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Agricultural Growth in Ethiopia (2004-2014): Evidence and Drivers

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ABSTRACT

Ethiopia's agricultural sector has recorded remarkable rapid growth in the last decade. This paper documents aspects of this growth process. Over the last decade, there have been significant increases - more than a doubling - in the use of modern inputs, such as chemical fertilizers and improved seeds, explaining part of that growth. However, there was also significant land expansion, increased labor use, and Total Factor Productivity (TFP) growth, estimated at 2.3 percent per year. The expansion in modern input use appears to have been driven by high government expenditures on the agricultural sector, including agricultural extension, but also by an improved road network, higher rural education levels, and favorable international and local price incentives.

1. INTRODUCTION

Ethiopia has been one of the fastest growing economies in the world in the last decade, a remarkable feat for a low-income country that exports relatively little oil and minerals. The growth of GDP, measured in constant market prices, became significantly faster and more stable during the latest decade compared to the previous one – indeed it rose rapidly and stayed in double digits from 2004 onwards. Ethiopia's growth acceleration since 2004 seems to be explained by three major drivers. First, there has been rapid physical capital accumulation spearheaded by a substantial expansion of public investment. Second, agricultural modernization has speeded up as reflected by a substantial rise in agricultural productivity. Third, the service sector has seen substantial surge during this period, exceeding that of the agriculture sector that further boosted productivity and exceeded that of the agriculture sector. These drivers, in turn, were supported by relatively stable political and macroeconomic environment.

The purpose of this paper is to further explore the second major driver of Ethiopia's growth acceleration: the rapid change in agriculture observed since 2004. The agricultural growth in Ethiopia as a contributor to overall economic growth has been remarkable for Africa and the world (Diao et al. 2008; Djurfeldt et al. 2005). National official data show that agriculture has grown on average by 7.6 percent per year over the last decade, and this agricultural growth in particular has been a major contributor to the important poverty reductions observed in the last decade in Ethiopia (World Bank 2014).[1]

This paper contributes to the literature in three main ways. First, it reviews the evidence on agricultural growth in Ethiopia and analyses the sources of this growth descriptively and through growth accounting. Second, it assesses the evidence on improved agricultural technology adoption in the last decade. Finally, it identifies the main drivers of Ethiopia's agricultural modernization process. In doing so, this paper focuses mainly on the transformations related to crop production – that of the livestock production sector is beyond the scope of this paper.[2] Similar to the experience during the Green Revolution, increasing adoption of improved seeds and chemical fertilizer have played a major role in agricultural output growth. While starting from a low base, the adoption of improved seeds and the use of chemical fertilizer more than doubled over the last decade. This increasing adoption of modern agricultural inputs has been facilitated by large investments in the agricultural sector and beyond, leading to improved road and communication networks, a better educated rural population, and a large agricultural extension workforce. To further stimulate growth in the agricultural sector in Ethiopia during the last decade, there were no major droughts, as previously suffered, there were better incentives for agricultural intensification because of more favorable international prices for export crops and improvements in modern input-output price ratios for locally consumed crops, and, more broadly, widespread civil conflict had ceased.

The structure of the paper is as follows. First, we describe the importance of the agricultural and food sector in Ethiopia's economy. Second, we provide evidence on growth in the agricultural sector over the last decade and further decompose this growth into different components. Third, we discuss the modernization of the agricultural sector and look at the increasing adoption of chemical fertilizer, improved seeds, and other modern and improved practices. Fourth, we identify major drivers that have contributed to agricultural growth in the country, and discuss more in particular, the role of extension,

[1] Such high linkages between agricultural growth and poverty reduction have been noted before in these settings (Christiaensen et al. 2011; Datt and Ravallion 1998).
[2] For further in-depth analysis of growth and transformation in Ethiopia's livestock sector, see Desta et al. (2015).

improved marketing, rural education, and incentives. We finish with the conclusions and a discussion of further challenges for agricultural growth in Ethiopia in the future.

2. THE AGRICULTURAL AND FOOD SECTOR IN ETHIOPIA'S ECONOMY

During the 2004/5-2013/14 period, real gross domestic product (GDP) in Ethiopia grew at an average annual rate of 10.7 percent, while real per capital GDP grew at an average annual rate of 7.9 percent (Table 2.1) – one of the fastest rates of economic growth in the world over the last decade. The agricultural sector grew at an average annual rate of 7.6 percent. It accounted for 47 percent of real GDP on average over the last decade, and it was the largest contributor to GDP until the services sector took over in 20010/11. Out of the 10.7 percent average annual growth in real GDP recorded during the last decade, agriculture accounted for 3.6 percent. This compares to 5.6 percent and 1.5 percent for the services and industry sectors, respectively. However, it should be noted that the contribution of agriculture to overall growth declined over the decade from 5.7 percent in 2004/05 to 2.3 percent in 2013/14. Within agriculture, the most important subsector was crop production. It represented 32 percent of GDP and grew at an average annual rate of 8.8 percent (Table 2.1). Livestock production on average contributed 10 percent to real GDP and grew at 6 percent on average, while forestry and fishing accounted for 5 percent of the GDP and grew at 3.4 percent. In further analysis of agricultural performance, we will focus on crop agriculture only.

Table 2.1—Real GDP – Levels and growth rates, 2004/5-2013/14

Subsector	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
	Real GDP and its components (in billion Birr, 2011 prices)									
Crop	83.4	95.8	106.4	114.9	122.3	133.0	146.8	154.1	166.7	177.7
Livestock	30.9	32.4	34.9	37.5	40.1	42.6	45.8	48.3	50.8	51.8
Forestry and Fishing	16.5	16.9	17.4	18.2	18.8	19.4	19.9	20.6	21.3	22.3
Manufacturing	10.1	11.2	12.1	13.3	14.5	16.1	19.0	21.2	24.8	27.6
Construction	10.0	11.1	12.3	13.7	15.3	16.9	19.1	25.1	34.8	47.5
Other industry	5.7	6.2	6.3	6.9	7.5	8.9	11.7	13.2	14.3	14.5
Trade, hotel, and others	73.6	83.1	95.8	110.2	124.4	139.0	159.5	175.6	196.2	222.6
Finance and real estate	21.2	24.8	28.6	34.3	39.8	45.7	56.0	60.5	61.1	65.3
Gross domestic product	251.4	281.5	313.9	349.0	382.7	421.8	477.7	518.6	569.9	629.3
Real per capita GDP (birr)	3,636	3,957	4,277	4,597	4,934	5,317	5,895	6,252	6,697	7,202
	Contribution of sectors to overall GDP growth rate in %									
	Average	**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**2010/11**	**2011/12.**	**2012/13**	**2013/14**
Agriculture	3.6	5.7	4.8	3.8	3.1	3.6	4.1	2.2	3.1	2.3
Industry	1.6	1.0	0.8	1.0	1.0	1.2	1.8	2.0	2.8	2.8
Services	5.5	5.2	5.9	6.4	5.6	5.4	7.3	4.3	4.1	5.4
Total GDP	10.7	12.0	11.5	11.2	9.7	10.2	13.3	8.6	9.9	10.4
Real per capita GDP (birr)	7.9	8.8	8.1	7.5	7.3	7.8	10.9	6.1	7.1	7.5

Source: National Bank of Ethiopia (2014).
Note: Livestock includes "animal farming and hunting".

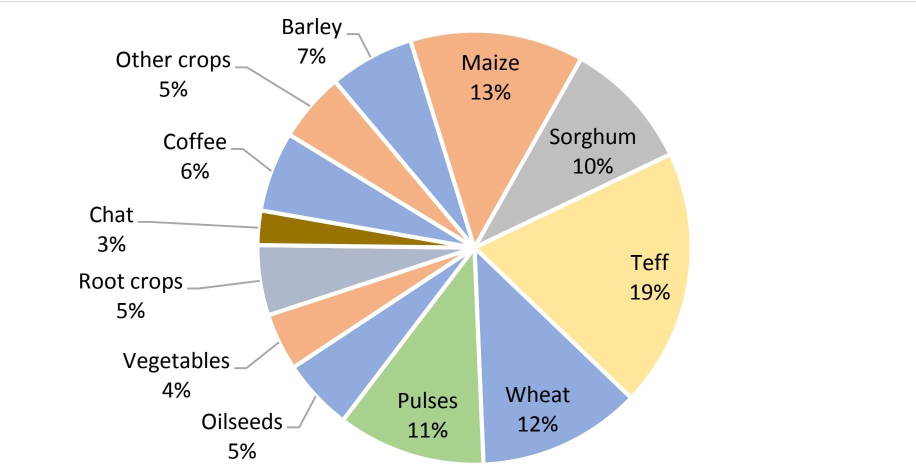
In this paper we study the importance of different crops by converting total crop production into real value of crop output. Accordingly, we use annual reports of the Central Statistical Agency (CSA) of Ethiopia on output (CSA Volume I 2005-2014) and CSA monthly producer prices and regional price indices to reconstruct real crop output and its components.[3,4] In an average year during the period 2004/5-2013/14, cereals accounted for 63 percent of the real value of crop output or about 20 percent of real GDP (Figure 2.1). Teff is Ethiopia's most important cereal crop accounting on average for 19 percent of real value of crop output or 6.1 percent of real GDP. The other major cereals, i.e. maize, wheat, and sorghum, accounted for 13 percent, 12 percent, and 10 percent of real crop output, respectively. In contrast with a

[3] The total value of real crop output that we compute differs slightly from the aggregate that is reported in National Bank of Ethiopia (2014). The total derived in this study is used to estimate the share of specific crops.

[4] We leave out *Enset*, a staple crop in southern Ethiopia, from our computations since data is unavailable in most years. In the four years in which data was available, the crop accounted for 1 percent of real value of crop output. These shares of value significantly underestimate the importance of *Enset* in consumption, particularly in southern Ethiopia. For instance, *Enset* accounted for about 5 percent of food expenditures in the HICE data for 2004/05 (Tafere and Taffesse 2010). The gap reflects the limited, yet growing, *Enset* market.

number of other countries, there is no single dominant crop. The figure further indicates the major export crops, coffee and oilseeds, are less important in terms of output, accounting for 6 percent and 5.3 percent of real crop output, respectively. Over time, we see relatively little change in diversification in crop agriculture (Table Appendix 1.1). For example, the share of cereals in total crop output was 63 percent in 2004/05 and remained at the same level up to 2013/14.

Figure 2.1—Composition of the real value of crop output, 2004/5-2013/14 average, %



Source: Authors' computations using CSA data

In terms of employment, agriculture engaged the largest proportion of the population of all sectors, employing 80 percent of all workers in Ethiopia in 2005 and 77 percent in 2013. Agricultural employment grew at an average annual rate of 2.5 percent during the same period (Martins 2015). In contrast, the manufacturing sector accounted for about 4.9 percent of total employment in 2005 and 4.7 percent in 2013, while the services sector made up the remaining 13 percent in 2005 and 15 percent in 2013 (Martins 2015).

Similarly, agriculture plays an important role in Ethiopia's commodity exports. Agricultural exports, on average, contributed 80.6 percent of total commodity exports during 2004/05-2013/14 (Table 2.2). Moreover, three of the four non-agricultural exports (textile, sugar, and wax) use agricultural raw materials as their main inputs. Over the last decade, the real value of total and agricultural exports increased at average annual rates of 11.0 percent and 9.6 percent respectively, and the total real value of agricultural exports was twice as high in 2013/14 than in 2004/05. The value of commodity exports grew particularly sharply during the period 2008/9-2010/11, which was mostly driven by high international commodity prices (Headey et al. 2010).

Coffee is the most important export crop, accounting for, on average, 29 percent of total exports (Table 2.2). However, we note increasing export diversification, with the relative share of coffee exports declining – but quantities of exports slightly increasing (Minten et al. 2014) from over 39 percent in 2004/5 to 22 percent in 2013/14. The next most important export after coffee are oilseeds, accounting for an average of 17.4 percent of total exports, followed by chat at 8.7 percent. Two products in particular showed rapid growth over the last decade. Flower exports comprised 1 percent of total exports in 2004/05 and these increased to 6 percent by 2013/14. Exports of meat products and live animals have also shown rapid growth (from 3 percent in 2004/05 to 8 percent in 2013/14). Although agricultural exports grew considerably in the last decade, the majority of agricultural output is still consumed domestically rather than exported. Tables 2.1 and 2.2 show a comparison of total export figures, which suggest that about 87 percent of agricultural output is consumed domestically.[5]

[5] There are also clear geographic dimensions to agricultural growth and this is important for policy making (Chamberlin and Schmidt 2013). For example, in the large Agricultural Growth Program (AGP), which only focuses on the high-potential areas, and the new Agricultural Commercial Cluster Strategy, there is an embedded principle that agricultural growth will be driven in the future by high potential areas, as defined by agro-ecology and proximity to markets. Disaggregating this growth at lower administrative levels is beyond the scope of this paper.

Table 2.2—Real value and composition of exports

Item	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	Average
Value of exports (billion real birr)											
Total	18.9	20.1	20.6	20.6	18.5	31.3	44.5	40.8	40.2	40.4	
Agricultural	15.9	17.0	17.3	18.0	16.1	25.1	33.4	30.3	29.8	31.7	
Growth rate in exports (percent)											
Total		6.2	2.6	0.1	-10.2	69.3	42.0	-8.3	-1.7	0.6	11.2
Agricultural		6.6	1.7	4.1	-10.6	56.3	33.0	-9.2	-1.8	6.2	9.6
Exports as a ratio of GDP (percent)											
Total	7.5	7.1	6.6	5.9	4.8	7.4	9.3	7.9	7.0	6.4	6.9
Agricultural	6.3	6.0	5.5	5.2	4.2	6.0	7.0	5.9	5.2	5.0	5.6
Contribution towards exports (percent)											
Non-agricultural	15.6	15.2	16.0	12.7	13.1	19.8	24.9	25.7	25.8	21.6	19.4
Agricultural	84.4	84.8	84.0	87.3	86.9	80.2	75.1	74.3	74.2	78.4	80.6
Contribution of major agricultural exports to total exports (percent)											
Coffee	39.6	35.4	35.8	35.9	25.8	26.5	30.6	26.5	24.2	22.0	29.2
Oilseeds	14.8	21.1	15.8	14.9	25.1	17.9	11.9	15.0	14.4	20.0	17.4
Chat	11.8	8.9	7.8	7.3	9.5	10.4	8.6	7.6	8.8	9.1	8.7
Pulses	4.2	3.7	5.9	9.8	6.2	6.4	5.0	5.1	7.6	7.7	6.4
Flower	0.9	2.2	5.4	7.6	9.0	8.4	6.4	6.2	6.1	6.1	6.4
Fruits and vegetables	1.9	1.3	1.4	0.9	0.8	1.6	1.2	1.4	1.4	1.4	1.3
Meat and live animal	3.2	4.6	4.4	4.2	5.3	6.2	7.7	9.0	7.8	8.0	6.4
Leather products	8.0	7.5	7.5	6.7	5.0	2.8	3.8	3.5	3.9	4.0	5.0

Source: Authors' computation using National Bank of Ethiopia (2014).
Note: Real values computed by deflating value of major exports (Appendix 2) using GDP deflator, with 2010/11 base prices (Annex 4) of National Bank of Ethiopia (2014).

While the agricultural sector is much broader than the local food economy, analyses of local consumption patterns enable further insights into the importance of the agricultural and food sectors in the last decade. We therefore analyze consumption patterns and their changes over time using three rounds of CSA's nationally representative Household Income Consumption and Expenditures Surveys (HICES) datasets, covering the period from 2000 until 2011. The results, which are presented in Table 2.3, illustrate a number of interesting patterns.

First, the share of non-food items in the total consumption basket increased significantly over time. In 2000, the share of non-food consumption expenditures accounted for 37.2 percent of the total. Over the following decade, this type of expenditure grew rapidly, and its share in total household expenditures surged to 52.1 percent in 2011. Such increases of non-food expenditures in total consumption aggregates are typical of transforming and improving economies, implying significant improvements in welfare in the country (World Bank 2014; MoFED 2012). This is because household expenditure shifts from food to non-food products when people's income increases.

Second, per capita total quantity of food consumed rose considerably (see bottom of Table 2.3). Consumption increased from 293 kg per capita per year in 2000 to 361 kg, representing an increase of 23 percent. The quantity of cereals consumed grew far less, changing from 141 kg per capita in 2000 to 155 kg per capita in 2011, an increase of 10 percent. Consistent with this trend, expenditures on food have grown in real terms in the last two surveys compared to 2000. Per capita, food expenditures in 2011 were 19 percent higher than in 2000.

Third, some important shifts occurred in consumption patterns within the food basket. Overall, the share of cereals in total food expenditures is declining. In 2000, the share comprised 47.5 percent of expenditures, but this had declined to 35.8 percent ten years later. Most growth in the non-cereal food categories (recorded in the 'other food' category), grew from 19.7 percent to 31.4 percent from 2000 to 2011. There is also an increasing importance attached to consuming animal products. While the share of these products is still relatively low, it has however grown from 7.6 percent of the food expenditures in 2000 to 10.8 percent in 2011. These patterns reflect Bennett's law that describes a relative decline in starchy staples and an increase in animal proteins with an increase in income (Bennett 1941).[6] The share of fruits and vegetables also increased over the same period, from 4.4 percent to 6.4 percent.

Fourth, cereal expenditures made up 35.8 percent of total food expenditures in 2011, but they made up 43 percent of quantity, indicating that cereals cost relatively less than other foods in the food consumption basket. In contrast, animal products constitute 10.8 percent of expenditures and 4.6 percent of the quantities consumed, representing the most expensive group in the food consumption basket. The categories ‘roots and tubers’ and ‘enset/kocho’ show the opposite pattern to that of the ‘animal products’ category since these represent a relatively cheap food category.

Table 2.3—Food consumption and real per capita expenditures, by category

	2000		2005		2011	
	Birr	**Share (%)**	**Birr**	**Share (%)**	**Birr**	**Share (%)**
Real per capita expenditures (Birr/capita/year)						
Teff	76	12.9	57	8.9	56	7.5
Wheat	51	8.6	57	8.9	55	7.4
Barley	22	3.7	28	4.4	18	2.4
Maize	64	10.8	55	8.6	57	7.6
Sorghum	37	6.3	52	8.1	37	4.9
Other cereals	19	3.2	11	1.7	11	1.5
Processed cereals	11	1.9	21	3.3	34	4.5
All cereals	*280*	*47.5*	*281*	*43.7*	*268*	*35.8*
Pulses and oilseeds	58	9.8	51	7.9	72	9.6
Vegetables and fruits	26	4.4	30	4.7	48	6.4
Roots and tubers	20	3.4	20	3.1	13	1.7
Enset/kocho	45	7.6	29	4.5	31	4.1
Animal products	45	7.6	56	8.7	81	10.8
Other foods	116	19.7	176	27.4	235	31.4
Total food	590	100.0	643	100.0	748	100.0
Food versus non-food						
Food	590	62.8	643	54.1	748	48.0
Non-food	349	37.2	546	45.9	812	52.1
Total	939	100.0	1,189	100.0	1,559	100.0
Consumption (kg/capita/year)	**kg**	**Share (%)**	**kg**	**Share (%)**	**kg**	**Share (%)**
Teff	30	10.3	26	8.0	26	7.3
Wheat	24	8.3	30	9.1	25	6.9
Barley	10	3.3	13	3.9	10	2.7
Maize	37	12.6	38	11.6	51	14.2
Sorghum	22	7.7	32	9.9	28	7.8
Other cereals	14	4.7	5	1.6	7	2.0
Processed cereals	4	1.5	6	2.0	7	2.0
All cereals	*141*	*48.3*	*150*	*46.2*	*155*	*43.0*
Pulses and oilseeds	16	5.5	17	5.3	18	5.1
Vegetables and fruits	26	9.0	34	10.5	36	10.0
Roots and tubers	22	7.5	27	8.3	24	6.7
Enset/kocho	56	19.2	41	12.8	47	13.0
Animal products	12	4.1	15	4.6	17	4.6
Other foods	18	6.3	40	12.4	64	17.6
Total food	293	100.0	324	100.0	361	100.0

Source: Worku et al. 2015

Fifth, within cereal consumption expenditures, teff, wheat, and maize comprise the most important crops. These crops accounted for 7.5 percent, 7.4 percent and 7.6 percent, respectively, of food expenditures in 2011. Over time, some minor

[6] Ethiopia is generally characterized by the lack of diverse diets (Headey et al. 2014), but this seems to be slowly changing over time. There were on average more diverse consumption expenditures in 2011 than 10 years earlier.

shifts within the consumption of cereals are observed. For example, the share of expenditures of sorghum in cereal expenditures was 6.3 percent in 2000 and 8.1 percent in 2005, but it declined to 4.9 percent in 2011. Compared to 2000, the share of maize in cereal expenditures has decreased as well. However, in quantity terms, maize is still by far the most important crop. Within the cereal category, the increase of processed cereals is notable, rising from 1.9 percent to 4.5 percent of total food expenditures, but still relatively low compared to other African countries (Tschirley et al. 2015).

Overall, we note the considerable – but declining with respect to nonfood – importance of food in total expenditures of the average Ethiopian consumer, which reflects the importance of agriculture in the Ethiopian economy. We also find an improvement in the quantities and diversity of food consumed over time.

3. THE GROWTH OF AGRICULTURE, 2004–2014

3.1. Evidence of growth from national data

In this section, we highlight trends in cultivated area, output, and yields in Ethiopia during the 2004/5-2013/14 period. We use administrative zone level aggregated data obtained from annual publications of CSA. These publications provide comparable information on variables of interest for the period we study.[7] In the 2013/14 main agricultural season, smallholder farmers in Ethiopia cultivated 12.9 million hectares of land (Table 3.1). The total cultivated area in 2013/14 was 27 percent higher relative to 2004/5, and annual growth averaged 2.7 percent during the decade. Grain[8] accounted for about 96 percent of the total cropped area during 2004/5-2013/14. In particular, nearly three-quarters of the area was covered by the five major cereals (i.e., teff, barley, wheat, maize, and sorghum). Next in order of importance, were pulses and, finally, oilseeds. Area allocated to pulses, vegetables, root crops, and fruits grew relatively faster compared to other crops, but from a low base. Growth in total cultivated area was thus mainly driven by an expansion of area covered by cereals.

Smallholder farmers dominate the agricultural land use in Ethiopia, making up 94 percent of total cultivated land in 2013/14.[9] However, the relative importance of commercial farmers is increasing over time: the area cultivated by commercial farms increased from 0.46 million hectares in 2007/08 to 1.0 million hectares in 2013/14. Commercial farms have also slightly higher yields than smallholders,[10] but they tend to specialize in other crops. For example, cereals made up 28 percent of the area cultivated by commercial farms, but 76 percent of all area cultivated by smallholders in 2013/14. The most important crops cultivated by commercial farms are sesame (27 percent of their total area), cotton (17 percent), and coffee (12 percent). The remainder of this paper focuses on trends and changes affecting smallholders in the *meher* season only, the most important season of Ethiopia's crop economy.

Table 3.1—Cultivated area, millions of hectares

Crop	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
All crops	10.1	10.5	11.0	11.3	11.6	11.9	12.3	12.6	12.8	12.9
Grains	9.8	10.2	10.6	11.0	11.2	11.5	11.8	12.1	12.3	12.4
Cereals	7.6	8.1	8.5	8.7	8.8	9.2	9.7	9.6	9.6	9.8
Pulses	1.3	1.3	1.4	1.5	1.6	1.5	1.4	1.6	1.9	1.7
Oilseeds	0.8	0.8	0.7	0.7	0.9	0.8	0.8	0.9	0.8	0.8
Vegetables	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.2
Root crops	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2
Fruit crops	0.05	0.05	0.1	0.1	0.05	0.1	0.1	0.1	0.1	0.1

Source: Authors' computation using CSA annual reports (CSA Volume I 2005-2014).

According to CSA estimates, total agricultural output in 2013/14, estimated at 32 million metric tons, was 124 percent higher than that in 2004/5 with annual growth in output averaging 9.4 percent (Table 3.2). Growth in agricultural output was

[7] The summary statistics in this section pertain to smallholder farmers referred to as "Private peasant holders" in CSA reports and cover the main agricultural season, locally known as *meher*. The *meher* cropping season follows the major rains during June through September, and defined in terms of harvesting, it runs from September to February. There is also a second rainy season, called *belg*, which primarily applies to some areas. The *belg* cropping season typically starts in March. According to CSA estimates, only 10 percent of all land was cultivated during the *belg* season in 2013/14. Over the last decade, there has been no major change in the relative importance of the *belg* compared to the *meher* for agricultural production.

[8] CSA uses the term "grain" to refer to an aggregate crop category that includes cereals, pulses, and oilseeds.

[9] Aggregating *belg* and *meher* area and comparing it to area cultivated by commercial farmers, defined as those cultivating more than 25.2 hectares.

[10] For instance, 40 quintal (qt)/ha of maize by commercial farmers vs. 32 qt/ha by smallholder farmers, and 26 qt/ha of sorghum vs. 23 qt/ha in 2013/14.

mainly driven by increases in cereals output, which grew at 9 percent per year and accounted for 72 percent of the total output on average during the same period. The number of smallholders grew from 11 million in 2004/5 to 15.3 million in 2013/14, an average annual growth rate of 3.8 percent (lower half of Table 3.2).

Table 3.2—Crop output (in millions of quintals) and number of farm smallholders (millions)

Crop	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Crop output (millions of quintals)										
All crops	142.4	156.2	171.9	186.1	198.7	215.5	246.4	258.9	291.6	319.7
Grains	119.1	133.8	149.6	161.2	171.2	180.8	203.5	218.6	231.3	251.5
Cereals	100.3	116.2	128.8	137.2	145.0	155.3	177.6	188.1	196.5	215.8
Pulses	13.5	12.7	15.8	17.8	19.6	19.0	19.5	23.2	27.5	28.6
Oilseeds	5.3	4.9	5.0	6.2	6.6	6.4	6.3	7.3	7.3	7.1
Vegetables	4.3	4.5	3.5	4.7	6.0	5.6	6.8	7.6	8.5	7.2
Root crops	16.2	13.4	14.1	15.3	12.1	18.1	19.2	16.7	36.3	41.6
Fruit crops	2.6	4.3	4.6	4.6	3.5	4.1	4.9	5.4	4.8	5.0
Number of smallholders (millions)										
All crops	11.0	11.6	11.9	12.9	12.9	13.3	14.3	14.3	15.0	15.3
Grains	10.4	11.0	11.3	12.3	12.2	12.2	13.2	13.5	14.1	14.1
Cereals	10.1	10.6	10.9	11.9	11.9	11.9	12.7	13.1	13.6	13.4
Pulses	6.2	5.9	6.5	6.8	7.1	6.7	6.7	7.5	8.5	8.3
Oilseeds	3.2	3.0	3.3	3.0	3.3	2.7	2.6	3.6	3.8	3.7
Vegetables	4.6	4.6	4.9	5.4	6.1	5.1	5.0	6.4	6.8	6.2
Root crops	4.6	4.5	4.8	5.0	5.1	5.0	5.2	5.6	6.3	6.4
Fruit crops	2.1	2.3	2.6	3.1	2.8	2.6	2.9	3.2	3.4	3.6

Source: Authors' computation using CSA annual reports (CSA Volume I 2005-2014).

Following on from these output data, Table 3.3 summarizes the trends in crop yields, which started from a low base at the beginning of the decade, but have since demonstrated major improvements. Yields in cereals averaged 21.4 quintals per hectare (q/ha) in 2013/14 and ranged from about 28 q/ha in maize to 13 q/ha in teff. Annual growth in yields averaged about 7 percent in all cereals, with specific average annual growth in barley, teff, wheat, sorghum, and maize yields standing at 4.8, 5.2, 5.9, 7.1, and 8.1 percent, respectively. Growth in cereal yields was faster relative to other crop groups.

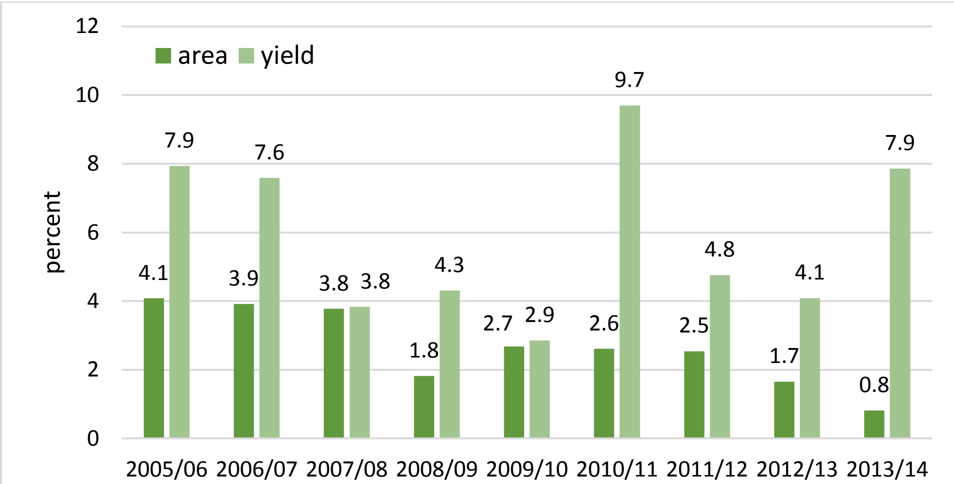
Table 3.3—Crop yields (in quintals per hectare)

Crop	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Cereals	11.8	12.7	14.4	15.3	16.7	16.9	17.8	20.0	21.6	21.4
Pulses	8.7	8.5	9.5	10.5	12.0	11.8	13.2	13.1	13.7	14.5
Oilseeds	5.4	4.8	5.5	8.2	8.2	7.8	8.6	8.1	8.4	8.7
Vegetables	57	47	43	50	51	54	58	68	64	63
Root crops	98	78	75	86	87	88	97	92	163	151
Fruits	47	86	83	67	67	73	68	79	70	60

Source: Authors' computation using CSA annual reports (CSA Volume I 2005-2014).

While we analyze the sources of agricultural output growth later on in the next section, Figure 3.1 further illustrates the contributions made by expanding cultivated area and yield growth to output growth for grain. It shows that the contribution of area expansion is declining over time. While cultivated area increased by 4 percent at the beginning of the decade, this had declined to 0.8 percent by 2013/14. Yields have grown consistently more than area expansion over the decade, but compared to the beginning of the decade, the difference has become significantly larger a decade later.

Figure 3.1—Growth in area cultivated and yield of grains



Source: Authors' computation using CSA annual reports (CSA Volume I 2005-2014).

By any standard, the growth in crop output in the last decade has been rapid. But, what is driving this growth? Is this growth sustainable? Are these exceptional growth rates supported by other sources of data? We explore these issues further in the following sections. We start in the following section by decomposing the growth of crop output into its different sources. We then comment on how sustainable these rates of agricultural growth are. Finally, we compare our previous estimates based on CSA data with other data sources to triangulate the robustness of our findings.

3.2. Growth decomposition

To quantitatively determine the sources of agricultural growth in the last decade in Ethiopia, we decompose growth in crop output into growth in application of inputs, exogenous factors, and total factor productivity (TFP). We apply the growth accounting method of decomposition (Solow 1957). The following equation encapsulates the methodology:

$$\Delta TFP = \frac{\Delta Q}{Q} - \sum\nolimits_J w_J \frac{\Delta J}{J} - \alpha \Delta RTS - \beta \Delta Z$$

ΔTFP, ΔQ, ΔRTS, and ΔZ stand respectively for changes between periods t and t+1 in TFP, output, returns to scale, and exogenous factors that affect production, respectively. α and β stand for the rate at which output changes per unit change in returns to scale and exogenous factors, respectively. w_j stands for wage or price paid per unit of input J used, where J includes primary inputs (labor, land, capital) as well as a number of intermediate inputs such as chemical fertilizer, improved seeds, pesticides, irrigation, and services. In Appendix 2 we provide a more detailed explanation of the methodology used and its caveats, and indicate sources of the data.

In the second column of Table 3.4 we provide changes in real crop output between each pair of consecutive years. The remaining columns of this table provide the results of analyses pertaining to factors affecting growth (growth accounting analyses), including the contribution of changes in input use on output growth as provided in columns 3 to 10. The last row summarizes the average annual growth in output and the corresponding contributions originating from various sources. Accordingly, average annual growth in crop output averaged 8.8 percent during the decade (column 2). On average, about 31 percent of this growth came from increases in the amount of labor applied to crop production (column 3). Similarly, expansion in cultivated land accounted for about 13 percent of the growth in crop production (column 5). A further 11 percent of the growth originated from increase in improved seed use (column 7), and 8 percent from chemical fertilizer use (column 6). Finally, rural roads and returns to scale contributed 3.3 and 8.3 percent, respectively, to overall crop output growth.

Table 3.4 also provides a basis to explore growth in crop output resulting from changes in TFP, possibly linked to farmers' better management skills because of improved education or access to improved information (Sumner 2014).[11] The

[11]Note, however, that in as much as inputs actually used in crop production are excluded from the growth accounting analyses, changes in TFP overstate improvements in techniques of production or know-how. In such cases, changes in TFP also include the contribution of inputs excluded from the analyses.

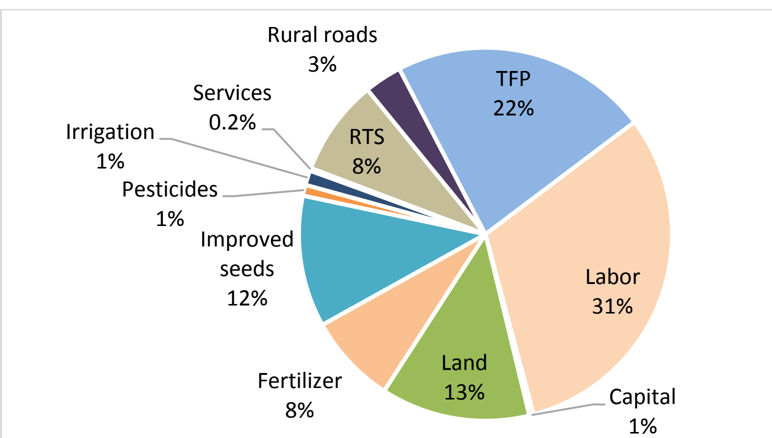
average annual increase in TFP was 2.3 percent during the period (implied by column 13).[12] It is interesting to note that the rates of increase were high during the early part of the decade (around 7 percent in 2005/06 and 6.3 percent in 2006/07), possibly reflecting the considerable investment in extension provision made since the late 1990s, and the growth potential being tapped from the initially low levels of productivity. Changes in TFP hovered around 0.5 percent to 3 percent for the rest of the period (Table 3.4 and Figure 3.2). Results of the growth accounting analyses, not only indicate the importance of labor and land in output growth recorded in the last decade, but also indicate the growing importance of modern inputs. Relative to the contribution of labor and land, modern inputs contribute less in absolute terms, however their contribution to growth has been increasing over time, especially growth from chemical fertilizers.

Table 3.4—Contribution of inputs, other factors, and TFP to crop output growth, %

		Primary inputs			Intermediate inputs						Contribution of		
Year	Change in real crop output (ΔQ/Q) (1)	Labor (2)	Capital (3)	Land (4)	Fertilizer (5)	Improved seeds (6)	Pesticides (7)	Irrigation (8)	Services (9)	Contribution of inputs $\left(\Sigma_f w_f \frac{\Delta x_f}{x_f}\right)$ (10)	Returns to scale (11)	Rural roads (12)	Δ TFP (13)
2005/06	15.0	24.1	0.3	5.4	14.6	2.9	1.0	0.9	0.2	49.5	1.6	2.7	46.2
2006/07	11.0	19.8	0.2	10.2	1.7	3.9	0.8	1.3	0.3	38.1	1.0	4.1	56.8
2007/08	8.0	43.6	0.7	19.1	1.5	3.9	1.0	1.8	0.3	71.7	1.5	3.7	23.1
2008/09	6.5	51.4	1.0	4.7	1.7	23.1	0.0	2.2	0.2	84.3	3.6	4.6	7.4
2009/10	8.7	36.3	0.3	16.1	0.3	28.3	1.1	1.6	0.2	84.3	11.5	2.4	1.8
2010/11	10.3	29.3	0.1	13.0	6.8	22.7	0.9	1.0	0.2	74.1	14.8	5.7	5.4
2011/12	5.0	33.2	0.2	23.6	13.0	7.6	0.2	2.1	0.2	80.2	11.8	2.3	5.7
2012/13	8.2	19.2	0.1	11.6	15.5	4.6	1.6	0.2	0.2	53.0	12.7	1.7	32.7
2013/14	6.6	23.2	0.4	12.6	15.0	5.7	2.0	0.3	0.2	59.3	16.5	2.0	22.2
Average	8.8	31.1	0.4	12.9	7.8	11.4	0.9	1.3	0.2	66.0	8.3	3.3	22.4

Source: Authors' computations using data from CSA (Volumes I, II, III, and IV 2005-2014) and National Bank of Ethiopia (2014).

Figure 3.2—Contributing factors to crop output growth, 2004/05–2013/14



Source: Authors' computations using data from CSA (Volumes I, II, and III 2005-2014) and National Bank of Ethiopia (2014).

A cursory look at outcomes in other countries provides a further perspective. Table 3.5 reports on maize and wheat yield levels and growth rates during 2004-2013 for selected countries. The impressive growth rates recorded in Ethiopia are clearly from a low base and the country had, and still has, a lot of catching up to do relative to those with higher yield levels. For instance, in 2004 Ethiopian maize yields were less than a quarter of those in Egypt and a fifth of those in the USA. By 2013, the gap narrowed, although still considerable, with Ethiopian maize yields reaching 44 percent of Egypt's and a third of USA's yield levels.

[12] Multiplying each entry of Columns 3-13 in Table 3.4 with the corresponding entry in Column 2 and then dividing by 100, will give the contribution to growth in real crop output of growth rate of each factor in percent. For example, if we use this method of calculation, the contribution of TFP is 6.91 in 2005/06 and 1.46 in 2013/13, which, averaged across the period provides, annual average growth rate is 2.3 percent (last row of Table A2.3).

Table 3.5—Maize and wheat yield levels (mt/ha) and growth rates, selected countries, 2004-2013

	China	Egypt	Ethiopia	Kenya	United States of America
			Maize		
2004	5.1	7.9	1.6	1.9	10.1
2013	6.2	7.2	3.2	1.6	10.0
Annual Average Growth rate (%)	2.3	-1.0	11.1	-1.8	-0.1
			Wheat		
2004	4.3	6.6	1.5	2.5	2.9
2013	5.1	6.7	2.4	3.0	3.2
Annual Average Growth rate (%)	2.1	0.2	6.8	2.5	1.0

Source: Authors' computation using FAOSTAT data (http://faostat3.fao.org/download/Q/QC/E).

The recent performance of Ethiopia's agriculture also is consistent with the recent recovery and growth of agriculture in many African countries. Nin-Pratt (2015) reports that agricultural output per worker grew by 2 percent during the period 2001-2012.[13] This compares to 0.6 percent growth during 1990s and no growth in the 1970s and 1980s. He also estimates annual average TFP growth rate of 2.2 percent for the best performers (ranging between -1.0 percent and 4.2 percent) during the period 1995-2012. Ethiopia's TFP growth rate for the same period stands at 2.6 percent.

3.3. Complementary data on agricultural growth

We complement the data on agricultural change from CSA with that from other rural household datasets that have been collected over the last decade in Ethiopia. We present four complementary methods of measuring agricultural growth. First, we compare yield measures of the main cereals collected in large rural household surveys. These include surveys implemented to measure the impact of the Agricultural Growth Program; the baseline survey of the Feed-the-Future program; the baseline survey of the Agricultural Transformation Agency; a survey to understand the teff value chain; a survey on the impact of teff row planting; and a survey on cereal availability in the country. These surveys cover relatively large parts of the country, including the areas with high potential for crop agriculture, and are comparable over time. A description of these surveys and consequent datasets is given in Appendix 3. Given that they were fielded in different areas and with different methodologies, caution is required in comparing yields over time. However, growth rates in yields of the five major cereals calculated using these different surveys generally are similar to the growth rates obtained from CSA data, except for sorghum (Table 3.6).

Table 3.6— Estimates from alternative datasets of annual cereal yield growth in Ethiopia, %

Crop	CSA	Ad hoc surveys	ERHS	CSA	CSA
Period	**2005-2014**	**2008-2013**	**2004 – 2009**	**1997-2012**	**2001-2012**
Number of surveys	**Annual**	**8 surveys**	**2 surveys**	**Annual**	**Annual**
Teff	5.8	4.7	1.7	4.2	4.6
Maize	6.2	6.2	0.4	3.4	4.2
Barley	4.8	6.8	10.1	-	-
Wheat	5.4	6.3	3.6	4.0	3.6
Sorghum	5.4	-1.8	-	4.5	4.8

Source: Authors' computation

Second, we also use data from the Ethiopian Rural Household Survey (ERHS), a unique longitudinal household survey that contains information on agriculture, consumption, assets, and income for more than two decades in 15 villages across the country. Almost 1,500 households in this survey are analyzed over the period 1994 to 2009, and therein we found significant improvements in yields over time. The real value of output grew annually by 5.2 percent. This growth rate was

[13] This pattern has been uncovered, albeit with different rates, by Yu and Nin-Pratt (2011) and others. Note also that the measure used is growth in output per worker rather than output. Therefore, it is not a direct comparison.

particularly rapid during the 2004-2009 period, when it averaged 6.7 percent. Average annual yield growth rates over the 2004-2009 period were 1.7, 0.4, 10.1, and 3.6 percent for teff, maize, barley, and wheat respectively (Table 3.6).

Third, as the last decade has been characterized by relatively good weather, as well as having recovered from a major drought at the beginning of the 2000s (which led to lower production levels at the start of the decade), we estimate growth rates based on CSA data, but for longer time periods. Table 3.6 shows that growth rates in yields over these longer periods for all cereals are significantly lower than those estimated for the period 2005-2014 (for a discussion of these longer periods, see Mellor (2014) and Mellor and Kuma (2014)). As the harvest in 2015 has been disrupted by irregular rain patterns, it is expected that growth rates would decrease if the yield growth analysis were to be extended beyond 2014 (EHCT 2015).

Fourth, focus groups in the AGP survey in 2011 were asked to evaluate yields at the time of the interview compared to ten years earlier.[14] All cereals were perceived to have shown significant yield growth in these communities. The highest yield growth was noted in the case of maize (44 percent) and wheat (35 percent). Yields of other cereals grew as well, but growth rates were lower, ranging from 20 percent, 18 percent, 17 percent, and 16 percent in the case of white teff, barley, black teff, and sorghum, respectively. Moreover, these focus groups were asked to evaluate how area cultivated had changed. Almost 80 percent of the communities stated that area cultivated had increased in their communities, and that this increase in cultivated land amounted to approximately 28 percent over the last decade. This is in line with estimates at national level by CSA.

Therefore, these complementary sources of data all illustrate significant yield and production growth in the cereal sector in the last decade, as shown earlier with CSA data. However, the available data also point to a number of issues that require further investigation. First, while growth rates between the different methods are found to be similar, notably there are differences in yield levels between these different data sources and survey methods. The national statistics on yield are collected through crop-cut methods, while the “ad hoc” and ERHS surveys rely on recall data. Methodological issues are likely to exist. Further experiments to understand and explain the differences in different yield collection methods in the Ethiopian context are called for (see Beegle et al. 2012; Carletto et al. 2013; Deininger et al. 2011).

Second, growth in cereal output over the last decade is estimated to be significantly larger than human consumption growth (although there is lack of consumption data during the second part of the period studied, i.e. 2011-2014). Further research to understand changes in the food balance, wastage and food losses, feed demand (Mellor 2014; Mellor and Kuma 2014), seed demand, formal and informal export and imports[15], possible issues with comparability of statistics over time[16], and changes in food demand by an increasing population (including international refugees) are some of the elements to consider. Moreover, real prices of cereals have not fallen over this period, which would have been expected in a situation where supply exceeds demand growth. Cereal price formation and the link of increasing incomes with food demand should be better understood in the Ethiopian context, e.g., Tafere et al. (2010) and Berhane et al. (2012).

Third, more detailed and updated analysis on land use changes in the country would be useful to increase understanding about where the additional agricultural land (an increase of 2.8 million hectares over the last decade) has derived from and the implications of this change in land use. CSA showed that fallow land had declined from 1.4 million hectares in 2004/05 to 0.7 million in 2013/14, likely contributing to the provision of additional cultivated land. Although deforestation is known to occur in the remaining forested areas of the country, data on recent rates of deforestation on a nation-wide basis are not available. McKee (2007) found rates of deforestation of 146,000 ha/year between 2000 and 2005. Butler’s (2006) estimates are similar with a loss of 141,000 ha/year during the period 2000-2005 (reducing the forested area from 13.7 million ha to 13.0 million ha). In a detailed land-use analysis in the north-western highlands, Teferi et al. (2013) show that the annual rate of increase of cultivated land has slowed down over time, which suggests a decrease in the extension of agricultural land over time.

[14] Focus groups were constituted by at least five people knowledgeable about the community, such as community leaders, producer association chairmen, elders, priests, and teachers. At least one of the five respondents was required to be female and a representative of the youth was also included in the group.

[15] Average official grain imports have been highly variable over the last decade, with an annual import level of 963,000 tons per year (based on NBE 2014). The average ratio of grain imports over grain output stood at 5.3 percent.

[16] For a discussion on consumption numbers and possible issues with these, see Stifel and Woldehanna (2014) and Mandefro and Jerven (2015); for issues with production numbers, see Dercon and Hill (2009) and Gollin (2011).

4. LAND INTENSIFICATION AND THE ADOPTION OF IMPROVED AGRICULTURAL TECHNOLOGIES

As shown in the previous section, land and labor expansion have seen significant changes over time and are estimated to have been important contributing factors to the increase in agricultural production and land intensification in the country. Using CSA's nationally representative dataset, cultivated land increased by 27 percent over the last decade, while the number of smallholders increased by 39 percent, indicating smaller sizes of farms over time – the average landholding size declined annually by 1.4 percent over this period – and therefore more intensive labor use per unit of land is likely, given the relatively little off-farm opportunities in rural areas (World Bank 2014a). Headey et al. (2014) confirm these stylized facts and document, using recent large-scale survey data from high-potential areas in Ethiopia, how Ethiopia's already small farm sizes have been declining rapidly, as well as how young farmers are cultivating substantially less land than previous generations. They also find that family labor use per hectare increases substantially with increasing land pressure, leading to higher gross incomes per hectare.

Technological change in agriculture - such as the replacement of traditional seed varieties with improved cultivars and the increased adoption of chemical fertilizers, often aided by better water management through improved irrigation – drove the dramatic increase of agricultural output in Asian countries in the 1960s and 1970s, usually referred to as the Green Revolution (Evenson and Gollin 2003). There has since been a significant effort to replicate this revolution in the African continent, and in Ethiopia in particular. Since the early 1990s, Ethiopia has implemented several cereal intensification programs promoting the adoption of modern agricultural technologies. At the center of these strategies has been the push for adoption of chemical fertilizer and improved seed packages by smallholders (Spielman et al. 2010). In this section, we assess in particular to what extent changes in the adoption of improved technologies have occurred in the last decade and how they might have contributed to agricultural growth in Ethiopia.

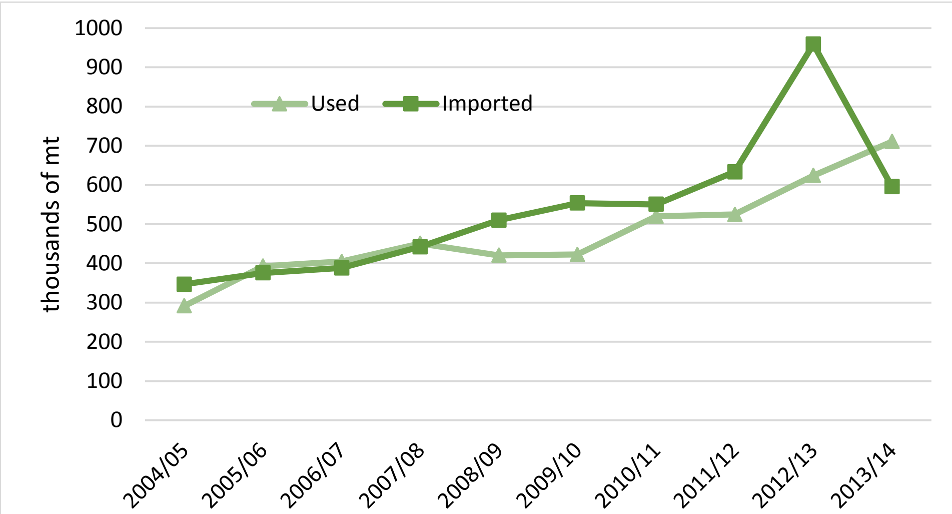
4.1. Chemical fertilizer

Ethiopia has some of the most depleted soils in Africa (IFDC 2012). Despite the introduction of chemical fertilizers in the late 1960s, their application levels have remained low for decades. National annual fertilizer imports remained below 100,000 metric tons (mt) up to the mid-1990s (Rashid et al 2012). However, fertilizer imports and their use have dramatically increased over the last two decades. Figure 4.1 shows the volume of fertilizer imports to Ethiopia over the period 2004/05 to 2013/14 against the volume of fertilizer used by smallholders over the same period.[17] In line with Ethiopia's intensification efforts in the last decade, both fertilizer imports and fertilizer use have increased rapidly. Fertilizer imports have increased by 124 percent from 346,000 mt in 2004/5 to 778,000 mt, the average annual imports of 2012 and 2013. Figure 4.1 further illustrates that fertilizer use by smallholders increased by 144 percent over the same decade. Recent studies have highlighted significant imported fertilizer carryovers (Rashid et al. 2012). This is illustrated by the higher levels of imports compared to farmers' use in Figure 4.1.[18]

[17] Note that data on imported fertilizer amounts is obtained from AISE and Comtrade. The data on fertilizer use came from the agricultural sample survey, collected by CSA.

[18] However, the data used in Figure 4.1 does not capture fertilizer use by large commercial farms, and fertilizer consumption has overall been seemingly close to fertilizer imports over the decade, except for the year 2012/13.

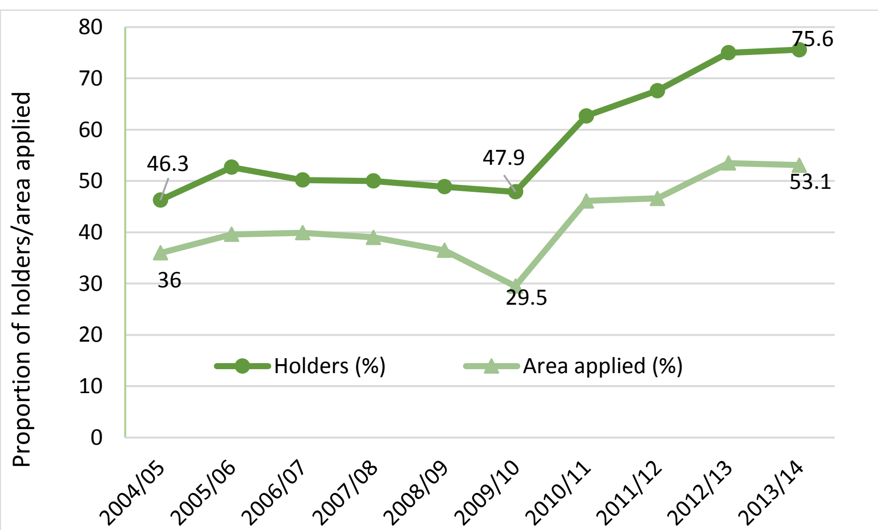
Figure 4.1—Total fertilizer use and imports, mt



Source: Authors' calculations. Data for imported fertilizer is obtained from the Agricultural Inputs Supply Enterprises (AISE) for the period 2004/05 until 2011/12 and from Comtrade afterwards; data for fertilizer consumption is obtained from the Agricultural Sample Survey (AgSS) conducted by CSA.

Owing partly to the attention given to cereal production to achieve food security, most fertilizer use in Ethiopia has been on cereals. According to reports by CSA, 4.7 million holders (46 percent) growing cereals used fertilizer in 2004/05, and this number increased to 10.1 million holders (76 percent) in 2013/14 (Figure 4.2). Cereal area applied with fertilizer – which nearly doubled during the same period from 2.7 million hectares in 2004/05 to 5.2 million hectares in 2013/14, or an increase from 36 percent to 53 percent of the total cereal area – accounted for at least 91 percent of total fertilized area in all years except in 2009/10.[19] The intensity of fertilizer use on those areas covered with fertilizer has also increased over the same period, from 95 kg/ha in 2004/05 to 122kg/ha in 2013/14.[20]

Figure 4.2—Proportions of cereal producing smallholders using fertilizer and cereal area of fertilizer applied



Source: Authors calculations based on AgSS data, CSA.

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[19] The slight kinks on the graphs for the proportions of holders using fertilizer and the proportion of area covered with fertilizer suggest that the major food price rise in 2008/09 may have prevented some holders (possibly net food buyers in rural areas) from using fertilizer. On the other hand, for those who were able to continue using fertilizer, it might have become even more profitable, as is shown later.

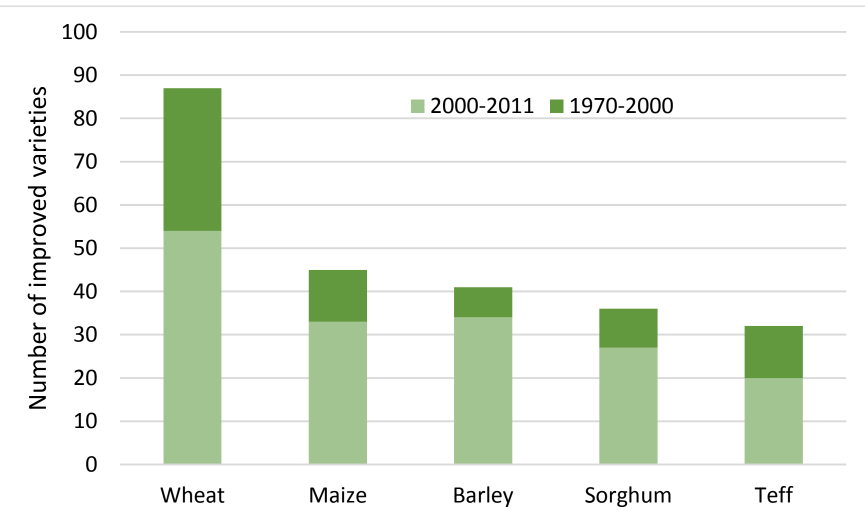
[20] These figures are consistent with those found in other datasets for the same period. For example, using a large dataset of 7,500 households from the Agricultural Growth Programme (AGP), Berhane et al. (2015) report that a little more than 67 percent of these households reported that they had used fertilizer at least once in the last seven years prior to 2010. Access to fertilizer, described as its timely availability and at the required quantity in the village, as well as access to finance to purchase it, increased from 77 percent in 2010 to 86 percent in 2012. However, 16 percent of households in 2010 and 12.4 percent in 2012 have reported that there was not enough supply of fertilizer in their villages.

Fertilizer use on other crops has also shown significant increases over the same period. However, fertilizer adoption is less prevalent for these crops than for cereals. For example, the proportion of area fertilized for other crops, such as pulses, oilseeds, and vegetables, has also nearly doubled in the same period – an increase from 7.9 percent to 14.5 percent for pulses, from 5.4 percent to 11 percent for oilseeds, and from 24.9 percent to 43.1 percent for vegetables. The proportion of area fertilized that was cultivated with root crops also increased from 20 percent in 2003/04 to 31 percent in 2013/04.

4.2. Improved seeds

A greater number of improved seed varieties have been developed and released in Ethiopia in the last decade than at any other time (Figure 4.3). Improved variety release has been particularly dynamic for wheat and maize. These improved varieties of wheat and maize were typically developed and released by the Ethiopian Institute of Agricultural Research (EIAR) in collaboration with the International Maize and Wheat Improvement Center (CIMMYT), one of the CGIAR (Consultative Group of International Agricultural Research) centers. In the case of wheat, it is estimated that 54 of the available 87 improved varieties over the last 40 years were developed and released in the period 2001-2011 (Figure 4.3). This compares to 33 and 45 respectively in the case of maize. For other cereals, the number of varieties were lower, possibly because of lower funding and less international interest. For example, 32 improved varieties of teff were released over the last 40 years of which 20 were released in the period after 2000.

Figure 4.3—Improved varieties of major cereals released over the period 1970-2011



Source: ATA-MoA (2014)

The Ethiopian Seed Enterprise (ESE), a parastatal company, has been a key player in the production and distribution of newly released improved seed varieties. In the past the ESE used to produce most of the newly improved varieties on its own farms, as well as on state farms, with large private farms playing only a minor role in production of new varieties. However, given the consistent shortage of base seed in the system, there has been an increasing decentralization in distribution, with other seed distributors being allowed to participate in the system to cover seed shortages (Alemu et al. 2010). Regional research institutes and private seed companies have therefore become more important over time in improved seed distribution, and it is estimated that there are now more than 30 private, agricultural cooperatives, and parastatal seed producers in Ethiopia (Benson et al. 2014). While there are still important problems relating to timeliness of seed delivery and the quantity and quality of seed provided (Benson et al. 2014; Spielman and Mekonnen 2013; Spielman et al. 2012), better seed availability has improved over the last decade, which has led to higher adoption rates and contributed to higher agricultural growth as shown in the previous section.

Table 4.1 shows, using CSA statistics, how the share of farmers that reported using improved seeds in the cereal sector has increased over the last decade. While overall adoption rates are low, the share has seen significant improvements, with more than a doubling noted over the last decade, from 10 percent of cereal producers in 2004/5 to 21 percent in 2013/4. This seems to have been driven especially by the rapid increase of improved seed adoption in the case of maize: improved seeds were used by 12 percent of the maize farmers in 2004 and 28 percent in 2013. Large increases are also noted in the case of teff, where adoption of improved seeds increased from 1 percent to 5 percent, and of wheat from 4 percent to 8 percent over that same period. While these official data show significant improvement in adoption over time, there might however be significant measurement errors in improved seed adoption data in the country, as discussed below.

Table 4.1—Proportion of improved seed applying farm holders (%)

Crop	2004/05	2009/10	2013/14
Barley	0.8	1.2	0.8
Maize	11.6	15.7	27.6
Sorghum	0.9	1.8	0.4
Teff	1.0	2.4	4.6
Wheat	4.5	4.1	7.7
Cereals	10.1	11.3	21.5

Source: CSA, Agricultural Sample Surveys, 2004/05-2013/14

There are two main types of improved seeds, hybrid and open-pollinated ones. Hybrid seeds often show significant yield gains, but these gains decrease rapidly after the first year of cultivation, thus requiring farmers to purchase new seeds every year in order to maintain hybrid vigor (heterosis). Hybrid seeds are especially important for maize in Ethiopia, and they are estimated to have significant yield advantages over conventional seeds.[21] Benson et al. (2014) estimate, by comparing production and demand figures, that hybrid maize production made up 35 percent of all maize seed demand in Ethiopia in 2013. Zeng et al. (2013) estimated in 2010 that 39 percent of the maize area in Ethiopia was planted with improved varieties, and that these improved maize varieties exhibited a yield advantage of 48 to 63 percent over traditional varieties. It, therefore, seems that CSA estimates are a reasonable approximation of improved maize seed adoption, but they are however lower than adoption rate estimates in the studies mentioned above.

In contrast to hybrid seed, open-pollinated varieties do not exhibit the sharp yield decrease after the first year. Improved varieties can therefore be multiplied by farmers themselves, and can often easily be obtained by farmers through informal distribution channels. This makes it difficult to estimate to what extent these improved open-pollinated varieties have spread in the country. For example, while only 8 percent of farmers report using improved wheat varieties, some key informants estimate that improved cultivars might represent over 75 percent of wheat cultivated in Ethiopia. It seems that CSA survey questions on whether a farmer grows an improved variety is framed in such a way that feedback from the farmer cannot easily capture whether improved seed has been adopted or not. Recent DNA fingerprinting exercises in 3 zones in Oromia seem to confirm this.[22] In this study, 62 percent of wheat farmers in the sample indicated that they use improved varieties, while the DNA analysis puts this number at 96 percent. The differences for maize were lower, seemingly because the use of hybrids that are annually purchased as a signal of the adoption of improved varieties, is in that case much clearer (56 percent indicated improved seed use, while DNA testing showed a 64 percent adoption rate).[23] Box 1 further illustrates to what extent a recent new variety of teff (the *quncho* variety) has quickly taken off in major teff producing zones in Ethiopia.

[21] 62 percent of the released improved maize varieties in the period 2000-2009 were hybrids.

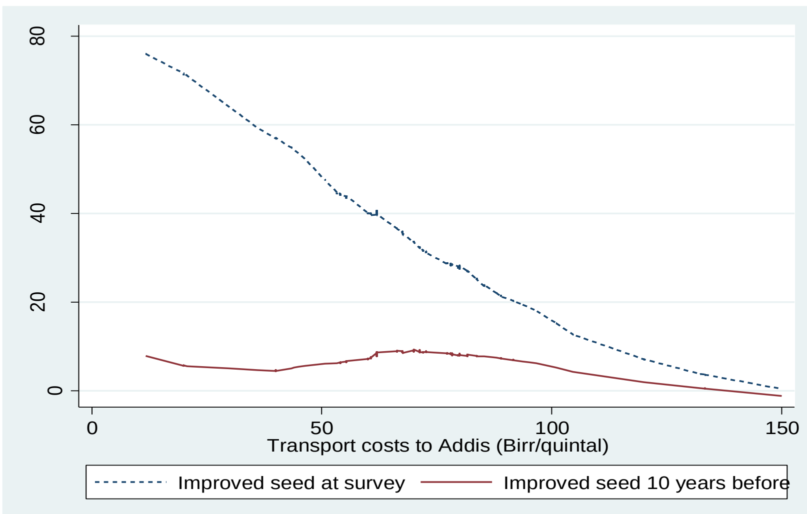
[22] http://www.slideshare.net/futureagricultures/results-dna-finger-printing-pilot-presentation-nairobi-july-14-2014

[23] Based on data from 3,000 farmers surveyed as part of the Ethiopian Agricultural Transformation Agency Baseline Survey in 2012, Spielman and Mekonnen (2013) further estimate that 11, 15, and 34 percent of the farmers obtained improved white teff, wheat, and maize seeds, respectively, from the formal market (regional bureaus of agriculture, cooperatives, NGOs and private firms) the year before the survey. The informal system to obtain seeds – farmer-saved seed and farmer-to-farmer seed exchanges – is significantly more important. By assuming that formal channels sell improved seeds, these numbers suggest that adoption rates of improved seeds – imperfectly measured by renewal rates – are low, but they are however higher than noted in CSA surveys. Also noteworthy, especially for teff and wheat, that no annual purchases from formal channels that distribute improved varieties are required to have had a spread of improved crop varieties in Ethiopia over time as they can spread through sales from farmer to farmer.

Box 1: The *quncho* teff seed success story

Quncho is a white teff variety that was developed and released by the Debre Zeyt research station in the mid-2000s. It combines the preferred white color characteristics of DZ-01-196 and better yield performance of DZ-01-974 (Fufa et al. 2011). Based on a 2012 survey of 1,200 teff farmers fielded in the major production zones, which account for about 40 percent of national teff production, it was estimated that 32 percent of teff producers had adopted the *quncho* variety in these zones (Minten et al. 2013). For those who adopted the variety, it was planted on 83 percent of the white teff area. None of these teff farmers has used *quncho* three years earlier, therefore illustrating the rapid speed of adoption. Moreover, a strong spatial pattern emerged in the adoption of improved white teff seeds, with those farmers living close to urban centers more readily adopting improved teff - mostly *quncho* - varieties (Figure 4.4).This is possibly driven by better access to *quncho* as well as better incentives for adoption because of higher output prices. It seems overall that the rapid *quncho* adoption was explained by the large price premiums offered for the preferred white teff in the market, good productivity results, and an important push to stimulate improved seed production and its adoption through different channels, including private and public institutions (Assefa et al. 2013).

Figure 4.4—Changes in adoption of improved teff seeds by distance to Addis Ababa (2001-2011)



Source: Minten et al. 2013

4.3. Other modern and improved practices

We further look at two other modern agricultural practices, irrigation and pesticides, which were also major contributors to the Green Revolution in Asia. Table 4.2 shows that access to irrigation is low and has not changed significantly in the last decade for any of the crop categories. Other data sources on irrigation, however, find much larger areas that are irrigated than those reported by CSA. For example, Hagos et al. (2009) estimate that the area under irrigation in 2006 was as high as 5 percent of total cultivated area. Mulat (2011) places the total irrigated area in 2011 at 610,878 hectares, or about 5 percent of all crop area. This is in line with estimates by Awulachew (2010). The progress report on the Growth and Transformation Plan (GTP) (MoA 2013) indicates significantly larger areas under irrigation as well (Table 4.2). These larger numbers are possibly explained by the fact that irrigation is practiced more by larger farms, such as sugarcane farms, or that irrigation is used more during the *belg* period for off-season crops.

When we further look at the use of pesticides, we also note significant increases over time. While 13 percent of the crop area was exposed to pesticides in 2004/05, that percentage increased to 21 percent in 2013/14 (Table 4.2). The proportion of cropped area to which pesticides were applied was essentially constant between 2004/05 and 2008/09, while it grew at an average annual rate of 16.5 percent between 2008/09 and 2013/14, mainly driven by the rapid increase in the proportion of cereal area to which pesticides were applied.

Table 4.2—Area under irrigation and pesticide use

	2004/05	2009/10	2012/13
Irrigation			
Crop area that is irrigated (*meher*, %), based on CSA annual reports			
All crops	0.8	1.0	0.8
Cereals	0.8	1.0	0.6
Pulses	0.5	0.5	0.2
Oilseeds	0.2	0.1	0.3
Vegetables	5.9	3.7	5.2
Root crops	6.8	5.4	9.1
Irrigated area ('000 ha, *meher* only) - CSA annual reports		154	152
Irrigated area ('000 ha) - MoA Annual GTP progress reports		*853*	*1,830*
Pesticides			
Crop area to which pesticides were applied (*meher*, %)			
All crops	13.0	12.4	21.5
Cereals	16.7	13.4	26.1
Pulses	0.8	9.6	6.5
Oilseeds	1.1	8.7	2.8
Vegetables	2.3	4.1	4.1
Root crops	3.0	3.9	12.6

Source: Authors' computations using CSA annual reports (CSA Volumes I and III 2005-2014).

In short, the analysis presented in this section illustrates that important changes have happened in the adoption of improved agricultural technologies over the last decade. There has been more than a doubling in the use of chemical fertilizer, improved seeds, and pesticides over this period, illustrating the increasing modernization and intensification of agriculture in Ethiopia. The analysis also shows that the uptake of these improved agricultural technologies has especially happened in the second half of the last decade, i.e. from 2009/2010 until 2013/14, and agricultural growth has been linked more with the increasing use of modern inputs in this period while land expansion and TFP growth were major contributing factors to agricultural growth in the period 2004/05 until 2009/10, ,.

5. DRIVERS FOR CHANGE

5.1. Identifying drivers

To identify the drivers for the increasing adoption of improved technologies in the last decade, two conditions are to be met. First, they need to be linked with significantly greater adoption of improved practices. Second, they need to have shown major positive changes over the last decade. In this section we focus on the first issue, using input from literature review as well as primary data analysis. Using data from CSA's Agricultural Sample Survey of 2008/09 (i.e. in the middle of the decade that is studied in this paper), Table 5.1 relates different associated aspects with the adoption of improved seeds or chemical fertilizer for four main cereals in the country, i.e. teff, maize, wheat, and barley. We run a probit model using the adoption of this improved technology (yes=1; no=0) as the dependent variable for these four crops, and household, plot, and climatic characteristics as right hand side variables. Table 5.1 presents the average marginal effects.

The results show large and significant effects for extension, remoteness, and education, except for one out of 12 coefficients (travel time to the nearest city in the case of maize), on improved technology adoption. Farmers who received visits from extension workers are associated with a higher likelihood to adopt improved technologies. Less remote households and more educated households are also more likely to adopt improved agricultural technologies. These factors are significant and consistent with the associates of improved technology adoption. These factors have changed considerably over the last decade (as we will argue below) and we can therefore justify these to be among the main drivers for improved technology adoption in the last decade.

Other factors show significant association with improved technology adoption as well. First, larger plots are associated with a higher likelihood of improved technology adoption. This holds for the four cereals. Second, cultivator managed plots have a lower likelihood of adoption of improved technologies. Third, households' access to credit leads to a higher likelihood of adoption of improved agricultural technologies. However, the effect of these other factors are not significant in all specifications, nor have they shown large changes over the period studied. [24]

Table 5.1—Associates of the adoption of improved seeds or chemical fertilizer in cereal production

Variables	Barley	Maize	Teff	Wheat
Received extension visit (1=yes)	0.3276***	0.5605***	0.3589***	0.3744***
	0.037	0.024	0.025	0.022
Avg. travel time to nearest city (pop. >=50000); hours	-0.0153***	-0.0035	-0.0134**	-0.0201***
	0.004	0.004	0.004	0.005
Age of head (years)	0.0001	-0.0007**	0.0004	-0.0004
	0.000	0.000	0.000	0.000
Household head is female (1=yes)	0.0323**	-0.0003	0.0271*	0.0346**
	0.011	0.009	0.012	0.013
Education (highest grade)	0.0103***	0.0049***	0.0074***	0.0073***
	0.002	0.001	0.002	0.002
Household size	0.0057**	0.0047***	0.0010	0.0043*
	0.002	0.001	0.002	0.002
Plot area in hectares	0.1357***	0.1557***	0.1371***	0.2339***
	0.034	0.024	0.021	0.038
All farm plots combined	-0.0020	-0.0034	0.0088	-0.0003
	0.004	0.004	0.006	0.005
Cultivator owns the land (1=yes)	-0.0262*	-0.0730***	-0.0228*	-0.0361**
	0.011	0.011	0.010	0.013
Cultivator used irrigation (1=yes)	-0.1212***	0.0529	-0.1896***	-0.1441*
	0.023	0.048	0.049	0.057
Cultivator rotated crops (1=yes)	0.0143	-0.0289	0.0611*	0.0590*
	0.023	0.019	0.027	0.027
Cultivator has access to credit (1=yes)	0.0310*	0.0465***	0.1163***	0.0884***
	0.013	0.011	0.014	0.014
Average population density in woreda	0.0000	0.0004***	0.0003**	0.0000
	0.000	0.000	0.000	0.000
Technology adoption rate in woreda (last year); all crops	0.5920***	0.3177***	0.6641***	0.6413***
	0.028	0.032	0.040	0.028
Rainfall, elevation, slope, and climate variables	Included	Included	Included	Included
Observations	18,913	38,390	31,247	19,619

Note: Table shows (average) marginal effects. For dummy variables marginal effect is the discrete change from the base level. Clustered standard errors (at EA level) below coefficients; * p<0.05 ** p<0.01 *** p<0.001

While these results from the national agricultural sample survey illustrate that these three drivers show a significant association with improved technology adoption, the results, however, do not unambiguously show that productivity change can be attributed to these factors because of possible methodological – most importantly endogeneity – issues. A number of authors have looked at this issue with better, but not nationally representative, datasets. We review the literature below.

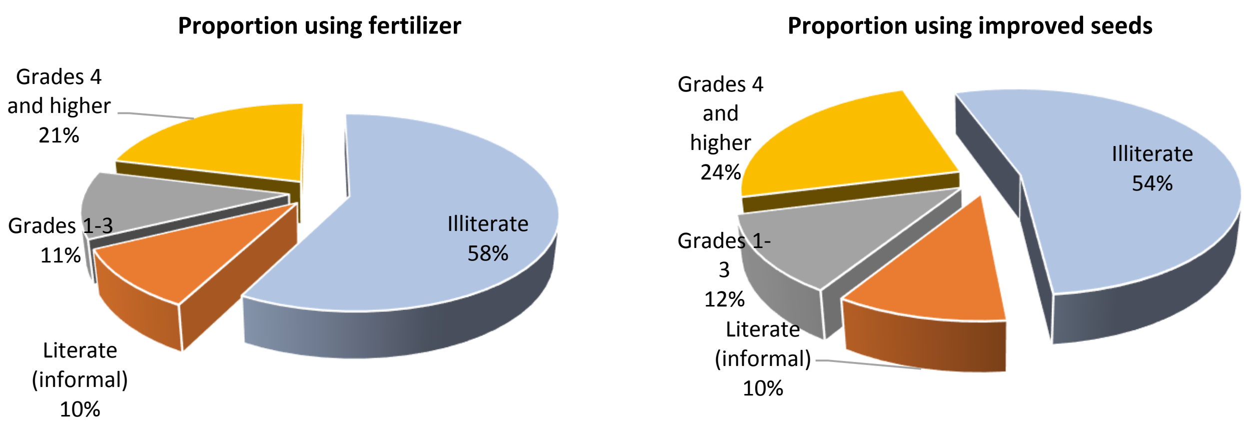
First, a number of studies have assessed the impact of the increased coverage by extension agents. Dercon et al. (2009) have shown that extension has yielded significant impacts on consumption growth. Others show that there is a strong association between increased use of technologies, mainly use of improved seeds, fertilizer and pesticides, and extension services provided (Ragasa et al. 2013; Berhane et al., forthcoming; Minten et al. 2013). Using large-scale panel data in high-potential agricultural areas, Berhane et al. (forthcoming) illustrate that the extension system does not increase productivity directly, but that it works mostly indirectly via its effects on input use. Krishnan and Patnam (2014) further illustrate that the effect of extension diminishes over time and that neighborhood effects become more important in stimulating improved technology adoption.

[24] Moreover, farmers' likelihood of adoption improves with past technology adoption rates in a woreda (district). Indeed, the marginal effect of this variable is the highest in all crops except maize. This may be a measure of spillover or neighbourhood effect (see Krishnan and Patnam (2014)) of extension over time, given that it is lagged.

Second, Dorosh et al. (2012) illustrate the importance of remoteness on the adoption of improved technologies for Africa as a whole. Using data collected in a quasi-experimental setting from a remote area in Ethiopia, Minten et al. (2013) show that a 20 km increase in the distance from the farm to the modern input distribution center and output market led to a 47 kg/ha and 6 kg/ha reduction in chemical fertilizer and improved seed use, respectively. Stifel and Minten (2015) further show a large association of remoteness with agricultural production. These results illustrate large impacts of remoteness on modern input use and they therefore suggest that an improved transportation network contributes significantly to the increase in modern input use.

Third, Huffman (2001) shows that the dominant effect of education on agriculture is technical change. International literature for developing countries shows that more educated farmers are more efficient and adopt modern technologies more easily (Ogundari 2014; Appleton and Balihuta 1996; Jamison and Lau 1982). In the case of Ethiopia, several authors have illustrated the important effect of education on fertilizer use and innovation more broadly, especially in traditional areas in Ethiopia (Endale 2011; Asfaw and Admassie 2004; Knight et al. 2003; Weir and Knight 2004). Illiterate farmers accounted for 63 percent of the total number in an average year during 2004/5-2013/14 (CSA Vol. III 2005-2014). Moreover, the proportion of farmers with informal education was 8.5 percent while those with formal education of grades 1-3 and 4 or higher accounted for 10.5 percent and 18 percent of the total, respectively. Figure 5.1 indicates that relative to their proportion, farmers with education in Ethiopia had higher rates of adoption of modern inputs, as shown by CSA surveys. In contrast, illiterate farmers accounted for 58 percent and 54 percent of the total number that adopted fertilizer and improved seeds, respectively.

Figure 5.1—Educational composition of farmers that adopt modern inputs



Source: Authors' computation using CSA annual reports (CSA Volume III 2005-2014).

Fourth, the ratio of output over input prices has been shown to be a major incentive for the adoption of fertilizer and other improved technologies in Africa (Morris 2007). Spielman et al. (2012) document to what extent incentives matter in the adoption of fertilizer in Ethiopia, in particular. Minten et al. (2013) illustrate for the north of Ethiopia how distances to input distribution centers and changes in value-costs-ratios, driven by transportation and transaction costs, lead to significantly lower adoption rates of chemical fertilizer, as well as improved seeds. The World Bank (2014) further shows that poverty reduction in the country was linked with improved agricultural performance, especially when prices were high, access to markets was good, and fertilizers were used.

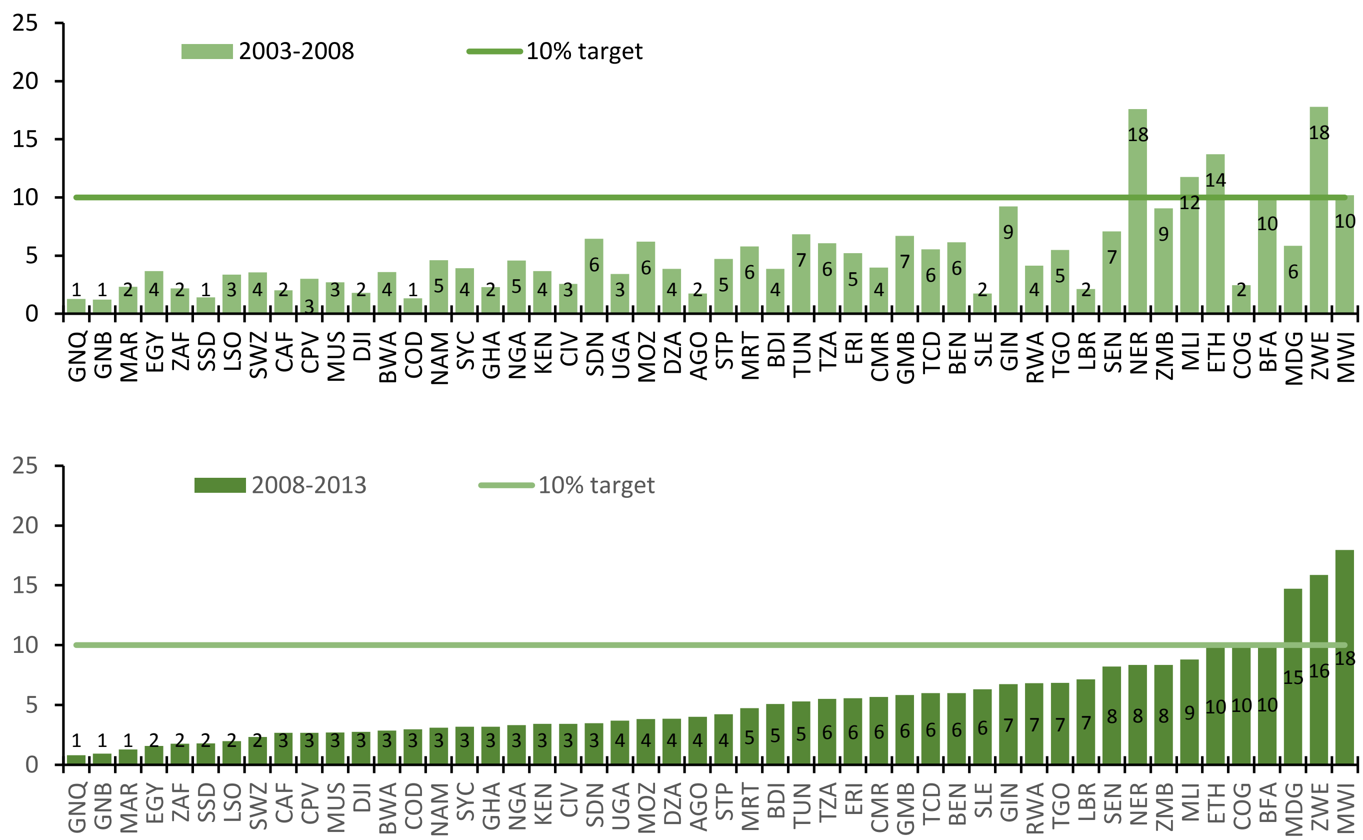
The available evidence therefore shows that these four factors are associated with increasing adoption of improved technologies in Ethiopia. Evidence on the changes in the last decade of these four main drivers – agricultural extension, road infrastructure, education, and incentives – for the adoption of improved agricultural technologies, as well as other factors are discussed in the section below.

5.2. Evidence on changes in drivers

Cognizant of the fact that the vast majority of the Ethiopian population resides in rural areas and mostly derive a livelihood from agriculture, the Government of Ethiopia has for a long time put agriculture at the center of its national policy priorities. The Agriculture Development Led Industrialization (ADLI) strategy was formulated in the mid-1990s to serve as a roadmap to transform smallholder agriculture in the country. The emphasis and focus given to ADLI paved the way for rethinking overall growth pathways and served as a blueprint of the national development agenda in the decades to come. ADLI envisioned national development through concerted efforts to transform Ethiopia's traditional agriculture sector first, which according to the plan, would eventually provide impetus to other sectors, including manufacturing. Rural education and health, rural infrastructure, extension services, and strengthening of public agricultural research were among the top priorities in the agenda.[25]

Ethiopia signed the CAADP agreement in 2003 and was one of the few countries in Africa to stick to the target of 10 percent of annual government expenditures going to agriculture.[26] This is shown in Figure 5.2. Agricultural expenditures were split between the periods 2003 to 2008 and 2008 to 2013 for all African countries where these expenditure data were available. African countries were ranked with respect to the level of expenditures in agriculture for the period 2008 to 2013. The graph illustrates that Ethiopia was one of only four countries that met the 10 percent target over the two periods (the three other countries were Malawi, Zimbabwe, and Burkina Faso). Ethiopia's agricultural expenditures made up 17 percent of the total budget in the first period (2003 to 2008). This declined to 10 percent for the period 2008 to 2013 (Benin 2014).[27] The sections below illustrate the extent to which some of these expenditures have contributed to facilitate improved agricultural performance and the adoption of improved agricultural technologies, which are likely to have contributed to a reduction in inefficiencies – for example, information, input and output markets, labor markets, credit markets, and risk – that have hampered improved technology adoption in the past (Jack 2011).

Figure 5.2—Agricultural expenditures over total government expenditures in Africa, 2003-08 and 2008-13, percent



[25] Government expenditures in Ethiopia have over the years been guided by several plans. Since 2005, a five-year planning period was used. The period 2005-2010 was guided by the Plan for Accelerated and Sustained Development to End Poverty (PASDEP). The period 2010-2015 was the first phase of the Growth and Transformation Plan (GTP). In these plans, Ethiopia has consistently advanced the agricultural sector as one of the important sectors in which to invest.

[26] The Comprehensive Africa Agriculture Development Programme (CAADP) was endorsed at the African Union Heads of State Summit as a New Partnership for Africa's Development (NEPAD) program in July 2003.

[27] One caveat in the case of Ethiopia might be that the large share (on average 60 percent over the period 2010-2014) of the budget of the Ministry of Agriculture is used towards the Disaster Risk Management and Food Security (DRMFS), financing a large food safety program (the Productive Safety Net Programme), in the country.

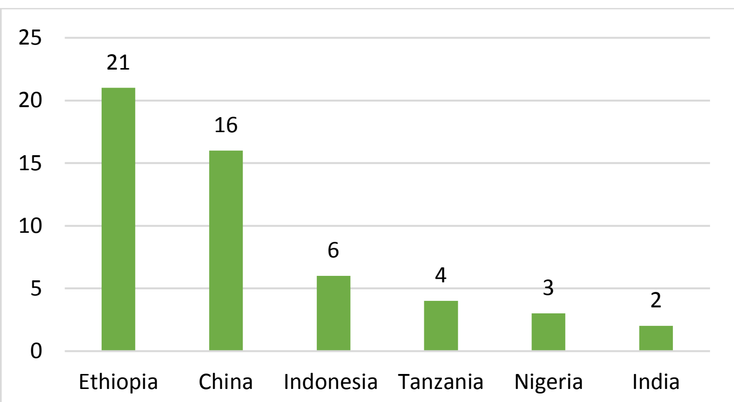
Source: Benin (2014)

CHANGES IN INFORMATIONAL EFFICIENCY AND THE ROLE OF AGRICULTURAL EXTENSION

Since 1992, the Government of Ethiopia has invested in an unprecedented way in providing a public agricultural extension system (Davis et al. 2010). These expenditures largely focused on the provision of advisory and training services through a public extension structure that extends from the federal ministry to the regions and down to the *woreda* and *kebeles* through frontline extension agents.[28] In an effort to redress the challenges faced and to scale up best practices learned in an earlier period, the government started a more comprehensive large-scale extension system in 2002.[29] As part of the scaling up, a new wave of training of Development Agents (DAs) was launched through Agricultural Technical and Vocational Education and Training (ATVET) centers, newly established throughout the country. The PASDEP plan outlined the assignment of at least three DAs (specializing in crop production, livestock, and natural resources) in each *kebele*. The new DAs were trained and mandated to carry out agricultural extension services to train farmers in each *kebele*. Each *kebele* planned to build a Farmer Training Center (FTC) where farmers would have access to participatory demonstrations for improved technologies and new farming systems.[30]

By 2008 and 2009, the ATVET centers which were established throughout the country, had trained some 60,000 DAs and around 8,500 Farmer Training Centers (FTCs) had been built at the *kebele* level (Davis et al. 2010).[31] As seen in Figure 5.3, Ethiopia achieved one of the strongest extension agent-to-farmer ratios in the world, roughly estimated at one DA for every 476 farmers or 21 DAs per 10,000 farmers, significantly higher than in other countries such as China, Indonesia and Tanzania, where this ratio stood at 16, 6, and 4, respectively (Davis et al. 2010).

Figure 5.3—Comparative extension agent-to-farmer ratio for selected countries (per 10,000 farmers)



Source: Davis et al. 2010

CSA data allow us to compare changes in advice given to farmers, as questions are asked in its annual surveys on access to extension. These clearly indicates the increasing presence of extension agents over the last decade. Figure 5.4 shows that the number of smallholders reporting the use of the extension advisory service tripled from 3.6 million in 2004/05 to 10.9 million in 2013/14, an increase from 33 percent of all smallholders to 71 percent (graph on the right). The number of

[28] A successful pilot run by Sasakawa Global (SG) - 2000 farmer plots in 1993 that promoted productivity-enhancing technologies, having access to inputs and credit as well as training, and closely supervised by research and extension personnel, convinced the Government of Ethiopia to adopt an aggressive extension intervention in 1995, coined as Participatory Demonstration and Training Extension System (PADETES). PADETES provided packages of improved inputs, mainly chemical fertilizers, improved seeds and credit. PADETES saw a massive flow of public resources to extension services and use of improved agricultural technologies. In subsequent years, improved use of technologies coupled with good weather, led to unprecedented increases in production levels, particularly in some high potential zones. This was, for example, manifested by the maize-bumper- harvest crisis in 2001/02 where maize prices dropped to a historical low. In some other areas, productivity increases were not as high as those observed in SG-2000, partly due to an insufficient number of extension staff to supervise the system.

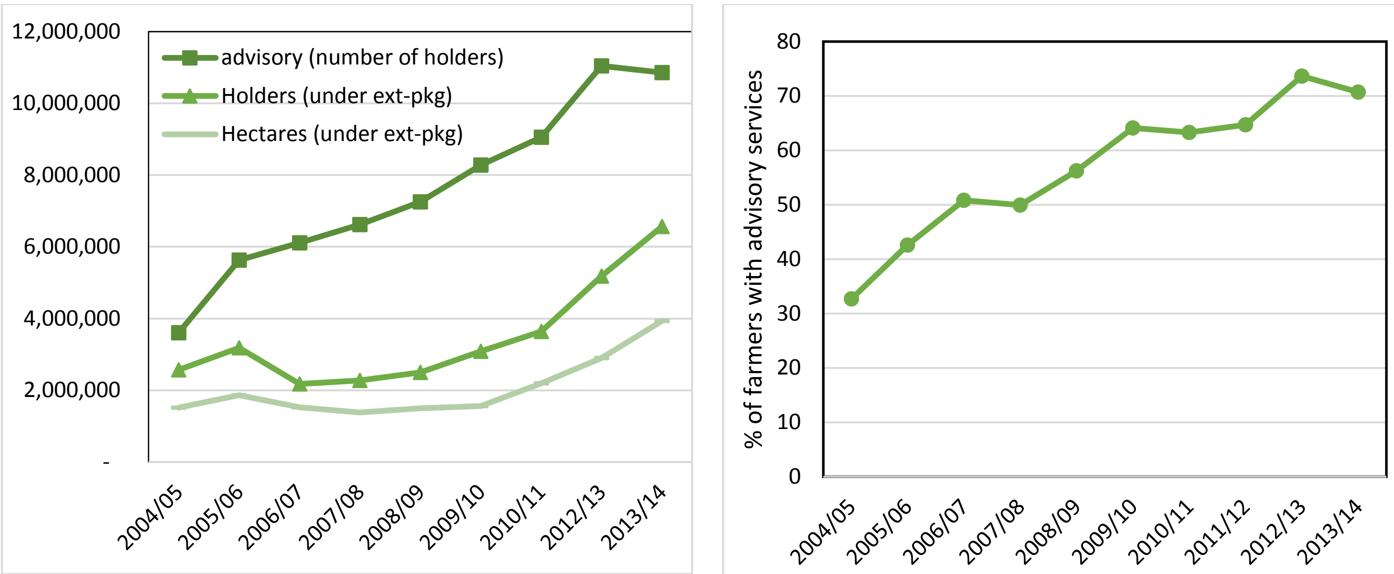
[29] A well-known 2002 ‘Green-Book’ of the Government of Ethiopia on ‘rural development policies and strategies’ outlines the directions and approaches of the new revitalized public extension system that the government planned to implement in the next decade (MoFED 2003). Core directions underlined in this document include the proper utilization of human labor, agricultural land, proper attention to local knowledge and best practices, agroecology-based innovations of specialization and diversification, as well as the need for integrated development approaches.

[30] The national extension coordination system was overhauled to administer the newly introduced institutional features. The regional and *woreda* offices were strengthened and given additional functional mandates to run the new system. All of these came with substantial additional budgetary implications that required re-allocation of resources from other areas as well as aligning and coordination of donor support to match these new activities.

[31] More were established through the Agricultural Growth Program (AGP) in the remaining kebeles at the beginning of the 2010s.

smallholders that participated in various crop type extension packages more than doubled from 2.6 million in 2004/05 to 6.6 million in 2013/14. In the same period, the cultivated area covered by the extension package program increased from 1.5 million hectares in 2004/05 to 3.9 million hectares in 2013/14. Moreover, most of the farmers seem satisfied by the services that these extension agents deliver (Davis et al. 2010; Berhane et al., forthcoming),

Figure 5.4—Number and share of holders and area covered through the public extension system, 2004/05-2013/14



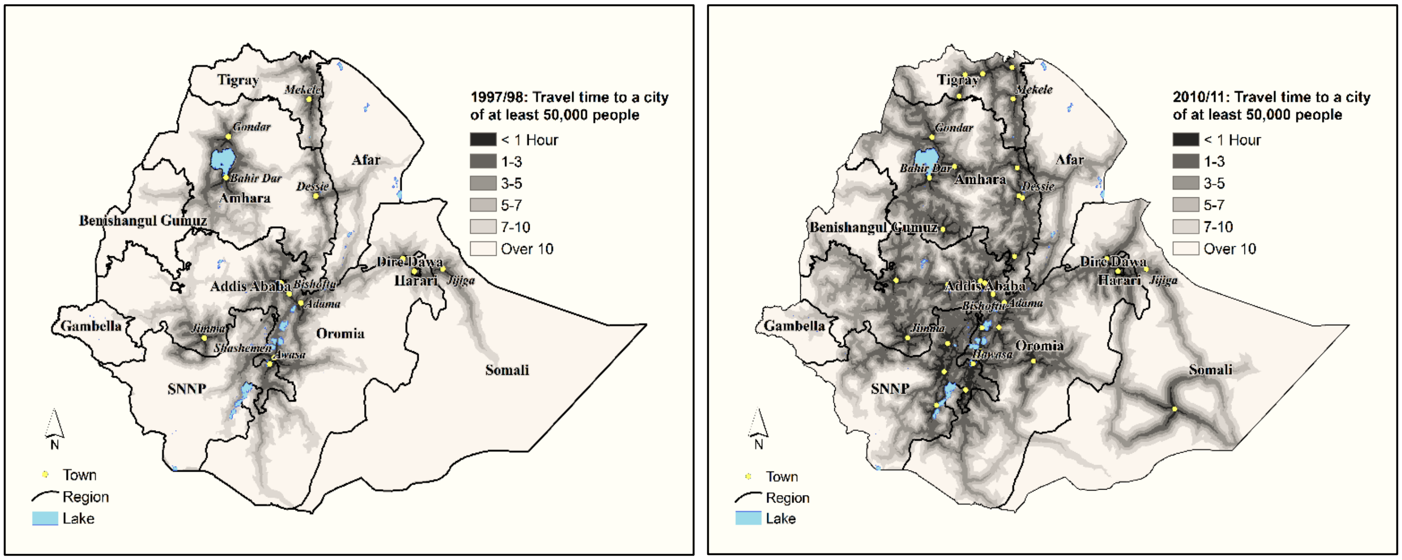
Source: Authors' computations using CSA annual Agricultural Sample Survey household level data (CSA 2004-2014)

CHANGES IN INPUT AND OUTPUT MARKET EFFICIENCY

Well-functioning agricultural marketing systems are important anywhere in the world but especially so in Ethiopia given disastrous implications in the past of badly functioning food markets for food security, with food stocks available in some parts of the country and widespread famine in other parts (von Braun et al. 1998). Major reasons for historically badly functioning food markets in Ethiopia have been linked to lack of market information, bad road infrastructure, and high transaction costs (e.g. von Braun and Olofinbiyi 2007). However, there have been important changes in this area in the last decade in Ethiopia which have improved the functioning of these markets.

Most importantly, the Ethiopian government has embarked on a large road investment program in the last two decades and the current level of infrastructure development in the country is unprecedented. The total length of all-weather surfaced roads tripled in less than 15 years, from an estimated 32,900 km in 2000 to 99,500 km in 2013 (NBE 2014). This type of road development has important effects on the connectivity of agricultural markets in the country. In 1996/97, transportation infrastructure connected Addis Ababa to a limited number of urban markets such as Mekelle, Bahir Dar, Jimma, and Dire Dawa. By 2010/11, secondary cities linked to each other, and major corridors linking key market centers were fully constructed (Figure 5.5).

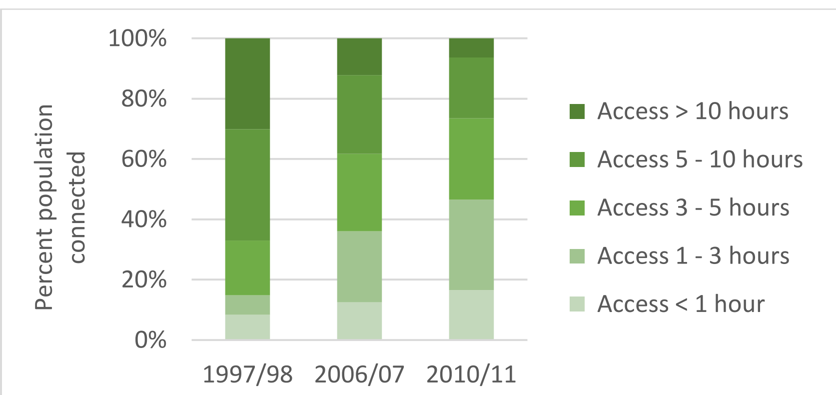
Figure 5.5—Travel time to a city of at least 50,000 people, 1996/97 and 2010/11



Source: Kedir et al. 2015

Moreover, in 1997/98 only 15 percent of the population was within 3 hours of a city with a population of at least 50,000. By 2010/11 this had changed to 47 percent of the population being within 3 hours of such centers (Figure 5.6). The improved road network has further led, among others, to a reduction of travel times between wholesale markets in the country by an estimated 20 percent. However, travel costs might have fallen even further with more competition and a shift to bigger and cheaper trucks (Minten et al. 2014). In this regard, the growing accessibility and expanding transport services have been shown to positively impact agricultural productivity (Li 2011).

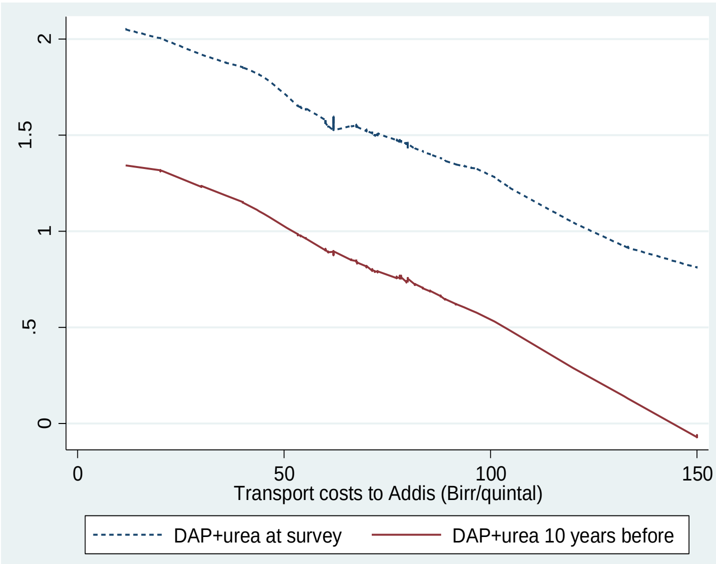
Figure 5.6—Share of population connected to a city of at least 50,000 people, by travel time



Source: Kedir et al. 2015

An important contribution to changes in market performance has also been urbanization and an increasing commercial surplus flowing from rural to urban areas. Urbanization has increased rapidly, but started from a low base. Compared to the beginning of the decade, an estimated 3.7 million more people are living in urban settings in Ethiopia. As urban people are much less likely to grow their own food, this implies that the commercial surplus from agricultural production has increased significantly over the last ten years. Moreover, access to urban centers leads to increasing agricultural intensification and urbanization, which can then act as an engine of agricultural transformation (Schultz 1951). For example, Figure 5.7 shows that adoption of chemical fertilizer – DAP and urea – for teff production was significantly higher in villages close to Addis than in more remote ones. While a significant improvement is seen over time for most farmers, intensification, however, has been more pronounced in villages close to cities (see also Kedir et al. 2015).

Figure 5.7—Changes in adoption of chemical fertilizer in teff production by distance to Addis Ababa

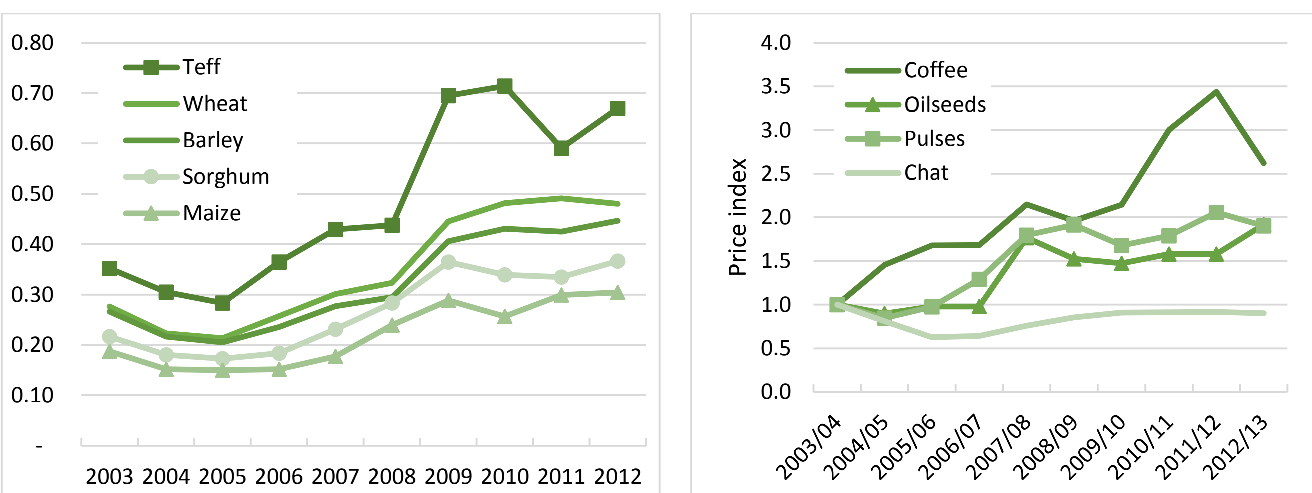


Source: Minten et al. 2013

Over the last decade, prices in input and output markets have changed significantly. leading to improved incentives for agricultural intensification. This has been the case for in both the tradable and non-tradable agricultural sub-sectors. First, Figure 5.8 illustrates the ratios of output (of the five main cereals) to chemical fertilizer prices, which was twice as high in 2012 than in 2004, indicating improved incentives for chemical fertilizer use for the production of these crops.[32] This changing ratio over time seems to have been linked to a number of factors including fixing the margins for chemical fertilizers for the distributing cooperatives in order to keep their prices low (although this led to profitability issues for some of these distributing cooperatives (Rashid et al. 2013)); increasing over-valuation of the Birr exchange rate, making imports cheaper (World Bank 2014); declining international fertilizer prices since 2008 (FAO 2012); and high output prices, especially from 2008 until 2010.

Second, international prices for most export crops were significantly higher at the end of the decade than at the beginning. We examine the price evolution of Ethiopia's four most important export commodity groups. Figure 5.8 shows that the price of coffee was 2.5 times higher in 2012/13 than in 2003/04, while the prices of oilseeds and pulses were twice as high. In contrast, the price of chat remained stable over this period. This general price increase for export commodities has led to significantly higher export revenues from these export crops, as well as increasing incentives for investments in these commodities, shown for example, in the rapid expansion of sesame cultivation in the country over the last decade.

Figure 5.8—Output – fertilizer price ratio (left) and export price indices (2003/04=1.0) (right)



[32] To calculate these ratios, we rely on average cooperatives union prices of chemical fertilizer reported at the regional level and CSA producer prices collected in a large number of rural zones.

Source: Berhane et al., forthcoming

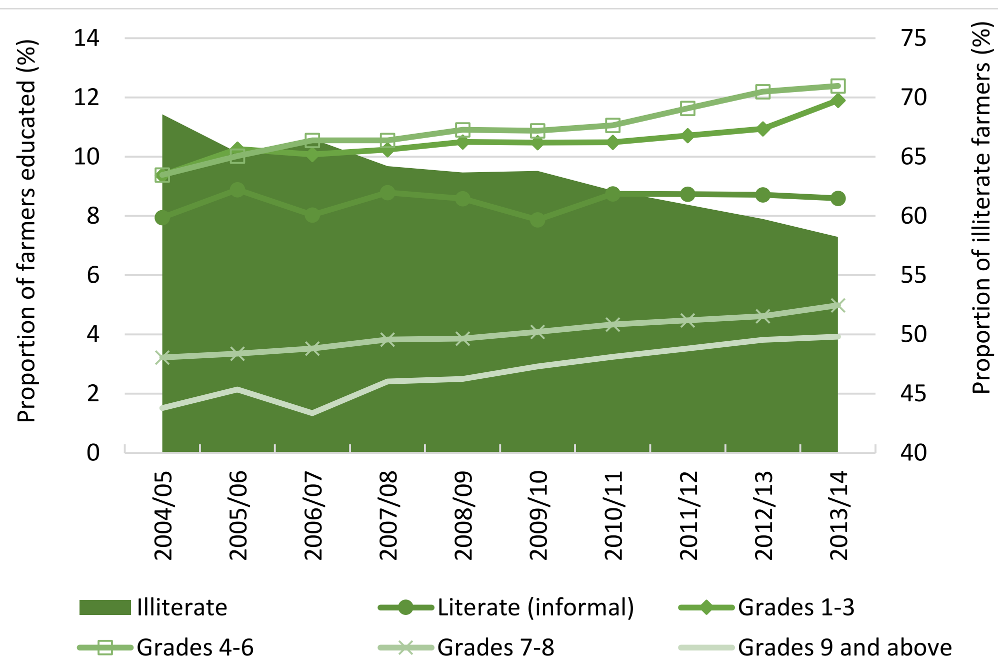
Other factors might have contributed to the reduction of input and output market inefficiencies. First, in the last decade, the use of mobile phones has spread in urban and rural areas in Ethiopia. This is likely to have impacted agricultural trade through better access to information. At the beginning of the decade, none of the agricultural traders and brokers used mobile phones, yet by the end of the decade phones were ubiquitous, making markets more efficient (Minten et al. 2014). On the other hand, the penetration of mobile phones in many rural parts of Ethiopia is still limited, especially when compared to neighboring Kenya. The available evidence also shows that the spread of mobile phones did not lead to major changes in agricultural pricing for farmers who had access to a phone (Tadesse and Bahiigwa 2015).

Second, in 2005 Ethiopia put in place a large safety net program – the Productive Safety Net Program (PSNP) – that covers a large area of the country and benefits more than 7 million vulnerable people. In this program, some of the participants are paid to participate in communal works to help improve communal infrastructure, such as rural roads, but also building irrigation systems and terraces. Taffesse et al. (2014) show to what extent investments in these communal assets have contributed to higher agricultural productivity. However, the area studied comprises only a small part of Ethiopia's cultivated land, and might therefore only partly explain national agricultural growth in the last decade.

CHANGES IN HUMAN CAPITAL ACCUMULATION AND LABOR MARKETS

Accumulation of human capital can affect adoption of improved technologies in important ways as shown above. Additionally, improving gender equality and removing stigma associated with minority groups may reduce labor constraints to technology adoption (Jack 2011). Ethiopia made significant strides to achieve universal primary education coverage, particularly in rural areas. This number of educated farmers may therefore increase as some of these students make their livelihood afterwards in the agricultural sector. Moreover, efforts have also been made to make adult education accessible. Growth in the proportion of farmers with higher levels of education over the last decade is striking. Relying on CSA data, Figure 5.9 shows that the share of illiterate farmers declined at 1.8 percent per year over this period. Furthermore, the proportion of informally educated farmers increased at an average annual rate of one percent, while those in grades 1-6 and 7-8 increased at about 3 percent and 5 percent, respectively. The increase in the proportion of those with at least grade 9 education was remarkable at 15 percent.

Figure 5.9—Proportion of farmers with different levels of education



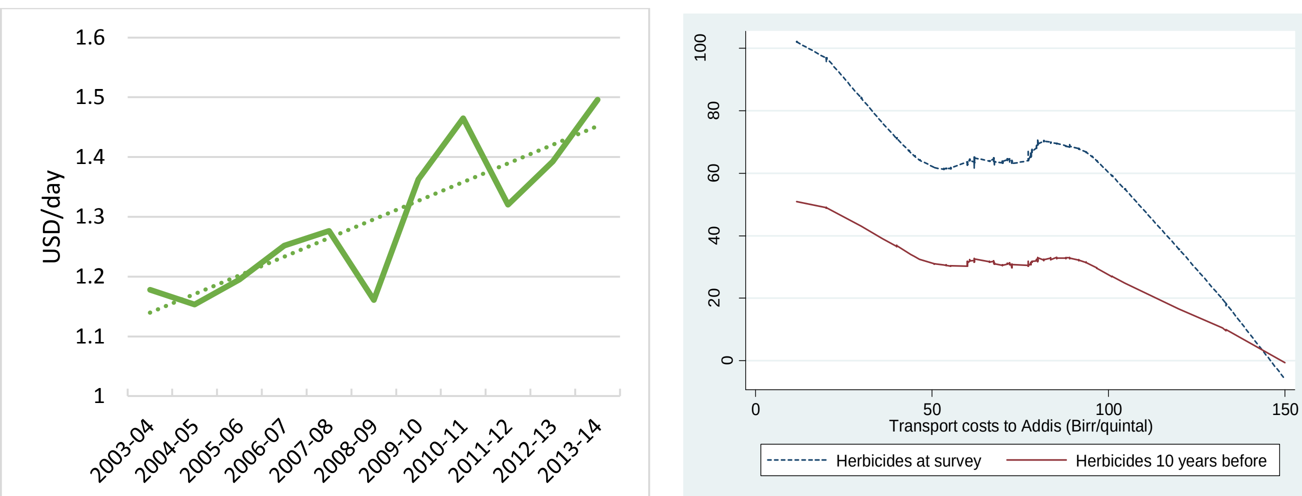
Source: Authors' computation using CSA annual reports (CSA Volume III 2005-2014).
Note: The proportions for each education category in 2011/12 is the average of 2010/11 and 2012/13.

Regarding gender relationships, Yimer and Tadesse (2015) show that women's empowerment in agriculture in Ethiopia is significantly lower than in other countries where such analyses were conducted, Bangladesh, Uganda and

Guatemala. They also illustrate how lower empowerment is associated with worse nutritional outcomes for children. Aguilar et al. (2015) further find that there is a strong gender gap in agricultural productivity where women land managers are shown to be less productive than men by 23 percent. Furthermore, Ragasa et al. (2013) show how women receive significantly less and lower quality extension advice in high-potential agricultural areas in Ethiopia, which results in less use of improved inputs and lower agricultural productivity by female farmers.

The majority of agricultural activities in Ethiopia is performed by family labor, as is the case in most countries. Bachewe et al. (2015) estimate that in high-potential areas of Ethiopia only 7 percent of agricultural activities are carried out by hired-in labor. However, this number might be higher for some particular crops. In commercial teff areas, 14 percent of the total agricultural labor was hired-in. This compares to 22 percent of the labor being exchanged (without monetary payments). It seems that two major changes have happened in this area in the last decade. First, real rural wages are on the rise. Figure 5.10 shows that rural wages were 25 percent higher at the end of the decade than at the beginning. Second, the increasing tightening of labor markets, combined with a decline in prices of substitutes, is leading to increasing adoption of new labor-saving technologies, such as herbicides and mechanization, especially in those areas where these constraints are most severe. For example, mechanized threshing – a substitute for manual post-harvest labor – has been quickly taken up in some areas in the maize belts of Ethiopia (Moges and Alemu 2014). Herbicides – a substitute for weeding labor – are increasingly adopted in commercial areas, such as major teff production areas close to Addis (Figure 5.10).

Figure 5.10—Rural real wages, 2003/04–2013/14 and change over ten years in herbicide use as a function of transport costs to Addis Ababa

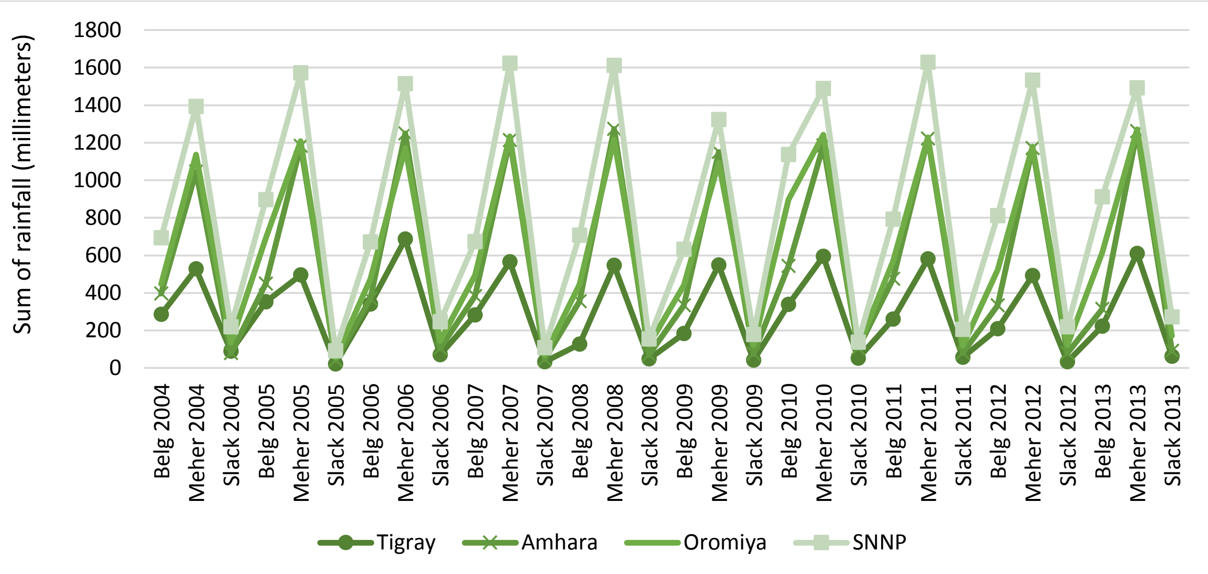


Source: Authors' computation using CSA prices and Minten et al. (2013)

CHANGES IN OTHER FACTORS

Given the rain-fed character of Ethiopia's agriculture, production is heavily dependent on timely and sufficient rainfall. Over the last decade, there have been no major incidences of the large-scale droughts that have plagued Ethiopia in the past. Figure 5.11 shows levels of rainfall for the four main agricultural regions, presenting the *meher*, *belg*, and slack seasons for the years 2004 until 2013. These levels illustrate, on average, the relative stability of rainfall patterns seen over the last decade. Moreover, Ethiopia is equipped with a good early warning system for the crop and the livestock sectors, as well as with a large safety net program – the Productive Safety Net Programme (PSNP) – in order to deal with the consequences of droughts. When there are droughts, government and donors have been addressing the production shortfalls sufficiently, as illustrated by interventions after the drought in the Horn of Africa in 2012 (Maxwell et al. 2014).

Figure 5.11—Patterns in total rainfall during meher and belg seasons of 2004-2013



Source: National Aeronautics and Space Administration (2015)
Note: We define the *belg* season to include the February-May months, meher the June-October months, and slack season of a given year the November-December months of that year and January of the next year.

Moreover, other factors have contributed to improved agricultural productivity but it seems that their importance in changes in agricultural performance over the last decade has been more limited than the drivers mentioned above. In his overview, Jack (2011) identifies, on top of informational and input and output market efficiencies, improvements in credit, risk, and land market efficiencies. These are discussed below.

First, lack of access to credit is often seen as one of the major constraints to increasing agricultural productivity and rural transformation overall. Following the international microfinance revolution in the 1980's and 1990's, Ethiopia has seen remarkable progress in this sector starting in the early 2000s. Over the last two decades, the number of microfinance institutions (MFIs) in the country has grown to 32 (from one in 1994).[33,34] Figure 5.12 indicates that the MFI industry has expanded enormously in the last decade both in terms of number of active borrowers – from around 500 thousand in 2003 to around 3.5 million borrowers in 2014 – and an outstanding loan portfolio from a little less than 2 billion in 2003 to around 11 billion birr (in 2011 prices) in 2014. In addition, significant amounts of government program loans were also disbursed through Rural Saving and Credit Cooperatives (RuSACos) in the last decade. Data from the Ministry of Agriculture indicate that in 2014 about 600 million ETB was disbursed to smallholders through RuSACos (which was about 56 million ETB in 2008/09). However, while there has been significant growth in this area, it is unclear how much of the micro-finance has been used towards the agricultural sector. For example, CSA data shows that the share of farmers that used credit for agricultural purposes has not changed significantly over time – it varied between 22 percent and 28 percent over the 2005-2013 period. It therefore seems that credit might have been more readily available in rural areas, but it might not have directly impacted agricultural activities.

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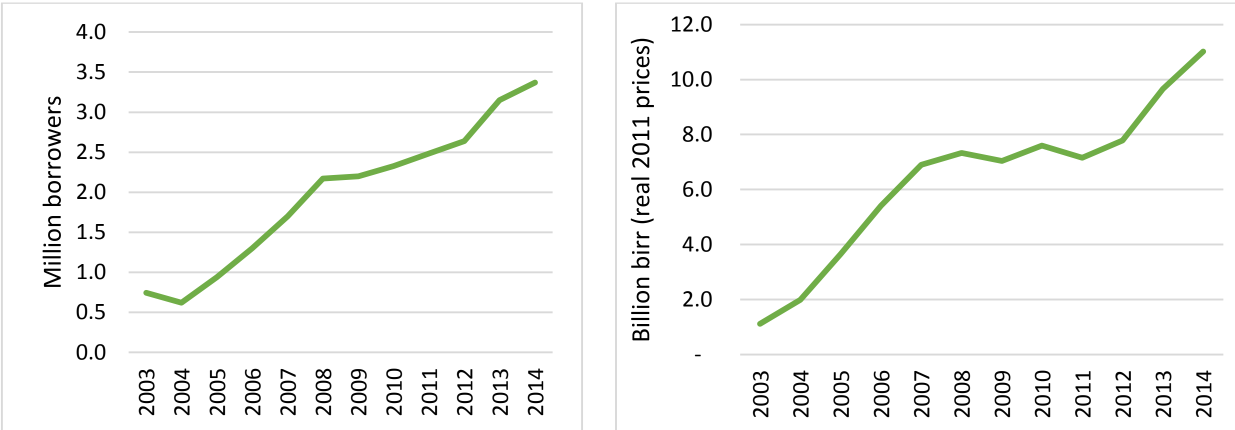
33 In fact, by 2007, Ethiopia had become home to two - ACSI and DECSI - of the top 50 largest MFIs in the world, measured in terms of size of their gross loan portfolio, efficiency, and risk (Forbes 2007). ACSI (the Amhara Credit and Saving Institution) was the 6th largest and DECSI (Dedebit Credit and Saving Institution) was the 31st largest of the top 50 MFIs in the world in 2007 (Forbes 2007).

34 The three largest MFIs, affiliated to the largest three regions in Ethiopia, ACSI (Amhara), OCSSCO (Oromia) and DECSI (Tigray) account for more than 65 percent of borrower clients and 74 percent of loan provision (Deribie 2013). A unique feature of the Ethiopian model of the MFI industry, is that they largely operate in rural areas, providing credit and saving services to smallholders, and yet, they are most cost-efficient with one of the lowest interest rates in Africa. These characteristics have enabled MFIs to reach millions of smallholders in rural Ethiopia.

Figure 5.12—Number of active borrowers and gross loan portfolio by micro-finance institution



Source: Association of Ethiopian Microfinance Institutions

Second, the risk situation might have changed in favor of higher agricultural productivity over the last decade. Dercon and Christiaensen (2011) show that uninsured risk is a significant constraint on technology adoption in Ethiopia, and although insurance markets may be no different in 2014 than in 2004, it is plausible that the riskiness of technology adoption has changed due to a number of factors: (i) the doubling of output-input price ratios makes negative returns to fertilizer use in the event of bad weather much less likely (Dercon and Hill 2009); (ii) there is now a functioning public safety net for many; (iii) a relatively long period of good weather may make the occurrence of bad weather shocks more muted (perhaps changing farmers' expectations of the risk); (iv) farmers are seemingly richer, have more assets, and are better able to self-insure; and (v) defaulting on loans from the micro-finance institutions may be easier than on loans from government, which used to be the main provider of credit.

Third, a large-scale land certification program was set up in the country in the 1990s to ensure more secure land property rights. This land certification program has been one of the largest, cheapest, and fastest in Africa (Deininger et al. 2008) – it is estimated that about half of farmers in the main four regions benefited from this certification program (Ghebru et al. 2015). While land remains the property of the state, the certificates have ensured more secure property rights, since they are found to encourage higher investments, more land rental market activity, higher productivity, and improved food security (Holden et al. 2007; Deininger et al. 2011; Ghebru and Holden 2013; Melesse and Bulte 2015). As this land certification program in most areas happened before the period under study, it might not have directly contributed to increased productivity in the last decade, but it seems that these more secure property rights have been an enabler for the increase in agricultural productivity seen in the last decade.

6. CONCLUSION AND FURTHER CHALLENGES

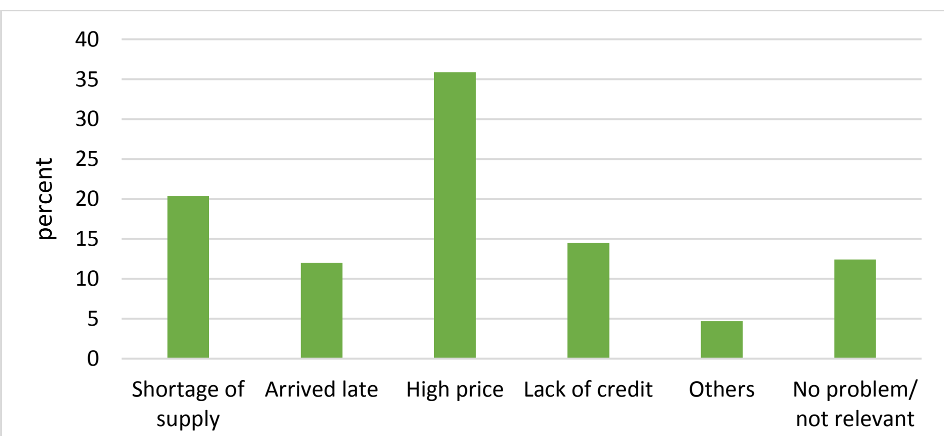
There have been significant changes in Ethiopia's agricultural and food economy in the last decade. Agricultural output more than doubled driven, in part, by area expansion, but more importantly by significant yield increases. The real value of agricultural GDP increased by 7.6 percent per year and export earnings from agricultural commodities doubled over this period. Moreover, average per capita food consumption increased by more than 20 percent, and we note a relative decline of expenditures on cereals in the consumption basket, indicative of important changes in food consumption habits. This agricultural growth is further shown to have been associated with significant poverty reduction (World Bank 2014).

The increased productivity is partly explained by a rapid uptake of a number of improved agricultural technologies. Over the period studied, total fertilizer consumption increased by 144 percent, with the share of cereal farmers applying chemical fertilizers increasing from 46 percent in 2004/05 to 76 percent in 2013/14. Other chemical use, such as the use of pesticides and herbicides by farmers, increased as well. More improved varieties for the major cereals were released in the period 2000-2011 than in the thirty years before, and, while there are still problems in distribution of improved seeds, their use – while still relatively low – doubled during this period. However, part of this growth cannot be explained by increasing adoption of these modern inputs, and other production factors. Significant growth in Total Factor Productivity (TFP), on average 2.3 percent per year, has contributed to this growth. We further note that the increasing adoption of these modern agricultural technologies and its contribution to agricultural growth has especially happened in the second half of the last decade. In the first half, agricultural growth was relatively more driven by area expansion and TFP growth.

Major drivers for the increasing adoption of modern inputs seem to be multiple, and linked with significantly higher expenditures in the agricultural sector. First, Ethiopia has built up a large agricultural extension system in the last decade, with one of the highest extension agent to farmer ratios in the world. Second, there has been a significant improvement in access to markets. While 67 percent of the population lived more than 5 hours from a city in 1997/98, this declined to 26 percent in 2010/11. Third, improved access to education led to a significant decrease in illiteracy in rural areas. Fourth, high international prices of export products as well as improving modern input - output ratios for local crops over the last decade, have provided better incentives for the agricultural sector. These factors all show a strong association with increasing adoption of improved technologies, and consequently agricultural productivity. However, other factors played a role as well, including good weather, better access to micro-finance institutions in rural areas, and improved tenure security.[35]

While the agricultural growth process in Ethiopia has been remarkable, there are a number of challenges that should be addressed to assure that this growth process will be continued in the future. First, sustainable intensification will need to receive even more attention as land constraints have increasingly become binding (Headey et al. 2014). It seems, therefore, that there will be a requirement for more widespread adoption of adapted modern inputs and improved technologies, especially as there is still significant opportunity for further growth. Chemical fertilizer use stays central to the government's effort to increase agricultural productivity. It has therefore initiated a unique soil mapping exercise in the country where fertilizer packages are adjusted to specific soil conditions. This is a promising development that is likely to address soil deficiencies in the country more appropriately. However, emphasis on an efficiently functioning fertilizer distribution system is also needed, as described in the feedback from farmers on constraints to adoption of fertilizer in the baseline survey of the AGP program. While the share of farmers using fertilizer in these high potential areas was high, there were still significant issues with the availability of fertilizer, as more than 20 percent and 12 percent of the farmers complained about lack of supply and late arrival of fertilizer respectively (Figure 6.1).

Figure 6.1—Households reporting particular factor as most important constraint to adoption of fertilizer, percent



Source: Authors' computations from AGP survey, 2011

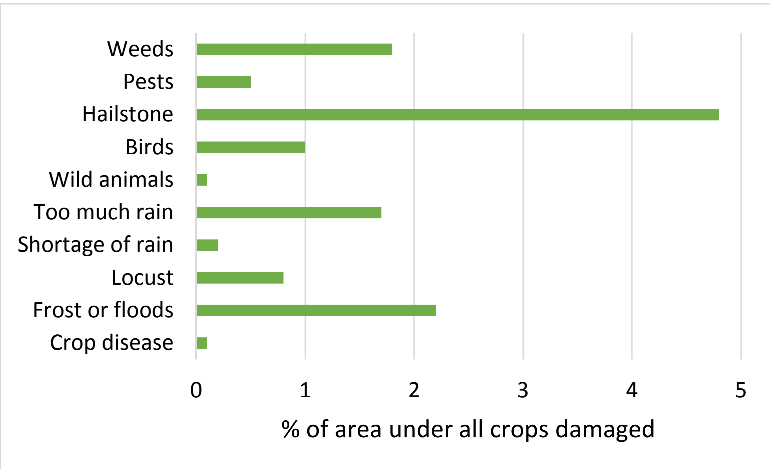
Higher adoption rates of improved and high-performing seeds are also needed. To stimulate adoption, better supply and marketing conditions are required. On the supply side, it seems that while the public sector has an important role to play and further local research resources to improve seed should be provided, given the high return on such investments (Alston et al. 2000), a more active role of the private sector is required as well. Moreover, marketing, distribution and information provision on improved seeds should be enhanced to generate a more vibrant seed sector in Ethiopia. To further agricultural intensification, there will also be a need for better water management and to increase irrigation, more intensive use of land through double cropping, and more attention paid to reduce important soil erosion problems in the country. The government

[35] There are a number of caveats in this analysis. While we have inferred major plausible pathways that might have led to productivity increases in the country, we lack the data to do more quantitative research that would enable a better understanding of the specific contributions of inputs and drivers to agricultural growth at the national level. Ethiopia is also an extremely diversified country with large variation in agro-ecologies. While we have analyzed the situation at the national level, more in-depth research is needed to understand specific issues at the disaggregated level. Finally, our analysis is based on the annual data of the Central Statistical Agency, and while we tried to triangulate our findings with other large-scale data sources, there are no alternative large-scale data sources with similar frequency available that are representative over this time period at national level.

and the private sector play an important role in this so as to ensure that appropriate technologies are developed and made available at an affordable price. As part of this effort, linking local agricultural innovation systems with the public extension system and the private sector should be institutionalized and strengthened.

Second, climate change is expected to have a significant impact on Ethiopian agriculture in the decades ahead. It is estimated that the shifting rainfall patterns and increasing temperatures will lead to decreases in crop yields, as well as lower incomes gained from livestock (Robinson et al. 2013). Moreover, the incidences of unexpected weather shocks is expected to increase. A case in point is the adverse effect of El Nino in the current 2014/15 crop year in which 8.2 million people in 172 woredas across Ethiopia are in need of relief assistance (EHCT 2015). Figure 6.2 illustrates that weather related events were already the major source of crop damage over the last decade. Incorporating climate change considerations in the design of agricultural development programs therefore will become increasingly important. This will have to be done through modifying farming practices to counteract the possible effects of climate change and to minimize greenhouse gas emissions.

Figure 6.2—Proportion of crop area damaged, by cause, 2004/05–2013/14



Source: Authors' computations using CSA data (CSA vol. III 2005-2014)

Third, while agriculture has shown high growth rates, which has contributed to significant welfare improvements, there is still significant scope for improvement. One concern is the slow change in nutritional indicators and the high level of stunting in the country, especially in rural areas (Headey et al. 2014). More attention therefore should be paid to how agricultural growth can have enhanced beneficial effects on food diversity and nutritional indicators. While there are still a number of unknowns on how this nutritional transformation can be most efficiently achieved, it seems that behavioral change communication, sanitation, improved market access, and production diversity, especially in less connected areas, could have a major role to play (Hirvonen and Hoddinott 2015; Hoddinott et al. 2013; Stifel and Minten 2015; Headey et al. 2015).

Fourth, most of the agricultural growth has happened in the cereal sector in the last decade. However, as the Ethiopian population is becoming richer and more urbanized, this will lead to changing demands for foods, different consumption baskets, and a transformed agricultural sector. For example, there will be an increasing demand for livestock products - with more cereals demanded for feed and fodder, fruits and vegetables, processed and ready-to-eat products. Some of these products require the development of new and different value chains, which in turn requires investing in local capacities, given the lack of relevant knowledge, seeds, and other inputs at present. Moreover, the high perishability of some of these emerging agricultural products means that additional investments are needed towards new off-farm technologies, such as cold storages and processing, that can help bridge the gap.

Fifth, gender issues are important in agriculture and addressing this area is valuable to improve agricultural performance, but more importantly to address nutritional indicators, in Ethiopia. As shown above, empowering women in agriculture has likely pay-offs for both nutritional and agricultural outcomes. This will require policies and interventions in different areas. For example, Kumar and Quisumbing (2015) show that reforms in law and land registration has been an important avenue to improve gender equality in Ethiopia.

Sixth, mechanization in Ethiopia's agricultural production and post-harvest activities is currently low. However, as described earlier, the increasing transformation of Ethiopia's economy is leading to higher real wages in rural areas. These higher rural wages will provide incentives for induced innovation towards labor-reducing technologies (Ruttan and Hayami

1984). This trend can already be seen by the increasing adoption of herbicides, a substitute of weeding labor, in commercial agricultural areas, but it will also drive the demand for more mechanization, especially for these activities that are done at times when there is a peak demand of labor, such as during planting and harvesting periods. Making sure that the right machines and spare parts at affordable prices are accessible to alleviate this constraint is also another important challenge for sustained higher agricultural productivity.

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APPENDICES

Appendix 1. Composition of real crop output

Table A1.1—Composition of real crop output, 2004/5-2013/14, billion birr, 2011 prices

Crop	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12.	2012/13	2013/14
Cereals	56.2	64.4	73.2	94.7	106.4	94.9	91.7	107.5	113.1	121.5
Barley	7.2	7.2	7.7	9.2	10.4	10.2	9.3	9.3	9.7	9.9
Maize	10.7	13.7	14.0	20.7	20.9	16.5	18.1	26.5	24.4	26.1
Sorghum	8.1	9.5	10.1	15.1	17.1	14.2	15.8	18.8	17.2	17.7
Teff	15.4	17.7	22.9	29.1	34.1	30.7	27.4	30.3	36.9	39.4
Wheat	12.4	13.7	15.8	16.7	19.3	18.9	17.2	18.4	19.8	22.7
Other cereals	2.3	2.6	2.7	3.9	4.6	4.4	3.9	4.2	5.0	5.6
Pulses	9.2	9.4	14.6	16.0	15.8	14.0	18.2	23.9	21.8	20.7
Oilseeds	5.9	4.9	5.1	8.8	7.9	7.9	9.8	9.5	8.1	9.6
Vegetables	3.3	4.4	3.0	8.0	8.1	5.3	5.5	10.0	9.6	6.7
Root crops	7.0	5.2	5.4	6.3	5.2	6.6	8.6	8.5	11.9	11.2
Fruit crops	1.0	1.7	1.9	2.0	1.4	1.7	1.8	2.4	2.1	2.2
Chat	2.1	3.0	3.6	4.0	2.8	2.8	4.4	4.1	5.5	5.2
Coffee	4.0	5.4	6.5	7.3	5.9	6.8	14.3	16.9	12.0	11.1
Sugar cane	0.2	2.9	1.8	1.5	0.9	1.2	2.6	1.9	2.2	2.7
All crops	88.9	101.4	115.0	148.7	154.5	141.3	156.8	184.7	186.2	190.8

Source: Authors' computations using CSA annual reports (Volume I 2005-2014), monthly producer prices (CSA 2015), and monthly regional general price index (2015).

Appendix 2. Output growth decomposition

CHANGES IN TOTAL FACTOR PRODUCTIVITY OF CROP PRODUCTION: GROWTH ACCOUNTING

The growth accounting method of decomposing changes in output into factors used in production begins with a functional relationship between output and those factors. The aggregate crop production function of Ethiopia in a given year *t* can be given as:

$$Q_t = A(t)f(L_t, K_t, T_t, F_t, H_t, P_t, I_t, S_t) \quad \text{(A1)}$$

where Q is the real value of crop output while $A(t)$ stands for the cumulative effect of technical change. Equation (A1) assumes neutral technical change that shifts the production function without affecting the marginal rates of substitution (Solow 1957). The variables in f(.) stand for factors used in production. This includes primary inputs: labor (L), land (T), and capital (K); intermediate service sector inputs (S); and intermediate manufacturing sector inputs: fertilizer (F), improved seeds (H), pesticides (P), and irrigation (I).[36]

Differentiating both sides of equation (A1) with respect to time and dividing the result by Q we find:

$$\frac{\Delta Q}{Q} = \frac{\Delta A(t)}{A} + \sum_J \frac{\partial Q}{\partial J}\frac{\Delta J}{Q} \text{ where } J \in [L, K, T, F, H, P, I, S] \quad \text{(A2)}$$

where ΔQ or $\partial Q/\partial t$ stands for time derivative of output; $\Delta A(t)$ for technical change, and ΔJ for time derivatives of the eight inputs used in production, with $J \in [L, K, T, F, H, P, I, S]$.

An important criticism of equation (A2) is that it leaves out the effect of factors that impact crop production, such as infrastructure. Moreover, it fails to account for gains in output that result from increasing returns to scale. By leaving out those factors, the equation overstates the contribution of changes in TFP for growth in output. In this study we conduct analyses that both exclude and include the factors. Equation (A2) can be rewritten including those factors as:

[36] The crop production subsector uses crops as inputs, mainly as seeds. For simplicity, we add that quantity into primary inputs used in the subsector after distributing it into primary input contents of crop output.

$$\Delta TFP = \frac{\Delta A(t)}{A} = \frac{\Delta Q}{Q} - \sum_J w_J \frac{\Delta J}{J} - \alpha \Delta RTS - \beta \Delta Z \quad \text{(A3)}$$

where *TFP* stands for total factor productivity. We use $w_J = (\partial Q/\partial J) * (J/Q)$ to obtain equation (A3); where w_J is the relative share of input *J* in crop output. Moreover, ΔZ stands for changes exogenous factors that affect production, which we proxy by rural roads, and β stands for the rate at which output changes per unit change in rural roads. ΔRTS and α stand for changes in returns to scale (RTS) and the rate at which output changes per unit change in RTS, respectively.

Equation (A3) decomposes changes in output into four groups of variables. The first group constitutes factor inputs. That is, outputs in period t+1 can be higher than period t if, among others, more inputs are used in year t+1. Using this method we can compute that part of the growth in output, results from increased use of the 8 inputs. The second and third groups constitute exogenous factors, such as infrastructure and returns to scale. The fourth factor, total factor productivity (TFP), is computed as a remainder of increases in output after accounting for the contribution to output growth of the first three. Given time series data on real crop output, shares and changes in factors used in crop production, data on rural roads, and an estimate of β, we could use equation (A3) to estimate the value of $\Delta A(t)/A(t)$.[37]

Unlike data on levels and changes in crop output and inputs, which are available at least annually, data on factor shares are infrequent. We derive the shares of five factors (labor, capital, land, fertilizer, and services) from two Social Accounting Matrices (SAMs) of Ethiopia: the 2005/6 and 2009/10 Ethiopia SAMs. Both SAMs exclude shares of the remaining three inputs that, as we shall discuss shortly, have contributed considerably to output growth. As a result, we complement factor shares obtained from the SAMs by relative output elasticities with respect to improved seeds, pesticides, and irrigation. This is obtained by estimating a production function using data from the Agricultural Growth Program (AGP) of Ethiopia baseline survey. The part of AGP dataset we use in the analysis pertains to the 2010/11 main agricultural season and includes about 7,000 households representing 8 million households residing in Tigray, Amhara, Oromiya, and SNNP regions. We provide in Table A2.1 the original factor shares derived from the 2005/6 and 2009/10 Ethiopia SAMs and those complemented with elasticities obtained from the AGP baseline data.[38]

Growth accounting computations that extend several years, ideally use factor shares that accurately reflect changes in the shares that occur during the period. Given such data is available for only 2005/6 and 2009/10, we considered different scenarios to compute the factor shares for years before 2005/6, after 2009/10, and in between the two years. Results obtained from the scenarios considered are similar for most inputs, mainly because there is little change in their shares (see Table A2.1) – the exceptions to the latter being labor and land. The results discussed here are obtained from a scenario that both appear logical and resulted in one of the lowest average changes in TFP. Namely, we apply factor shares in 2005/6 and 2009/10 (columns 4 and 6 of Table A2.1) in the respective years. For years between 2005/6 and 2009/10, we apply factor shares, such as that in column 5 of Table A2.1, which are computed by assuming that differences in the 2005/6 and 2009/10 Social Accounting Matrices factor shares occurred uniformly across the years. Moreover, we apply the uniform changes in factor shares for the period before 2005/6 and after 2009/10 to compute shares such as those given in column 8.[39]

[37] We discuss below how the effect of returns to scale is computed from the data.

[38] As much as the AGP dataset is spatially and temporally limited, the shares are only an approximation. However, the 4 regions together accounted for over 95 percent of the nationwide area, output, and number of farmers during 2004-2014 (CSA Vol. I 2005-2014). Furthermore, the number of households in the AGP dataset is larger than any other dataset, and several studies that use this dataset obtain results that are more or less robust nationwide.

[39] Results obtained from other scenarios are available upon request.

Table A2.1—Factor shares used in growth accounting analyses.

Factor	Factor shares in Ethiopia Social Accounting Matrices of		Factor shares in Ethiopia Social Accounting Matrices and AGP dataset			
	2005/06[a]	2009/10[b]	2005/06[c]	2007/08	2009/10[d]	2013/14
Labor	0.716	0.605	0.666	0.614	0.563	0.460
Capital	0.007	0.007	0.006	0.006	0.006	0.006
Land	0.225	0.346	0.209	0.265	0.322	0.434
Fertilizer	0.050	0.041	0.047	0.042	0.038	0.029
Improved seeds			0.039	0.039	0.039	0.039
Pesticides			0.006	0.006	0.006	0.006
Irrigation			0.025	0.025	0.025	0.025
Services	0.002	0.002	0.002	0.002	0.002	0.001

Source: EDRI (2009) and Engeda et al. (2011)

The data on most of the remaining variables are obtained from annual CSA reports. In Table A2.2 we summarize the data on agricultural labor (which we proxy by number of farm holders), crop area, capital (which we proxy by number of draft cattle used to plow land), chemical fertilizer, improved seeds, pesticides applied area, and irrigated area. The table also summarizes the data on rural roads and real crop output (Q) obtained from National Bank of Ethiopia (2014). Furthermore, we proxy changes in intermediate service sector inputs by changes in real agricultural output. The assumption made is that increases in the use of service sector outputs is proportional to growth in crop output.

Table A2.2—Summary of data used in growth accounting.

Variable	2005/06	2007/08	2009/10	2011/12	2013/14
Number of farm holders (millions)[a]	11.6	12.5	13.7	14.6	15.3
Number of draft cattle (millions)[b]	10.4	11.5	12.8	13.2	13.8
Crop area (million hectares)[c]	11.3	12.4	13	13.7	14.1
Chemical fertilizer (million quintals)[d]	3.9	4.1	4.2	5.2	7.1
Improved seeds (000 quintals)[d]	160.8	186.4	302.6	387.4	414.7
Pesticides applied area (million ha)[d]	1.6	1.9	2.1	2.3	2.7
Irrigated area (000 ha)[d]	128	141.2	154.4	164.6	166.4
Rural roads (thousand kilometres)[e]	20.2	23.9	26.9	31.6	33.6
Real crop output (billion birr)[e]	95.8	114.9	133	154.1	177.7

Sources: a) CSA Volume I (2005-2014); b) CSA Volume II (2005-2014); c) CSA Volume IV (2005-2014), d) CSA Volume III (2005-2014); e) National Bank of Ethiopia (2014).

We substitute β by Zhang and Fan's (2004) elasticity of TFP with respect to rural roads, which is 0.042. Returns to scale are considered as constant, increasing, or decreasing if output increases at the same, higher, or lower rate relative to increases in all inputs. The effect of returns to scale is a multiple of α and ΔRTS (see also Carlaw and Lipsey 2003). α represents the excess of the sum of factor shares over 1, which occurs if returns to scale were constant, or:

$\alpha = \sum_J w_J - 1$ where $J \in [L, K, T, F, H, P, I, S]$

Change in returns to scale, ΔRTS, is given as the excess of the sum of payments to factors, weighted by changes in factors, over the rate of growth in the number of new establishments, or the rate of expansion of the crop production subsector. ΔRTS is then given as:

$$\Delta RTS = \sum_J w_J \frac{\Delta J}{J} - f$$

where *f* denotes the rate of expansion of crop production subsector. In each year during the period studied we proxy *f* by the minimum of growth in cultivated area and labor, inputs indispensable in crop production.[40]

The growth accounting analysis is simple but the results, particularly TFP changes, can have important policy implications. One of the most important debates that surround the concept of TFP is what it does or does not measure (see

[40] We also conduct the analyses assuming the rate of expansion of the crop production subsector is given by the minimum growth rate of all 8 inputs. Those results are close to what we report here.

Carlaw and Lipsey (2003) for a summary). TFP is often referred to as a ‘residual’ factor due to the way it is calculated, while it is also referred to as ‘Manna from Heaven’ because the costs that generate TFP are external or not directly incurred by producers. Some claim TFP represents ‘pure’ technical changes, while others label it as a ‘measure of our ignorance’ (Carlaw and Lipsey 2003). In his ground-breaking work, Solow (1957) uses the phrase technical change [TFP change] as “…a short-hand expression for any kind of shift in the production function…” which includes slowdowns, speed-ups, and improvements in human capital.

We are aware that crop production in Ethiopia is likely to have been affected by many more factors, with direct and external costs to farmers, than those included in our analyses. For instance, farmers’ use of compost, row planting, and sustainable land and water management (SLWM) practices may have a direct or indirect positive impact on crop production. In addition to costs that farmers directly incur in using those factors, the Ethiopian Government invested in expanding SLWM practices, credits, and to introduce and expand mobile phone services. In so far as these and other factors are not included in the analyses changes in TFP computed also include the effect of those factors. Ideal analyses that capture and disaggregate all such factors into their different components, will also disaggregate what our study considers as changes in TFP. In particular, that part of the change in TFP resulting from farmers’ deliberate investments, will be categorized into contributions made by the respective factors. However, a considerably large proportion of changes in TFP that result from our computations are expected to represent changes in crop production know-how and techniques that resulted from the extensive efforts and investments of the Ethiopian Government on extension infrastructure and personnel.

RESULTS OF GROWTH ACCOUNTING

In Table A2.3 we provide the contribution for changes in output of factors included in equation (A3). In the second row we provide changes in real crop output between each pair of consecutive years, which are computed using the last row of Table A2.2. The next eight rows provide the contribution of inputs referred in the heading. For instance, the first entry in the third row indicates that 3.6 percent of the 15 percent increase in crop output during 2005/6 is due to increased labor use. Similarly, during 2005/6 increased use of capital (primarily plowing oxen), land, fertilizer, improved seeds, pesticides, irrigation, and service sector intermediate inputs contributed 0.05, 0.8, 2.2, 0.4, 0.15, 0.14, and 0.04 percent, respectively. The baseline specification, which considers the contribution of only the latter factors and computed using equation (A2), indicates that about 7.6 percent of the 15 percent growth in output during 2005/6 is due to increase in TFP. This is given in the second row to the bottom in Table A2.3. The last row provides changes in TFP obtained by including the effects of returns to scale (RTS) and rural roads (using equation (A3) – in 2005/6, this contributed 6.9 percent.

Table A2.3—Contribution of inputs, exogenous factors, and TFP changes for growth in crop output.

Source of change	2005/06	2007/08	2009/10	2011/12	2013/14	Average
Changes in real crop output (ΔQ/Q)	0.1500	0.0800	0.0870	0.0500	0.0660	0.0881
Labor	0.0361	0.0348	0.0317	0.0165	0.0153	0.0262
Capital	0.0005	0.0005	0.0003	0.0001	0.0003	0.0003
Land	0.0081	0.0152	0.0141	0.0118	0.0083	0.0105
Fertilizer	0.0219	0.0012	0.0003	0.0065	0.0099	0.0069
Improved seeds	0.0043	0.0031	0.0247	0.0038	0.0038	0.0096
Pesticides	0.0015	0.0008	0.0009	0.0001	0.0013	0.0009
Irrigation	0.0014	0.0014	0.0014	0.0011	0.0002	0.0011
Services	0.0004	0.0002	0.0002	0.0001	0.0001	0.0002
Total contribution of inputs $\left(\sum_f w_f \frac{\Delta X_f}{X_f}\right)$	0.0741	0.0573	0.0737	0.0400	0.039	0.0556
ΔTFP **- Baseline (P&I inputs)**	0.0755	0.0226	0.0137	0.0099	0.0268	0.0325
ΔTFP **- Modified (P&I inputs, RTS, and infrastructure)**	0.0691	0.0184	0.0016	0.0029	0.0146	0.0229

Source: Authors’ analyses using data from CSA (Vols. I, III, and IV 2005-2014) and National Bank of Ethiopia (2014).
Note: a) ‘P&I’ and ‘RTS’ stand for *primary and intermediate* and *returns to scale*, respectively.

The results in Table A2.3 indicate that, if we assume the baseline specification that incorporates the effects only of primary and intermediate factors, then out of the 8.8 percent average annual growth in output during the period 2005/6 to 2013/4, increased use of inputs contributed about 5.6 percent (third to last row, last column). Out of this, labor contributed 2.6 percent, land was next in importance at 1.1 percent, about 1.8 percent was contributed by modern inputs, while draft power and services sector intermediate inputs together contributed 0.05 percent. The remaining 3.2 percent increase in output resulted from increases in total factor productivity. If we assume that crop production is affected also by RTS and infrastructure, then these factors on average contributed about 1 percent for growth in crop output and the contribution of TFP averaged 2.3 percent.

Appendix 3. Complementary datasets

A. The Agricultural Growth Program baseline and mid-term survey. A large-scale survey was fielded in 2011 and 2013 as part of the impact evaluation of the Agricultural Growth Program (AGP) in the high-potential areas of Ethiopia with the purpose of tracking both program implementation and estimating the impact of the program over time. The survey was conducted in the four regions in Ethiopia that are agriculturally important (Tigray, Amhara, Oromia, and SNNP). Included in the survey were 93 woredas and 305 enumeration areas (EAs). Almost 8,000 households were interviewed in this survey.

B. The Feed-the-Future baseline survey. The purpose of the survey was to obtain pre-intervention (baseline) information in localities that were to receive investments to improve agricultural production and nutrition under the Feed the Future (FtF) program (funded by the United States Agency for International Development (USAID)) or in localities that were to act as comparison sites for the evaluation of FtF. While these data are not representative of these regions, the sample is large – 7,011 households – and widespread, the survey having been implemented in 252 villages in 84 woredas. The data were collected between June and July 2013 in five regions of Ethiopia: Amhara, Oromiya, SNNPR, Somali, and Tigray.

C. The Agricultural Transformation Agency baseline survey. To support the activities of the Ethiopian Agricultural Transformation Agency (ATA), the International Food Policy Research Institute (IFPRI) carried out a baseline survey in 2012. The survey was based on a stratified random sample of 3,000 households in the four main regions of Ethiopia: Tigray, Amhara, Oromiya, and the Southern Nations, Nationalities, and People's (SNNP) region. The selected households were dispersed across 100 woredas and 200 kebeles.

D. The cereal availability survey. A study was conducted in 2008 in Ethiopia with the purpose to measure cereal availability in the country. 1,500 households were interviewed using a three-stage stratified random sampling. The survey was conducted in the four regions that are agriculturally important.

E. The teff value chain survey. 1,200 teff farmers were interviewed at the end of 2012 in the five zones with the highest commercial surplus of teff in the country. In 2011/12, these five zones combined represented 38 percent and 42 percent of the national teff area and commercial surplus, respectively. In total, 240 farmers were interviewed per zone.

F. The teff row planting impact evaluation survey. 847 teff farmers were interviewed as part of a study on the impact of teff row planting. The sample design followed a two-stage randomization approach. First, from the 23 Agricultural Growth Program (AGP) *woredas* in the Oromia region (a major teff producing region), ten *woredas* were randomly selected. The selected farmers in the survey area were visited 2 times during a baseline survey (October 2012) and the impact survey (February 2013).

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The Ethiopia Strategy Support Program is an initiative to strengthen evidence-based policymaking in Ethiopia in the areas of rural and agricultural development. Facilitated by the International Food Policy Research Institute (IFPRI), ESSP works closely with the government of Ethiopia, the Ethiopian Development Research Institute (EDRI), and other development partners to provide information relevant for the design and implementation of Ethiopia's agricultural and rural development strategies. For more information, see http://www.ifpri.org/book-757/ourwork/program/ethiopia-strategy-support-program or http://essp.ifpri.info/ or http://www.edri-eth.org/.

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