6	6.8	9.1

Note: [a] Data for 2009/10 calculated using average growth rate of the respective variable for WDI and EIA.

Table A.2—Annual changes in TFP under baseline three-factor specification.

	Scenario				Annual changes in TFP					
Scenario number	Growth in labor use → / Growth in capital services ↓	Agricultural employment	Private holders	Average of the two	2004/05-2005/06	2005/06-2006/07	2006/07-2007/08	2007/08-2008/09	2008/09-2009/10	Average Growth
1.1.1	Stock of draft livestock	X			0.080	0.049	0.026	0.025	0.034	0.043
1.1.2	Gross capital formation	X			0.087	0.030	0.009	0.033	0.027	0.037
1.1.3	Investment in agriculture	X			0.089	0.054	0.034	0.032	0.040	0.050
1.1.4	Average of the three	X			0.085	0.045	0.024	0.030	0.034	0.044
		Average across 4 scenarios			0.085	0.044	0.023	0.030	0.034	0.043
2.1.1	Stock of draft livestock		X		0.056	0.059	-0.033	0.080	0.066	0.046
2.1.2	Gross capital formation		X		0.063	0.039	-0.050	0.087	0.060	0.040
2.1.3	Investment in agriculture		X		0.065	0.064	-0.025	0.087	0.073	0.053
2.1.4	Average of the three		X		0.061	0.055	-0.035	0.085	0.067	0.047
		Average across 4 scenarios			0.061	0.054	-0.036	0.085	0.066	0.046
3.1.1	Stock of draft livestock			X	0.068	0.054	-0.005	0.051	0.050	0.044
3.1.2	Gross capital formation			X	0.075	0.035	-0.022	0.059	0.043	0.038
3.1.3	Investment in agriculture			X	0.077	0.059	0.003	0.059	0.056	0.051
3.1.4	Average of the three			X	0.073	0.050	-0.007	0.056	0.051	0.045
		Average across 4 scenarios			0.073	0.050	-0.008	0.056	0.050	0.044
		Average growth across 12 scenarios			0.073	0.049	-0.007	0.057	0.050	0.045
		Median growth across 12 scenarios			0.073	0.050	-0.007	0.057	0.050	0.045
		Maximum growth across 12 scenarios			0.089	0.064	0.034	0.087	0.073	0.069
		Range of growth across 12 scenarios			0.033	0.034	0.084	0.062	0.046	0.052

Source: Changes in TFP resulting from using three-factor specification and calculation from results
Note: In these scenarios Labor and land rental rates are assumed to be the average of constant 2004/05 rates and growing rates.

Table A.3—Annual change in agricultural TFP using the five-factor specification.

Assumed growth in intermediate services inputs				Annual changes in TFP					
Baseline scenario	Real value of SrGDP[a]	Real value of AgGDP[b]	Average of the two	2004/05-2005/06	2005/06-2006/07	2006/07-2007/08	2007/08-2008/09	2008/09-2009/10	Average Growth
1.1.1	X			0.0630	0.0480	0.0207	0.0299	0.0339	0.0391
1.1.1		X		0.0628	0.0476	0.0197	0.0290	0.0330	0.0384
1.1.1			X	0.0680	0.0315	0.0052	0.0337	0.0268	0.0331
1.1.2	X			0.0684	0.0325	0.0074	0.0357	0.0287	0.0345
1.1.2		X		0.0682	0.0320	0.0064	0.0348	0.0279	0.0339
1.1.2			X	0.0701	0.0491	0.0262	0.0332	0.0369	0.0431
1.1.3	X			0.0704	0.0501	0.0284	0.0352	0.0387	0.0446
1.1.3		X		0.0703	0.0496	0.0273	0.0343	0.0379	0.0439
1.1.3			X	0.0670	0.0431	0.0177	0.0317	0.0326	0.0384
1.1.4	X			0.0673	0.0440	0.0199	0.0336	0.0344	0.0399
1.1.4		X		0.0672	0.0436	0.0189	0.0327	0.0336	0.0392
1.1.4			X	0.0392	0.0570	-0.0438	0.0792	0.0636	0.0390
2.1.1	X			0.0395	0.0579	-0.0416	0.0811	0.0655	0.0405
2.1.1		X		0.0394	0.0575	-0.0426	0.0802	0.0646	0.0398
2.1.1			X	0.0446	0.0414	-0.0571	0.0850	0.0585	0.0345
2.1.2	X			0.0449	0.0424	-0.0549	0.0870	0.0603	0.0360
2.1.2		X		0.0448	0.0419	-0.0559	0.0860	0.0595	0.0353
2.1.2			X	0.0466	0.0590	-0.0361	0.0845	0.0685	0.0445
2.1.3	X			0.0470	0.0600	-0.0339	0.0865	0.0704	0.0460
2.1.3		X		0.0468	0.0595	-0.0349	0.0856	0.0695	0.0453
2.1.3			X	0.0436	0.0530	-0.0446	0.0829	0.0642	0.0398
2.1.4	X			0.0439	0.0539	-0.0424	0.0849	0.0660	0.0413
2.1.4		X		0.0437	0.0535	-0.0434	0.0840	0.0652	0.0406
2.1.4			X	0.0511	0.0520	-0.0114	0.0533	0.0479	0.0386
3.1.1	X			0.0514	0.0529	-0.0092	0.0553	0.0498	0.0400
3.1.1		X		0.0512	0.0525	-0.0103	0.0544	0.0490	0.0394
3.1.1			X	0.0565	0.0364	-0.0247	0.0591	0.0428	0.0340
3.1.2	X			0.0568	0.0374	-0.0225	0.0611	0.0447	0.0355
3.1.2		X		0.0566	0.0369	-0.0236	0.0602	0.0438	0.0348
3.1.2			X	0.0585	0.0540	-0.0038	0.0586	0.0528	0.0440
3.1.3	X			0.0589	0.0550	-0.0016	0.0606	0.0547	0.0455
3.1.3		X		0.0587	0.0545	-0.0026	0.0597	0.0538	0.0448
3.1.3			X	0.0554	0.0480	-0.0122	0.0570	0.0485	0.0393
3.1.4	X			0.0558	0.0489	-0.0100	0.0590	0.0504	0.0408
3.1.4		X		0.0556	0.0485	-0.0111	0.0581	0.0495	0.0401
3.1.4			X	0.0554	0.0481	-0.0127	0.0582	0.0489	0.0396
Overall average				0.0552	0.0481	-0.0136	0.0590	0.0494	0.0396
Overall median				0.0557	0.0490	-0.0112	0.0588	0.0492	0.0397
Range between maximum and minimum growth rates				0.0312	0.0284	0.0854	0.0580	0.0435	0.0400
Standard deviation of growth rates				0.0100	0.0080	0.0264	0.0207	0.0133	0.0402

Source: Changes in TFP resulting from using 5-factor specification and calculation from results
Note: In these scenarios Labor and land rental rates are assumed to be the average of constant 2004/05 rates and growing rates; [a] SrGDP stands for service sector GDP. [b] AgGDP stands for Agricultural GDP

Table A.4—Average change in TFP, modified specification and rentals averaged

Starting baseline scenario	Assumed effect of infrastructure on TFP	Annual changes in TFP					Average Growth rate
		2004/05-2005/06	2005/06-2006/07	2006/07-2007/08	2007/08-2008/09	2008/09-2009/10	
1.1.1	Zhang and Fan (0.042)	-0.042	-0.065	-0.001	0.054	0.005	-0.010
1.1.2		-0.036	-0.085	-0.019	0.062	-0.003	-0.016
1.1.3		-0.033	-0.062	0.009	0.062	0.012	-0.002
1.1.4		-0.037	-0.070	-0.002	0.059	0.005	-0.009
2.1.1		-0.067	-0.054	-0.068	0.114	0.041	-0.007
2.1.2		-0.060	-0.075	-0.089	0.123	0.034	-0.014
2.1.3		-0.057	-0.052	-0.056	0.121	0.047	0.000
2.1.4		-0.061	-0.060	-0.070	0.119	0.042	-0.006
3.1.1		-0.055	-0.059	-0.035	0.083	0.023	-0.009
3.1.2		-0.048	-0.080	-0.054	0.091	0.016	-0.015
3.1.3		-0.045	-0.057	-0.024	0.090	0.029	-0.001
3.1.4		-0.049	-0.065	-0.036	0.088	0.024	-0.008
1.1.1	Binswanger et al. (0.201)	-0.056	-0.093	0.006	0.028	-0.008	-0.025
1.1.2		-0.049	-0.113	-0.012	0.036	-0.015	-0.031
1.1.3		-0.047	-0.090	0.016	0.036	-0.001	-0.017
1.1.4		-0.051	-0.098	0.005	0.033	-0.007	-0.023
2.1.1		-0.081	-0.083	-0.062	0.088	0.029	-0.022
2.1.2		-0.074	-0.103	-0.083	0.096	0.022	-0.028
2.1.3		-0.071	-0.080	-0.050	0.095	0.034	-0.014
2.1.4		-0.075	-0.088	-0.063	0.093	0.029	-0.021
3.1.1		-0.068	-0.087	-0.028	0.057	0.011	-0.023
3.1.2		-0.061	-0.108	-0.048	0.065	0.004	-0.030
3.1.3		-0.059	-0.085	-0.017	0.064	0.017	-0.016
3.1.4		-0.063	-0.093	-0.029	0.062	0.011	-0.022
1.1.1	Fan et al. (0.2896)	-0.064	-0.108	0.010	0.014	-0.015	-0.033
1.1.2		-0.057	-0.129	-0.009	0.021	-0.022	-0.039
1.1.3		-0.054	-0.106	0.020	0.021	-0.008	-0.025
1.1.4		-0.058	-0.114	0.008	0.019	-0.014	-0.032
2.1.1		-0.089	-0.098	-0.058	0.073	0.022	-0.030
2.1.2		-0.081	-0.119	-0.079	0.082	0.015	-0.037
2.1.3		-0.079	-0.095	-0.046	0.080	0.028	-0.023
2.1.4		-0.083	-0.103	-0.059	0.079	0.022	-0.029
3.1.1		-0.076	-0.103	-0.024	0.042	0.004	-0.032
3.1.2		-0.069	-0.124	-0.044	0.050	-0.003	-0.038
3.1.3		-0.066	-0.100	-0.014	0.049	0.010	-0.024
3.1.4		-0.070	-0.108	-0.026	0.047	0.005	-0.030

Table A.4 continued—Average change in TFP, modified model and rentals averaged

Starting baseline scenario	Assumed effect of infrastructure on TFP	Annual changes in TFP					Average Growth rate
		2004/05-2005/06	2005/06-2006/07	2006/07-2007/08	2007/08-2008/09	2008/09-2009/10	
1.1.1	Average of three studies (0.178)	-0.054	-0.089	0.005	0.032	-0.006	-0.022
1.1.2		-0.047	-0.109	-0.013	0.040	-0.013	-0.029
1.1.3		-0.045	-0.086	0.015	0.040	0.001	-0.015
1.1.4		-0.049	-0.094	0.004	0.037	-0.005	-0.021
2.1.1		-0.079	-0.078	-0.063	0.092	0.030	-0.020
2.1.2		-0.072	-0.099	-0.084	0.100	0.024	-0.026
2.1.3		-0.069	-0.076	-0.051	0.098	0.036	-0.012
2.1.4		-0.073	-0.084	-0.064	0.097	0.031	-0.019
3.1.1		-0.066	-0.083	-0.029	0.060	0.013	-0.021
3.1.2		-0.059	-0.104	-0.049	0.069	0.005	-0.028
3.1.3		-0.057	-0.081	-0.018	0.068	0.019	-0.014
3.1.4		-0.061	-0.089	-0.030	0.066	0.013	-0.020
Average change in TFP		-0.061	-0.089	-0.031	0.067	0.012	-0.021

Source: Changes in TFP using the modified model.

Table A.5—Zonal average literate farmers and application of modern inputs 2003/04–2009/10.

Region	Variable	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	Average
Tigray	Proportion of literate farmers	0.29	0.28	0.36	0.36	0.36	0.34	0.33
	Fertilizer applied (KG/ha)	0.17	0.18	0.19	0.18	0.19	0.16	0.18
	Improved seed used (KG/ha)	0.02	0.02	0.03	0.01	0.03	0.02	0.02
	Prop. of area with pesticides application	0.02	0.02	0.04	0.05	0.05	0.06	0.039
Amhara	Proportion of literate farmers	0.23	0.23	0.25	0.25	0.26	0.28	0.25
	Fertilizer applied (KG/ha)	0.23	0.28	0.35	0.36	0.42	0.40	0.34
	Improved seed used (KG/ha)	0.02	0.01	0.02	0.01	0.02	0.01	0.02
	Prop, of area with pesticides application	0.02	0.04	0.06	0.05	0.06	0.07	0.05
Oromia	Proportion of literate farmers	0.34	0.33	0.37	0.35	0.37	0.39	0.36
	Fertilizer applied (KG/ha)	0.29	0.28	0.34	0.32	0.33	0.29	0.31
	Improved seed used (KG/ha)	0.02	0.01	0.02	0.02	0.02	0.02	0.02
	Prop. of area with pesticides application	0.13	0.16	0.21	0.21	0.23	0.19	0.19
SNNP	Proportion of literate farmers	0.32	0.32	0.35	0.33	0.38	0.38	0.34
	Fertilizer applied (KG/ha)	0.27	0.22	0.26	0.31	0.48	0.36	0.32
	Improved seed used (KG/ha)	0.03	0.03	0.04	0.02	0.02	0.02	0.03
	Prop. of area with pesticides application	0.14	0.18	0.16	0.16	0.21	0.20	0.18

		Growth rate in percent					
	Variable	2003/04–2004/05	2004/05–2005/06	2005/06–2006/07	2006/07–2007/08	2007/08–2008/09	Average
Tigray	Proportion of literate farmers	-2.9	27.1	-1.4	0.6	-5.2	3.6
	Fertilizer application	2.0	10.1	-7.2	4.9	-15.8	-1.2
	Improved seed application	-13.4	67.0	-56.4	143.7	-38.8	20.4
	Prop. of area with pesticides application	-10.9	83.4	32.8	3.8	11.1	24.0
Amhara	Proportion of literate farmers	0.2	7.9	-0.8	4.8	7.1	3.9
	Fertilizer application	18.1	25.8	3.4	16.9	-4.6	11.9
	Improved seed application	-15.6	22.8	-15.0	10.8	-15.8	-2.6
	Prop. of area with pesticides application	62.0	48.8	-17.1	34.8	17.4	29.2
Oromia	Proportion of literate farmers	-2.5	13.6	-5.9	5.5	4.0	2.9
	Fertilizer application	-4.2	21.9	-5.8	1.9	-12.9	0.2
	Improved seed application	-34.4	111.2	-34.7	22.0	-6.4	11.5
	Prop. of area with pesticides application	29.6	28.4	-0.7	9.9	-16.0	10.2
SNNP	Proportion of literate farmers	-0.5	10.0	-6.9	15.4	0.6	3.7
	Fertilizer application	-18.3	15.8	19.0	57.6	-24.9	9.8
	Improved seed application	1.0	40.5	-36.0	-3.8	-13.7	-2.4
	Prop. of area with pesticides application	29.8	-10.5	-4.7	36.0	-7.5	8.6

Source: CSA Reports on Land Utilization Volume III and Farm Management Practices Volume IV 2003–2004 through 2008–2009.
Note: SNNP = Southern Nations, Nationalities and Peoples Region

Table A.6—Zonal average level use of services and proportion of damaged area, 2003/04–2008/09

Region	Variable	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	Average
Tigray	Proportion of area extension applied	0.43	0.31	0.18	0.15	0.18	0.18	0.24
	Proportion of farmers using credit	0.45	0.32	0.61	0.39	0.51	0.55	0.47
	Proportion that used advisory services	0.49	0.63	0.85	0.85	0.83	0.85	0.75
	proportion of damaged crop area	0.20	0.29	0.15	0.16	0.20	0.25	0.21
Amhara	Proportion of area extension applied	0.12	0.18	0.20	0.21	0.16	0.19	0.17
	Proportion of farmers using credit	0.12	0.12	0.32	0.36	0.40	0.36	0.28
	Proportion that used advisory services	0.30	0.49	0.66	0.72	0.71	0.77	0.61
	proportion of damaged crop area	0.18	0.22	0.18	0.15	0.18	0.16	0.18
Oromia	Proportion of area extension applied	0.08	0.11	0.15	0.12	0.08	0.07	0.10
	Proportion of farmers using credit	0.17	0.05	0.27	0.29	0.26	0.22	0.21
	Proportion that used advisory services	0.19	0.26	0.45	0.45	0.43	0.45	0.37
	proportion of damaged crop area	0.17	0.17	0.17	0.15	0.16	0.18	0.17
SNNP	Proportion of area extension applied	0.04	0.07	0.07	0.04	0.03	0.04	0.05
	Proportion of farmers using credit	0.07	0.03	0.13	0.16	0.16	0.16	0.12
	Proportion that used advisory services	0.10	0.18	0.33	0.36	0.37	0.46	0.30
	proportion of damaged crop area	0.19	0.17	0.15	0.15	0.14	0.12	0.15

Region	Variable	Annual rate of growth, percentage					
		2003/04–2004/05	2004/05–2005/06	2005/06–2006/07	2006/07–2007/08	2007/08–2008/09	Average
Tigray	Proportion of area extension applied	-28.0	-42.5	-17.5	24.1	-3.9	-16.0
	Proportion of farmers using credit	-29.3	92.6	-35.6	29.3	9.3	14.2
	Proportion that used advisory services	27.8	35.9	-0.5	-2.0	2.3	15.3
	Proportion of damaged crop area	40.3	-47.6	5.2	25.0	27.3	5.7
Amhara	Proportion of area extension applied	46.9	11.5	7.0	-22.9	15.1	10.6
	Proportion of farmers using credit	-3.9	175.7	10.5	12.1	-10.5	48.6
	Proportion that used advisory services	65.5	33.8	9.7	-1.8	9.4	26.8
	Proportion of damaged crop area	23.8	-16.8	-18.7	20.1	-10.7	2.1
Oromia	Proportion of area extension applied	33.7	42.7	-21.1	-36.5	-6.8	4.7
	Proportion of farmers using credit	-71.2	441.1	5.1	-9.4	-15.7	91.4
	Proportion who used advisory services	34.1	72.1	0.8	-5.7	6.1	25.3
	Proportion of damaged crop area	1.7	-3.6	-10.0	9.0	10.2	-0.7
SNNP	Proportion of area extension applied	68.3	10.3	-45.6	-19.4	35.7	3.4
	Proportion of farmers using credit	-62.1	345.8	26.2	3.7	-3.8	78.4
	Proportion who used advisory services	81.7	85.6	7.7	3.3	25.2	44.6
	Proportion of damaged crop area	-12.1	-10.2	-0.7	-8.7	-11.6	-7.9

Source: CSA Reports on Farm Management Practices Volume IV 2003–2004 through 2008–2009.
Note: SNNP = Southern Nations, Nationalities and Peoples Region

Table A.7—Ordinary least squares estimates of Cobb-Douglas production functions, baseline and modified specifications with flexible dummy variables using zone level data for 2003/04–2008/09.

	Baseline		Modified	
Variable	Coefficient	Standard error	Coefficient	Standard error
Labor	0.383***	0.049	0.346***	0.056
Drought livestock	0.017	0.037	0.008	0.040
Area	0.792***	0.061	0.862***	0.078
Fertilizer			0.009	0.018
Improved seeds			-0.022	0.020
Pesticides			-0.019	0.015
2004/05 Tigray dummy	0.068	0.185	0.001	0.189
2005/06 Tigray dummy	0.225	0.185	0.174	0.188
2006/07 Tigray dummy	0.287	0.186	0.227	0.190
2007/08 Tigray dummy	0.332*	0.187	0.281	0.189
2008/09 Tigray dummy	0.344*	0.187	0.295	0.189
2003/04 Amhara dummy	0.018	0.163	-0.048	0.168
2004/05 Amhara dummy	0.045	0.163	-0.023	0.168
2005/06 Amhara dummy	0.185	0.164	0.121	0.168
2006/07 Amhara dummy	0.224	0.164	0.155	0.169
2007/08 Amhara dummy	0.236	0.164	0.172	0.169
2008/09 Amhara dummy	0.245	0.165	0.181	0.169
2003/04 Oromia dummy	0.238	0.159	0.209	0.160
2004/05 Oromia dummy	0.197	0.160	0.159	0.162
2005/06 Oromia dummy	0.329**	0.160	0.309*	0.161
2006/07 Oromia dummy	0.405**	0.160	0.371**	0.161
2007/08 Oromia dummy	0.380**	0.160	0.351**	0.161
2008/09 Oromia dummy	0.395**	0.160	0.363**	0.162
2003/04 SNNP dummy	0.338**	0.135	0.317**	0.137
2004/05 SNNP dummy	0.485***	0.134	0.469***	0.137
2005/06 SNNP dummy	0.723***	0.135	0.714***	0.136
2006/07 SNNP dummy	0.671***	0.135	0.662***	0.138
2007/08 SNNP dummy	0.646***	0.137	0.629***	0.140
2008/09 SNNP dummy	0.653***	0.135	0.640***	0.138
R-squared	1.000		1.000	

Source: Analysis conducted using CSA data.
Note: Coefficients with *** , **, and * are significant at 1, 5, and 10 percent significance levels. SNNP = Southern Nations, Nationalities and Peoples Region

Table A.8—Zone level efficiency patterns using regionally separate panel data, 2003/04–2008/09.

Region	zone	Year						
		2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	Average
Tigray	North West Tigray	0.90	0.79	0.99	0.64	0.69	0.99	0.83
	Central Tigray	0.67	0.75	0.91	0.55	0.62	0.89	0.73
	East Tigray	0.80	0.74	0.79	0.57	0.80	0.85	0.76
	South Tigray	0.78	0.81	0.93	0.71	0.71	0.85	0.80
	Western Tigray	0.95	0.99	0.93	0.57	0.71	0.90	0.84
Amhara	Agew Awi	0.98	0.99	0.99	0.99	0.92	0.98	0.97
	East Gojjam	0.95	0.98	0.98	0.97	0.86	0.99	0.96
	North Gondar	0.87	0.97	0.98	0.96	0.73	0.96	0.91
	North Shewa	0.96	0.97	0.98	0.98	0.69	0.84	0.90
	North Wollo	0.91	0.85	0.86	0.79	0.60	0.83	0.81
	Oromia	0.86	0.83	0.89	0.86	0.62	0.80	0.81
	South Gondar	0.77	0.74	0.96	0.88	0.68	0.79	0.80
	South Wollo	0.94	0.97	0.90	0.81	0.61	0.77	0.83
	Wag Hemra	0.73	0.59	0.95	0.92	0.53	0.71	0.74
	West Gojjam	0.98	0.99	0.99	0.98	0.88	0.99	0.97
Oromia	Arsi	0.98	0.97	0.87	0.93	0.81	0.99	0.92
	Bale	0.98	0.92	0.95	0.94	0.84	0.99	0.93
	Borena	0.97	0.71	0.96	0.94	0.87	0.99	0.90
	East Hararghe	0.96	0.84	0.77	0.92	0.93	0.98	0.90
	East Shewa	0.98	0.93	0.96	0.97	0.88	0.98	0.95
	East Welega	0.94	0.90	0.79	0.96	0.87	0.98	0.91
	Illubabor	0.95	0.90	0.88	0.98	0.88	0.99	0.93
	Jimma	0.85	0.82	0.82	0.95	0.83	0.98	0.88
	North Shewa	0.89	0.78	0.74	0.98	0.64	0.97	0.83
	West Hararghe	0.98	0.84	0.77	0.95	0.94	0.99	0.91
	West Shewa	0.96	0.93	0.87	0.97	0.74	0.98	0.91
	West Welega	0.91	0.96	0.83	0.96	0.93	0.99	0.93
SNNP	Bench Maji	0.84	0.87	0.77	0.91	0.93	0.95	0.88
	Dawro	0.82	0.84	0.63	0.86	0.90	0.94	0.83
	Debub (South) Omo	0.51	0.73	0.46	0.61	0.74	0.91	0.66
	Gamo Gofa	0.72	0.77	0.71	0.82	0.86	0.91	0.80
	Gedeo	0.66	0.88	0.79	0.85	0.81	0.85	0.81
	Gurage	0.72	0.83	0.65	0.72	0.87	0.89	0.78
	Hadiya	0.87	0.91	0.92	0.91	0.92	0.95	0.91
	Kembata Tembaro	0.91	0.94	0.92	0.93	0.94	0.95	0.93
	Keffa	0.79	0.88	0.78	0.91	0.93	0.95	0.87
	Sheka	0.77	0.92	0.91	0.95	0.95	0.96	0.91
	Sidama	0.47	0.85	0.91	0.87	0.89	0.94	0.82
	Silti	0.88	0.86	0.69	0.83	0.88	0.91	0.84
	Wolayita	0.94	0.96	0.92	0.92	0.95	0.94	0.94
	Alaba special woreda	0.88	0.91	0.48	0.72	0.89	0.92	0.80
	Amaro special woreda	0.42	0.36	0.70	0.70	0.85	0.88	0.65
	Basketo special	0.64	0.80	0.53	0.81	0.88	0.93	0.77
	Burji special woreda	0.26	0.84	0.27	0.27	0.47	0.85	0.49
	Dirashe special	0.29	0.58	0.46	0.57	0.81	0.86	0.59
	Konso special woreda	0.11	0.41	0.23	0.23	0.72	0.89	0.43
	Konta special woreda	0.92	0.95	0.93	0.94	0.95	0.96	0.94
	Yem special woreda	0.88	0.91	0.89	0.93	0.95	0.95	0.92
Average		0.81	0.84	0.81	0.83	0.81	0.92	0.84

Source: Analyses using CSA data
Note: SNNP = Southern Nations, Nationalities and Peoples Region

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