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The rapid – but from a low base – uptake of agricultural mechanization in Ethiopia: Patterns, implications and challenges

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ABSTRACT

The uptake of agricultural mechanization in Ethiopia is low with less than one percent of agricultural plots plowed with a tractor. However, in recent years the uptake of agricultural machinery has accelerated. We note an impressive increase in imports of combine-harvesters and of tractors, seemingly associated with the increasing costs of agricultural labor and animal traction, substitutes for agricultural mechanization. We estimate that a quarter of the area in Ethiopia planted to wheat – the fourth most important cereal in the country – is currently harvested by combine-harvesters, and they are widely used in the major wheat growing zones in the southeast of the country in particular. Private mechanization service providers have rapidly emerged. Smallholders in these wheat growing zones rely heavily on agricultural machinery rental services for plowing, harrowing, or harvesting. We find that mechanization is associated with significantly lower labor use, and that the adoption of combine-harvesters – but not tractors – is significantly associated with higher yields, seemingly due to lower post-harvest losses. While further expansion of mechanization in the country is desired, given the environmental and financial cost of holding oxen and the higher yields linked with some forms of mechanization, it appears to be hampered by farm structures, particularly small farm sizes and consequent limits in scale; fragmented plots; crop diversity; physical constraints, such as presence of stones, steepness of fields, and soil types; and economic and financial constraints, including limited access to foreign exchange and credit and the still relatively low wages in less commercialized zones.

1. INTRODUCTION

Ethiopia's economy is quickly transforming with double-digit average growth rates noted in the last decade. Specifically, Ethiopia's agricultural sector is transforming rapidly, and it has been an important contributor to the overall economic growth process as well as to significant poverty reduction in the country (World Bank 2015a). Over the last decade, this sector has modernized as seen by large increases – more than a doubling – in modern input use, such as chemical fertilizers and improved seeds, which explain part of the growth.[1] Evidence shows that this agricultural growth has been associated with significant increases in real rural wages over this same period – real rural wages have risen by 54 percent in the last decade, albeit from a low base (Bachewe et al.2016) – as well as rises in costs of animal traction. As agricultural economies grow and as relative factor costs change, because of changes in wages and costs of animal traction, a typical pattern towards greater use of machinery in agriculture is observed internationally (Bigot and Binswanger 1987). Empirical evidence documenting these emerging trends in the mechanization of agriculture in Ethiopia is, however, scarce.

At the policy side, we see an increasing interest in the country to stimulate agricultural mechanization. This interest is seemingly driven by two reasons. First, a large portion of agricultural work in Ethiopia is done with the help of livestock. However, livestock are an important contributor to global warming. To make the economy more climate resilient, there are plans to restructure the livestock sector, to rely on fewer (but more productive) livestock that are used less in land preparation and threshing activities (GoE 2011). Second, successful changes have occurred in Ethiopia's rural and agricultural economy in the last decade, and there is an increasing push towards further agricultural transformation and modernization of the sector (Bachewe et al. 2015). Mechanization is seen as an integral part of this transformation. This is reflected in the development of a new comprehensive mechanization strategy by the Agricultural Transformation Agency (ATA) and the Ministry of Agriculture and Natural Resources (MoANR), as well as by the setting of ambitious targets on mechanization in the Growth and Transformation Plan (GTP) for the period 2016-2020. It is planned that agricultural mechanization levels will be raised from about 0.1 kW/ha at present to 1 KW/ha by 2025 (ATA 2014). Such targets fit well within the objectives of the country's industrialization strategy and for the greening of its economy (GoE 2011).

This emphasis on mechanization as a means to achieve a better performing agricultural sector is not new to Ethiopia. During the Emperor's era before 1974, there was a significant effort to increase agricultural mechanization in the country, albeit mostly focused on large commercial farms. During the Derg period from 1974 to 1991, most of these large farms were nationalized and attention to agricultural mechanization focused on these large state farms. However, cooperatives in cereal-based system were also targeted (Facasi project 2016). The focus of the current government has been on improving smallholder production through adoption of improved technologies in which mechanization until

[1] Bachewe et al. (2015) show that 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.

recently played a relatively minor role (ATA 2014). Although there have been some recent efforts in Ethiopia to promote small-scale mechanization, such as two-wheeler tractors (Baudron et al. 2015), the focus has largely been on large-scale mechanization, e.g., large horsepower tractors.

In the research presented in this paper, we analyze patterns in agricultural mechanization in Ethiopia based on unique primary and secondary data. We demonstrate that the use of agricultural mechanization has been rapidly increasing in Ethiopia, although it is still mostly limited to specialized wheat growing areas. This low level of adoption is partly linked to adverse economic conditions for increased mechanization in farming, such as low rural wages, problematic access to foreign exchange, and limited access to credit. Mechanization is, however, also hampered by technical constraints due to smallholder agriculture and its small and fragmented plots, Ethiopia's rugged topography, and the widespread presence of stones in fields, which complicate mechanized plowing. Moreover, the diversification in Ethiopian crop agriculture farming systems makes it difficult for a single machine to take off as different crops might need different harvesting equipment. Nonetheless, recently we have seen significant dynamics in the use of mechanization in farming, noting a fast increase in the number of tractors and combine-harvesters in the country, though starting from a low base. The number of imported tractors has increased five-fold over the last five years, and the annual import value of combine-harvesters is now more than ten-fold what it was fifteen years ago. While a large share of the functional tractors is being used by larger commercial farmers and state farms, we also see increasing uptake of mechanization by smallholders, especially so in the wheat sector. Commercial mechanization service providers are rapidly emerging that provide plowing, harrowing, and harvesting services for a fee. This change is seemingly associated with rapidly increasing costs of farm labor and animal traction, for which these machines substitute. However, demand for mechanization might still be an issue in these settings, as there appears now to be an over-supply of tractors in the country.

The objectives of the paper are five-fold. We first illustrate mechanization patterns in the country, and particularly focus on smallholder mechanization. We limit our discussion to the most commonly used forms of mechanization in the country, i.e. tractors and combine-harvesters. Second, we illustrate changing trends in demand conditions. Third, we look at mechanization service provisions and related policies. Fourth, we focus on analyzing the associates of mechanization on modern input adoption, labor productivity, and yields. We perform these analyses through a combination of quantitative and qualitative methods. Finally, we finish with a discussion of the implications and challenges for further upscaling agricultural mechanization in Ethiopia.

2. DATA AND METHODOLOGY

To gather the required information for this study, we conducted two types of activities. First, interviews were held with key informants in mid and late 2016. These informants included representatives of the Ethiopian Institute of Agricultural Research (EIAR), the Ministry of Agriculture and Natural Resources (MoANR), private importers, the Metals and Engineering Corporation (METEC), the Agricultural Transformation Agency (ATA), cooperative unions, operators of tractors and combine-harvesters, brokers, the Mechanization Service Provider Association, and farmer focus groups.

Second, we relied on three sources of quantitative data:

1. Import data for the last decade from the United Nations' Comtrade webpage.[2] These data include information on quantities, country of consignment, values, and prices of imported agricultural machinery.
2. Household data on the Zone of Influence of the Feed-the-Future (FtF) Program in Ethiopia.[3] These data are representative of the Zone of Influence (ZOI) within which the FtF program operates, but are not regionally or nationally representative. However, the sample is large – nearly 7,000 households – and widespread, the survey having been administered in 252 villages in 84 of Ethiopia's 670 rural districts (woredas). Together the treatment and the control groups represent more than 25 million people residing in more than 6 million households.
3. Household data from the Ethiopia Socioeconomic Survey (ESS). The ESS 2013/14 was implemented in 433 enumeration areas and comprises 5,262 households. Sampling of rural, small towns (population with less than 10,000 people), and urban areas (greater than 10,000 people) was implemented to allow representative population estimates for six regional strata as well as national level estimates.

[2] http://comtrade.un.org/

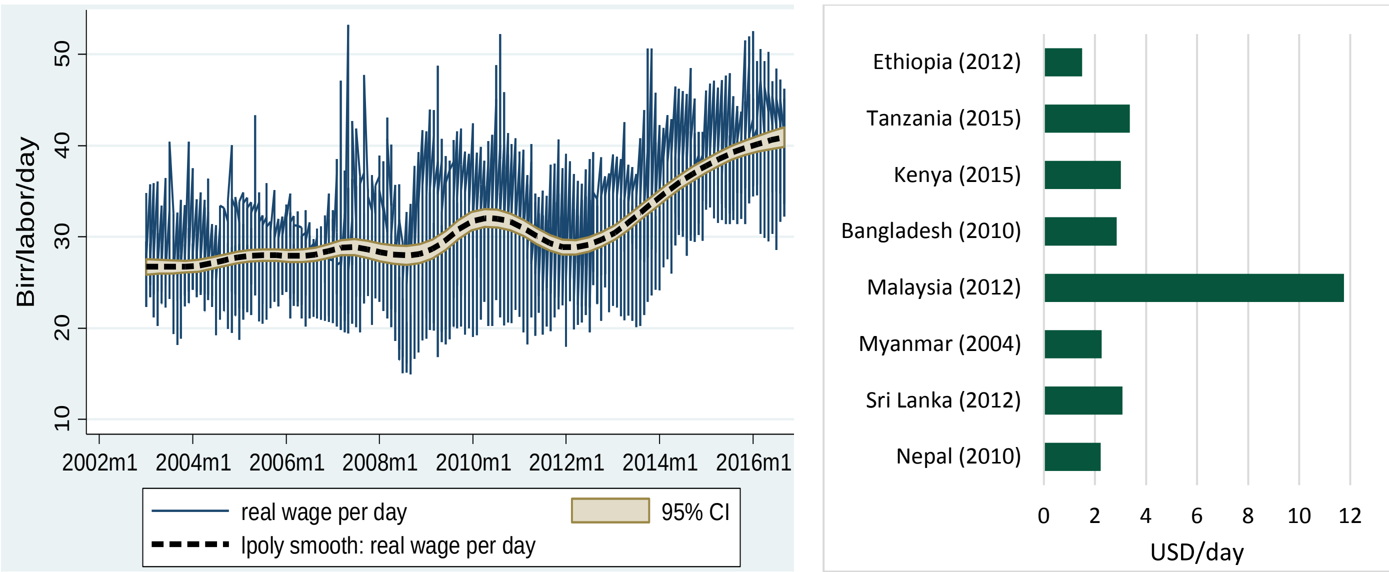
[3] The main purpose of the FtF survey is to obtain pre- and post-intervention information in localities that received investments to improve agricultural production and nutrition under the FtF program, or in localities that were to act as comparison sites for the evaluation of FtF.

This paper focuses on agricultural mechanization and associated implements, which we define in one of two ways in this paper. We will follow the distinction made by ATA (2014) of High and Intermediate Mechanization Implements (HIMI) – including tractors, combine-harvesters, threshers – and Low Mechanization Implements (LMI). The latter category includes implements such as traditional plows, sickles, etc. Manufacture of LMI are mostly done by local blacksmiths, in contrast to HIMI which are mostly imported. While we present some statistics on the ownership of the LMI, in this paper we mainly focus on patterns in use, demand, and supply in HIMI, particularly tractors and combine-harvesters.

3. AGRICULTURAL GROWTH AND STRUCTURAL TRANSFORMATION IN ETHIOPIA

Ethiopia is among the poorest countries in the world, but it has registered remarkable economic growth and poverty reduction over the last decade (World Bank 2015a). Real GDP grew annually by an average 10.7 percent over the period 2005 to 2014. The agricultural sector also grew rapidly at an average annual rate of 7.6 percent. The sector 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 superseded it in 2010/11. Part of the growth in the agricultural sector is explained by increasing adoption of modern inputs, such as chemical fertilizer. Bachewe et al. (2016) show that chemical fertilizer use increased by 144 percent over the period 2005 to 2014, and 76 percent of the cereal farmers in the country adopted chemical fertilizer in 2014 from 46 percent in 2004. We also see important changes in the agricultural economy related to employment and wages, livestock prices, connectivity and market access, as well as small changes in farm sizes. As these changes might impact the agricultural mechanization process, they are discussed consecutively.

Figure 3.1: Real daily wages of unskilled laborers in rural areas of Ethiopia, 2003 to 2016; and rural wage data from other developing countries



Source: Authors' calculations based on CSA data, Bachewe et al. (2016) and Bymolt and Zaal (2015)

Despite the important overall economic growth that has been observed recently, we see little structural transformation in terms of employment with labor moving from the agricultural sector to the service and manufacturing sectors.[4] On the other hand, we see a significant increase in the level of rural wages paid, as seen in Figure 3.1 (on the left). Real wages of unskilled labor in rural areas increased by more than 50 percent over the period 2000 to 2016. However, while there has been growth in wages in rural areas, these wages notably are still significantly lower than those in other comparable countries. Rural wage data from other countries are shown on the right panel of Figure 3.1.[5] We find that wages in Ethiopia in 2012 were significantly lower than those in Asian countries for which data are presented. It is estimated that average unskilled labor (daily) wages in Nepal, Bangladesh and Myanmar in about 2012 were 0.95, 1.59, and about 1.00 USD higher, respectively, than average daily wages in Ethiopia. Agricultural wages in Ethiopia were only

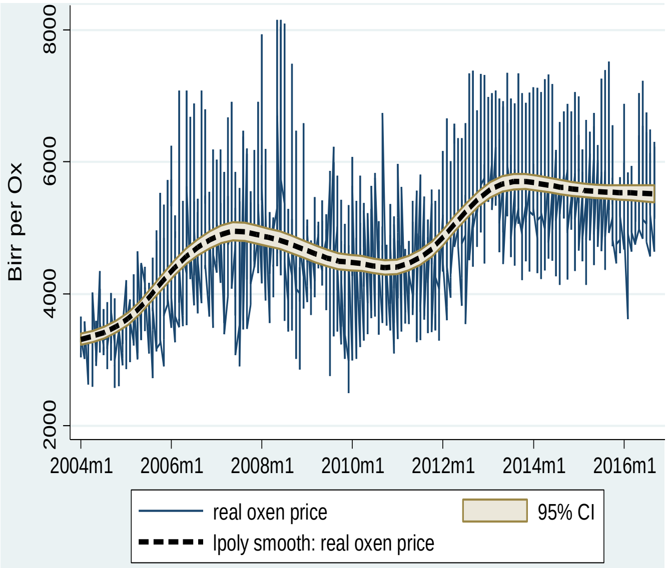
[4] Most Ethiopia's population remains in rural areas deriving their living mainly from agriculture, and the non-farm sector is remains small when compared to other countries (Bachewe et al. 2016). For example, Schmidt and Bekele (2016) find that the growth of the non-farm sector only contributed to a small drop in the share of people making a living in the agricultural sector, i.e. 3 percent between 2005 and 2013, a drop from 80 to 77 percent.

[5] Unfortunately, as wage data are not widely available, these data only provide an indication of wages paid in a limited number of Asian and African countries.

57, 44, and 56 percent of the average agricultural wages paid in these respective countries. Compared to two East-African countries (Tanzania and Kenya) for which we have data, wages in Ethiopia are significantly lower as well.

Second, agricultural growth over the last decade has been achieved partly through an increase in the area of land cultivated, but mostly though yield increases. Using CSA's nationally representative dataset, cultivated land increased by 27 percent over the last decade (Bachewe et al. 2015). This increase has led to increasing pressure on land use for other purposes – such as forests and communal lands – and to subsequent scarcity of grazing areas for livestock, which has led to growth in the commercial feed sector, as noted in the rapid emergence of commercial feed mills (Mekasha et al. 2014). This trend seems to have contributed to relatively higher costs of holding cattle, which has impacted the cost of animal traction. This is illustrated in Figure 3.2 below. The average oxen price in the country almost doubled in real terms over the period 2001 to 2016.

Figure 3.2: Real prices of oxen in Ethiopia, 2004-2016



Source: Authors' calculations based on CSA price data

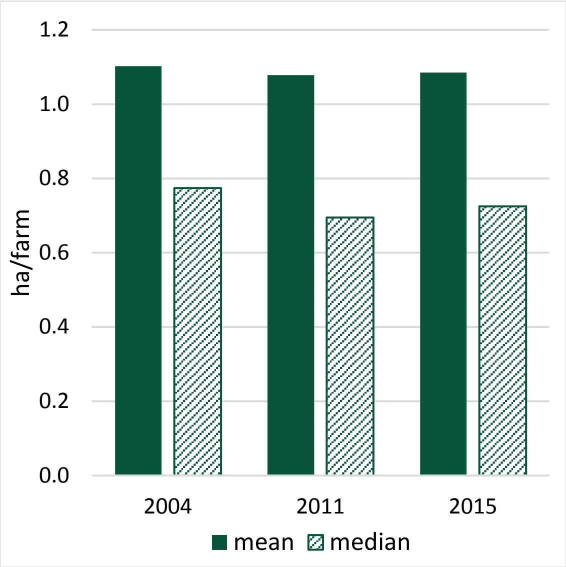
Third, the functioning of agricultural markets has improved significantly over the last decade (Minten et al. 2014). Two major factors have contributed to better connecting rural farmers to demand centers. First, urbanization in Ethiopia is one of the lowest in the world, with only 17 percent of its population estimated to live in cities in 2012 (World Bank 2015b). However, rapid growth of cities has occurred in the last decade and even faster changes are expected in the future. Schmidt and Kedir (2009) estimate that, based on an agglomeration index approach and using the last three national censuses (1984, 1994, 2007), urbanization rates increased from 3.7 to 14 percent over the period studied, almost quadrupling the urban share of the national population (FDRE 2008). Second, driven by complementary rapid road infrastructure development, 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). Kedir et al. (2015) further estimate that only 15 percent of the population was located within 3 hours of a city with a population of at least 50,000 in 1997/1998, but in 2010/11, this number had changed to 47 percent of the population.[6] This development in markets and connectivity are important factors in providing necessary incentives for increasing investments in agriculture, including in capital-intensive agricultural mechanization.

Fourth, Ethiopia is largely characterized by smallholder agriculture. Smallholder farmers dominate agricultural land use in Ethiopia, making up 94 percent of total cultivated land in 2014/15 with this share changing little over the last decade.[7] Figure 3.3 illustrates how the mean and the median farm size of these smallholders has evolved over the last ten years. Farm sizes were small at the beginning of the decade with a mean and median of 1.10 and 0.77 hectares per farm respectively. These figures had declined slightly by 2015 to 1.08 and 0.72 hectares per farm, respectively. This pattern of small farm sizes adversely affects mechanization as smaller farms are generally less capitalized and rely less on mechanization, as we will see later.

[6] The World Bank (2015) expects that urban populations will continue to grow rapidly in Ethiopia. They project an annual growth rate of 5.4 percent over the coming decades, which would lead to a tripling of the urban population from 15.2 million in 2012 to 42.3 million in 2034. By 2028, 30 percent of the population of Ethiopia is expected to be living in urban areas.

[7] Smallholders cultivated 14.22 million hectares (CSA 2015a) in the main meher season in 2014/15. This compares to 0.98 million hectares for commercial farmers (CSA 2015b).

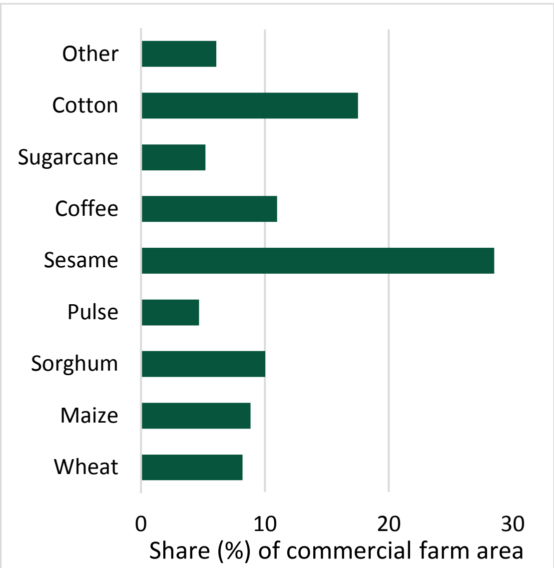
Figure 3.3: Evolution of farm sizes of smallholders (less than 25 hectares) in the country

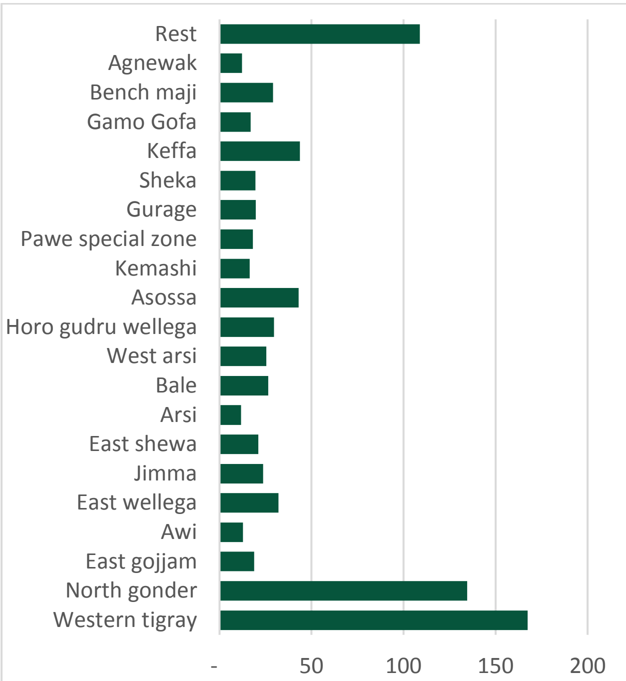


Source: Authors' calculations based on CSA's Agriculture Sample Surveys

While the importance of smallholders in Ethiopian agriculture is large, the relative importance of commercial farmers – defined by the Central Statistical Agency as those that have more than 25.2 hectares – is increasing over time, although starting from a relatively low base. The area cultivated by commercial farms increased from 0.46 million hectares in 2007/08 to almost 1.0 million hectares in 2014/15 (CSA 2015b). Moreover, these commercial farms are spatially concentrated and are focused on specific crops (Figure 3.4). The five most important crops grown by commercial farms are sesame, cotton, sorghum, maize, and wheat. Several of these crops are spatially clustered – commercial farms producing sesame are mostly located in the northwest; maize, mostly in the west; and wheat in the south and southeast of the country. (Cotton and sorghum are more scattered across Ethiopia).

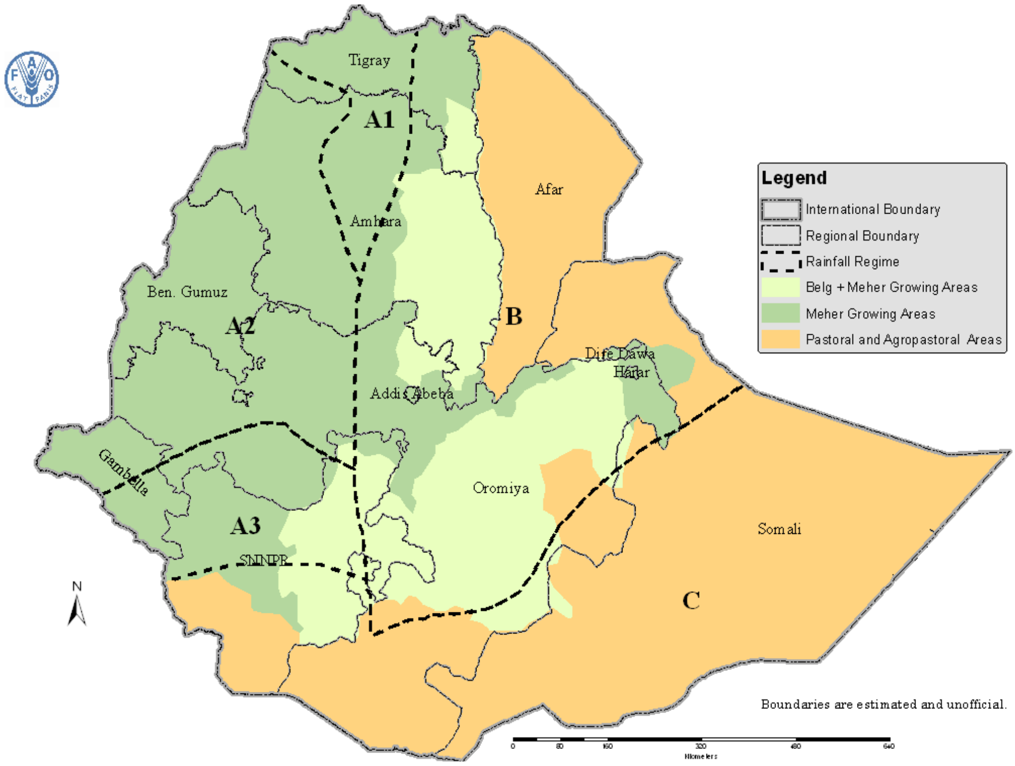
Figure 3.4: Commercial farms: Crops grown and area under commercial farms by zone, '000s ha





Source: Authors' calculations based on CSA's commercial farm survey

Figure 3.5: Rainfall patterns in Ethiopia



Source: FAO

Finally, to understand the demand for mechanization, two defining characteristics of Ethiopian agriculture are important to highlight. First, Ethiopia is characterized by a rugged topography with strong differences in altitude over short distances. When considering agricultural production environments, a distinction is made between the highlands (higher than 2500 masl), the midlands (about 1600-2500 masl), and the lowlands (less than 1600 masl). Second, there are distinctive rainfall patterns in the country. Rainfall is unimodal in the west and north of the country, with one main harvest (Meher), while it is bi-modal in the east and southeast of the country, giving rise to a second season (Belg) in those areas (Figure 3.5). Moreover, rainfall is more reliable in the west and southeast of the country compared to other parts. Based on these characteristics, Chamberlin and Schmidt (2012) divide the country into five development domains: moisture-reliable highlands, moisture-reliable lowlands, drought-prone highlands, drought-prone lowlands, and pastoralist areas.

4. DEMAND SIDE ANALYSIS

4.1. Current machinery use and ownership

Using data from the FtF survey, Table 4.1 illustrates ownership of different types of machinery by size of farm, divided into quintiles. The median size of the farm in the dataset varies between 0.3 hectares for the smallest quintile up to 3.4 hectares for the largest quintile. The median for the whole sample is 1.1 hectares, close to the average for the country.[8] Ownership of HIMI is shown overall to be low in the country – 0.1, 0.3, and 0.1 percent of households report owning a motorized water pump, a small tractor, and a hand-held motorized tiller, respectively. The mean value of HIMI for these households is 144 Birr (or about 7 USD). The median value is zero. As expected, we see a strong association of farm size with ownership of HIMI. In the case of small tractors, 0.5 percent of the largest farms report owning a small tractor, but this declines to zero for the smallest farms.

Table 4.1 also presents statistics on the ownership of LMI. The average value of LMI assets amounts to 521 Birr (or 27 USD), still low, but significantly higher than the value of HIMI owned. We see a strong association between farm size and ownership of LMI with the reported value of LMI for the highest quintile being almost four times higher than that of the lowest quintile. The median shows an even higher gradient. Within the LMI category, household ownership of *mareshas* (oxen-pulled plows) stands at 65 percent, sickles at 80 percent, and axes at 71 percent. Few farmers own more modern LMI, such as chemical sprayers (1 percent) and mechanical water pumps (4 percent). The ESS results,

[8] It is to be noted that the commercial farms larger than 25 hectares are not part of this survey.

presented at the bottom of Table 4.1, illustrate a similar pattern to the LMI ownership results in the FTF survey. (However, no data on HIMI ownership were available in this dataset.)

Table 4.1: Ownership of machinery

Ownership	Unit	All	Farm size (by quintile) Q1	Q2	Q3	Q4	Q5
FTF areas							
Average size of farm	Mean hectares	1.6	0.3	0.7	1.2	1.8	4.2
	Median hectares	1.1	0.3	0.8	1.1	1.8	3.4
High and Intermediate Mechanization Implements (HIMI)							
Motorized water pump (diesel)	% of households	0.1	0.0	0.0	0.0	0.0	0.3
Small tractor	% of households	0.3	0.0	0.3	0.1	0.7	0.5
Hand-held motorized tiller	% of households	0.1	0.0	0.0	0.0	0.1	0.2
Total value HIMI	Mean Birr	144	0	10	6	19	685
	Median Birr	0	0	0	0	0	0
Low Mechanization Implements (LMI)							
Plow yoke	% of households	64.3	30.6	56.4	69.6	79.3	86.0
Plow beam	% of households	64.1	30.8	55.3	70.2	78.9	85.5
Plow lever	% of households	63.3	30.6	54.7	68.6	78.1	84.8
Plow blade	% of households	63.6	30.4	55.1	68.8	78.6	85.3
Miran (leather tie for plow)	% of households	61.6	29.0	52.3	67.5	75.7	83.7
Plow metal support (*wegel*)	% of households	63.7	30.0	56.1	69.1	78.9	85.0
Maresha (metal)	% of households	65.1	31.4	57.4	71.0	79.8	86.0
Sickle	% of households	79.9	60.3	76.9	84.0	87.4	90.9
Pick ax (*doma*)	% of households	38.1	27.3	36.7	38.4	41.7	46.7
Axe (*metrebia*)	% of households	71.1	51.9	64.8	75.7	79.3	84.1
Pruning/Cutting shears (*megrezia*)	% of households	9.1	8.9	6.9	7.2	11.5	11.1
Gesso (wood/metal)	% of households	19.1	17.3	14.7	18.0	16.4	28.9
Mencha (wood/metal)	% of households	4.8	3.0	4.1	4.8	4.6	7.3
Hoe (*mekotkocha*)	% of households	53.9	47.5	50.9	58.7	60.1	52.5
Spade or shovel (*akefa*)	% of households	38.8	25.0	30.3	37.5	42.9	58.5
Knapsack chemical sprayer	% of households	1.0	0.8	1.9	3.1	4.4	8.6
Mechanical water pump (hand, foot)	% of households	3.8	0.0	0.1	0.5	0.4	0.5
Broad bed maker (oxen-pulled)	% of households	0.3	0.0	0.1	0.2	0.4	0.9
Total value LMI	Mean Birr	521	229	416	516	619	829
	Median Birr	425	130	347	465	535	660
National level (ES survey)							
Low Mechanization Implements (LMI)							
Sickle	% of households	80.5	78.2	82.2	86.4	89.5	85.8
Axe (*metrebia*)	% of households	42.8	49.7	43.3	42.8	42.3	43.7
Pick ax (*doma*)	% of households	51.1	57.4	52.4	52.2	53.2	50.8
Plough/*Maresha* (traditional)	% of households	69.7	63.4	69.6	75.6	83.2	76.6
Plough/*Maresha* (modern)	% of households	2.2	2.1	2.3	1.9	2.3	2.9
Water pump	% of households	3.5	3.6	1.6	1.1	0.8	4.5

Source: Authors' calculations based on the household data from the FTF and ES survey

Table 4.2 illustrates the use of machinery by farm size for different agricultural operations. In the FTF survey, information was collected on land preparation, harvesting, and threshing activities. In the ESS survey, only information on plowing was requested. The latter survey shows that in only one percent of plots was a tractor used for plowing. The most prevalent means of tilling is through animal traction or by hoe. The results of the survey also show strong links between the size of the farm and the use of tractors. The adoption of tractors for the farms in the largest farm size quintile is at 3 percent, three times as high as for the average farmer (at 1 percent). When we look at data from the FTF survey, similar trends are noted. Land preparation is mostly done through animal traction (79 percent of the plots) and by hoe (20 percent). Machines were reported to only have been used on 0.7 percent of plots. Other agricultural operations also illustrate the low level of use of machines: only 1.2 percent and 2.3 percent of the harvesting and threshing operations, respectively, were done using machines or mechanical equipment.

Table 4.2: Use of machinery, percent of plots

	Farm size (by quintile)					
	All	Q1	Q2	Q3	Q4	Q5
FTF areas						
Land preparation						
Hoe only*	20.5	33.2	19.5	15.6	16.5	16.7
Animals**	78.8	66.4	79.8	83.9	82.9	81.9
Machine***	0.7	0.4	0.6	0.6	0.6	1.5
Observations	*28,966*	*6,244*	*5,389*	*5,420*	*5,944*	*5,969*
Harvesting						
Manual	98.80	98.90	99.00	99.20	98.90	98.00
Machine	1.20	1.10	1.00	0.80	1.10	2.00
Observations	*30,800*	*6,609*	*5,705*	*5,636*	*6,301*	*6,549*
Threshing						
Manual	49.8	59.6	47	41.4	47.1	54.3
Sheller	1.5	1.6	1.2	0.7	1	3
Animals	47.9	38.2	51.1	57.4	51.4	41.2
Mechanical	0.8	0.7	0.7	0.5	0.5	1.5
Observations	*24,930*	*4,793*	*4,583*	*4,818*	*5,266*	*5,470*
National level (ES survey)						
Plowing						
Tractor	0.9	0.4	0.6	0.5	0.8	2.8
Livestock	32.6	10.0	23.1	39.9	56.3	48.6
Dig by hand	25.3	54.8	28.7	21.2	12.8	9.6
Other	41.1	34.8	47.7	38.5	30.1	39.0

Source: Authors' calculations based on the household data from the FTF and ES survey
* Plots that were prepared using only hoe
** Plots that were prepared with some involvements of animals
***Plots where machines were used somehow (solely or together with hoe and animals)

We further try to understand to what extent differences in the use of mechanization might exist between crop types. We present the results for both cereals and non-cereals in Table 4.3. In the case of cereals, using data from the FtF survey, machines were used for land preparation, harvesting, and threshing on 1.1, 1.6, and 2.2 percent of the plots, respectively. We note that mechanization is most prevalent for the wheat crop where 6.5 and 6.6 percent of the farmers reported to have relied on machines for harvesting and threshing, respectively. In the case of sorghum, we see a relatively high use of machines for land preparation (3.7 percent). The ESS survey shows overall similar results. For non-cereals, oilseeds show the highest use of machines for land preparation (3.3 percent).

Table 4.3: Use of machinery by crop, percent of plots

	All cereals	Teff	Barley	Wheat	Maize	Sor-ghum	Other cereals	Oil-seeds	Pulses	Root crops	Fruits, Vege-tables	Chat	Coffee
FTF areas													
Land preparation													
Hoe only	5.9	2.0	8.0	2.2	10.8	5.8	1.0	2.9	9.0	31.3	84.3	89.9	92.8
Animals	93.0	97.8	91.6	96.7	87.9	90.5	98.5	93.7	90.9	68.6	15.6	9.8	7.1
Machine	1.1	0.2	0.4	1.1	1.4	3.7	0.4	3.3	0.2	0.1	0.1	0.3	0.1
Observations	*17,039*	*3,830*	*2,152*	*2,635*	*5,649*	*1,517*	*1,256*	*616*	*4,190*	*2,131*	*1,344*	*328*	*769*
Harvesting													
Manual	98.4	99.2	98.9	93.5	99.6	99.5	98.4	99.5	99.5	99.0	99.5	99.0	99.6
Machine	1.6	0.8	1.1	6.5	0.4	0.5	1.6	0.5	0.5	1.0	0.5	1.0	0.4
Observations	*16,799*	*3,788*	*2,132*	*2,594*	*5,520*	*1,523*	*1,242*	*617*	*4,157*	*2,100*	*1,942*	*452*	*1,477*
Threshing													
Manual	42.4	23.2	20.0	17.0	86.1	35.2	23.8	73.2	44.3				
Sheller	1.0	0.6	0.3	0.7	1.9	0.5	0.5	1.3	0.4				
Animals	55.4	75.5	79.3	76.4	11.8	64.1	75.5	25.6	55.2				
Mechanical	1.2	0.6	0.3	5.9	0.2	0.2	0.2	0.0	0.0				
Observations	*16,541*	*3,784*	*2,123*	*2,580*	*5,296*	*1,518*	*1,240*	*607*	*4,081*				
National level (ES survey)													
Plowing													
Tractor	0.9	0.8	0.5	0.7	1.7	5.5	0.3	2.5	1.0	0.8	0.7	1.0	0.0
Livestock	32.6	84.5	72.6	83.0	61.5	55.2	84.3	79.7	68.1	27.4	14.7	6.5	0.0
Hoe	25.3	3.6	13.2	5.1	24.4	24.9	1.6	8.9	18.3	66.6	77.3	82.4	0.0
Other	41.1	11.2	13.7	11.1	12.3	14.5	13.8	8.9	12.6	5.2	7.3	10.1	0.0

Source: Authors' calculations based on the household data from the FTF and ES survey

In focus group interviews conducted during the FtF survey, questions were asked about the use of different types of mechanization in the community in which the focus group interviews were held. We present these results by zone. Although caution is warranted in interpretation as the results are not representative at the zonal level, we believe that they provide a good indication of the type of machines in vogue, as well their spatial spread (Table 4.5). The results confirm the overall low use of machines in farming in the country. Tractors (4.1 percent), combine-harvesters (3 percent), and water-pumps (2.5 percent) are the most used. We further note the higher uptake of tractors and combine-harvesters in specific parts of the country. More than 5 percent of the households used tractors in Western Tigray, South Gondar, West Gojjam, East Shewa, Arsi/Bale, and in parts of the Somali region (Jijiga/Liben). The data further show that combine-harvesters are seemingly most widely used in the southeast (Arsi/Bale/West-Arsi) as well as in the Somali region (the Jijiga zone).

Table 4.5: Share of households that use machines, by zone, as reported by focus groups

Zone	Tractor	Combine-harvester	Planter	Thresher	Mechanical weeder	Water pump	Others
Central Tigray	0.1	-	-	-	-	2.5	-
Eastern Tigray	3.1	-	-	-	-	0.8	-
Southern Tigray	1.5	-	-	-	0.0	0.4	-
Western Tigray	23.6	-	0.3	33.3	-	1.6	-
North Gondar	1.1	-	-	0.2	-	0.1	-
South Gonder	8.3	-	-	-	-	0.3	-
North Shewa	2.4	-	-	-	-	0.7	4.4
East Gojjam	1.0	0.8	-	-	-	0.4	0.0
West Gojjam	7.4	-	-	-	-	0.4	0.0
Wag Himra	0.3	-	-	-	-	0.1	-
Awi	0.5	-	-	-	-	16.0	-
West Wellega	-	-	-	-	-	1.0	-
Ilu Aba Bora	0.4	-	-	-	23.9	2.6	-
Jimma	0.0	-	-	-	1.2	1.1	0.4
West Shewa	0.6	-	-	-	-	-	-
North Shewa	2.4	-	-	-	-	6.1	-
East Shewa	8.7	0.9	-	0.7	-	10.4	-
Arsi	6.8	14.5	-	-	-	-	-
Bale	8.5	30.9	5.1	-	-	-	-
Borena	1.9	-	-	0.9	-	9.4	2.2
West Arsi	5.6	14.0	-	19.7	-	0.3	0.3
Qeleme Wellega	-	-	-	-	-	4.7	-
Horo Gudru Wellega	0.2	-	-	1.0	-	5.5	-
Jijiga	37.6	33.3	-	-	-	-	-
Liben	8.3	-	-	-	-	8.0	-
Gurage	7.1	-	-	-	-	-	-
Kembata Timbaro	-	-	-	-	-	5.8	-
Sidama	0.0	-	-	-	-	2.0	2.7
Gedeo	-	-	-	-	-	0.1	-
Wolayita	2.5	-	-	-	-	6.1	-
Sheka	1.5	-	-	-	-	3.2	-
Kefa	1.1	-	-	-	-	0.1	-
Konta	0.2	-	-	-	-	0.4	-
Siliti	0.4	-	-	-	-	2.4	0.2
Total	4.1	3.0	0.1	1.5	0.6	2.5	0.4

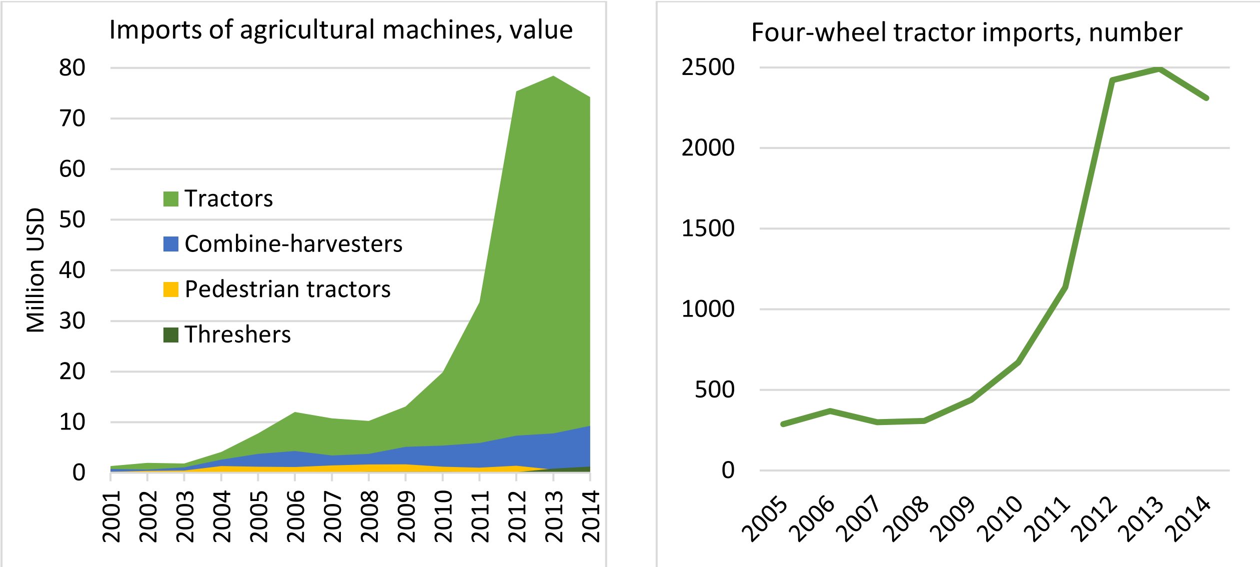
Source: Authors' calculations based on the household data from the FTF survey

The data from these surveys therefore indicate the low level of ownership and use of machines for agricultural activities by smallholders in the country. However, we note important patterns by crop and over space. Mechanization is more prevalent in the case of wheat where we see mechanized plowing and harvesting for 5 percent of wheat plots. We also note more uptake in the north-west, south and southeast of the country as well as in the Somali region. Furthermore, these FtF and ESS surveys do not cover commercial farms in the country. While these farms cultivate significantly less land than smallholders, they are however relatively more important for mechanization. Moreover, while levels of use of mechanization are low, important dynamics are noted. This is covered in the next section where alternative datasets are considered.

4.2. Changes over time

We rely on trade data from Comtrade to look at changes over time in large machine imports. As there are no local manufacturers of tractors and combine-harvesters, these trade data allow us to assess levels and dynamics in their ownership and use. Figure 4.1 shows how the value of imports of main agricultural machinery, including tractors, combine-harvesters, two-wheel tractors, and threshers, has changed over the period 2000 to 2015. To make the trends in imports clearer, we rely on 3-year moving averages. While the value of imports of agricultural machinery was around 10 million USD in 2005-06, this number had increased to over 70 million USD by 2013-14. The major contributor to that change has been the large increase in imports of four-wheel tractors. More than 60 million USD was spent on the import of these tractors in 2014. The second largest category is combine-harvesters. The import value of two-wheeled tractors and of threshers was relatively much less important. The graph on the right in Figure 4.1 shows the moving average of the number of four-wheel tractors imported into the country over the period 2004 to 2015. While less than 500 tractors were imported in 2005, this number had increased to almost 2,500 in 2013-14. Over the period 2004 to 2015, 12,128 tractors were reported imported in total. These import data indicate overall that large changes have occurred in the last decade, and especially so in the last five years.

Figure 4.1: Imports of main agricultural machines into Ethiopia, three-year moving averages, 2004 to 2015



Source: Authors' calculations based on Comtrade data

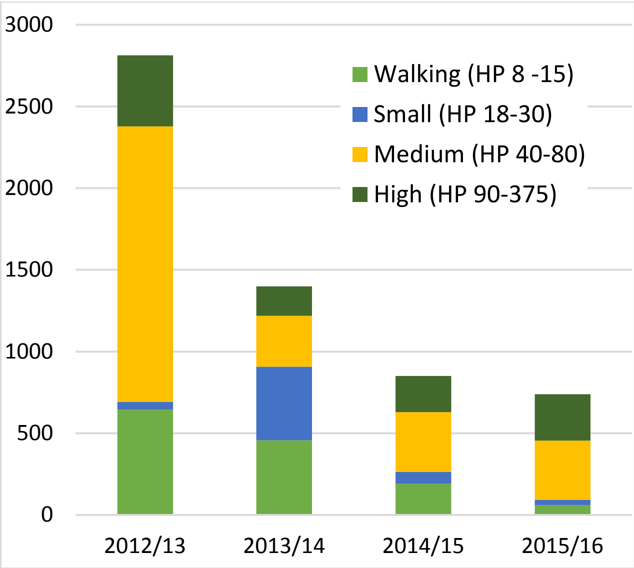
One important new player in the tractor market in Ethiopia is Adama Agricultural Machinery Industry (AAMI) from which we obtained detailed sales data for the period 2012/13 up to 2015/16. While five main companies dominated the imports of tractors up to 2011 (World Bank 2012), this all changed when the Metals and Engineering Corporation (METEC) became more aggressively involved in the assembly of tractors in the country. Established as the Nazareth Tractor Assembly Plant (NTAP) in 1984 through a technical and economic cooperation agreement between Ethiopia and the USSR, NTAP was renamed the Adama Agricultural Machinery Industry (AAMI) in 1992 with the start of the new government. It was then transferred to the Metals and Engineering Corporation (METEC) in 2010. Before the transfer to METEC, it had assembled about 6,000 tractors over a 20-year period or about 300 tractors per year on average. Its mode of operations, however, changed drastically when it became part of METEC, given the additional resources and technical know-how of METEC.[9]

The sales data on tractors presented in Figure 4.2 show that AAMI sold more than 2,500 tractors in 2012/13 – at the beginning of its association with METEC. However, then sales have been dropping off quickly – sales in 2015/16 were only a quarter of those in 2012/13.[10] As AAMI apparently has continued assembly of tractors over time (as seen in the import data), these data indicate that the firm has a significant number of unsold tractors in stock. Comparing numbers in Figures 4.1 and 4.2 shows that in 2014, about 850 tractors were sold by AAMI while total imports stood at 2,300 that year. While imports by private dealers have increased, they did not show that much of an increase – as reported by them – to make up for the important gap. These data therefore indicate that there is an oversupply of tractors in the country.

[9] See http://www.METEC.gov.et. METEC operates 15 "Industries" of which AAMI is one. AAMI operates four factories: 1/ tractor factory; 2/ implement factory (in collaboration with Adama University); 3/ pumps factory; and 4/ irrigation material factory. In total, AAMI employs 800 permanent and temporary workers.

[10] The reasons are not very clear. It might be due to the supply of spare parts. As AAMI has regularly changed the makes of tractors that they assemble, complaints have been logged about the availability of such spare parts.

Figure 4.2: Tractor sales by Adama Agricultural Machinery Industry (METEC)



Source: Authors' calculations based on AAMI sales data. HP = horsepower

The data from AAMI also provide an idea on the type of tractors in demand or sold. Almost half of the tractors sold by AAMI were between 40 and 80 horsepower (Figure 4.2). Two-wheel tractors were relatively less important at 23 percent of their sales. In the last four years, 1,350 of such two-wheeled tractors were sold by AAMI. Large tractors of 90 horsepower and above made up almost 20 percent of the number of tractors sold. Figure 4.2 further illustrates the increasing share of larger tractors in AAMI sales. While two-wheeled (or walking) tractors and small tractors (of between 18 and 30 horsepower) represented a quarter of their sales in 2012/13, this fell to 12 percent in 2015/16. For the business operations of AAMI, these smaller tractors are far less important, as the sales price of a 90-horsepower tractor is 40 times higher than the price of a two-wheeled tractor.[11] During an interview with AAMI, they described the type of clients that purchased different types of tractors. They noted that about 50 percent of the tractors were bought by "medium" (or commercial farmers), 20 percent by "small-scale" farmers, and 30 percent by "large-scale" farmers or state farms.[12]

In the last decade, there has also been a rapid increase in the number of combine-harvesters imported. Figure 4.3 shows that the real value of combine-harvester imports to the country in the beginning of the 2000s was around one million USD. This had increased in 2014 to almost 10 million USD, a ten-fold increase. The average value of a combine-harvester imported was just over 100,000 USD over the period 2006-2015. The graph on the right in Figure 4.3 shows the changes in the number of combine-harvesters imported into Ethiopia over the last decade. The number increased from around 40 in 2007 to almost 80 in 2014. Total imports of combine-harvesters in the last ten years amounted to 600, a similar estimate mentioned by key informant interviews on current functional combine-harvesters in the country.[13] To access the importance of combine-harvesters in the country, along with the area harvested, we rely on back-of-the envelope calculations.[14] Using such an approach, we estimate that a quarter of the cultivated wheat area was harvested by combine-harvesters in 2014/15.[15]

[11] Reported prices by AAMI at the time of interview (mid 2016) were as follows: Walking tractor: 26,000 Birr; 15-horsepower tractor: 40,000 Birr; 40-horsepower tractor (plus harrow and plow): 388,000 Birr; and 90-horsepower tractor: 945,000 Birr.

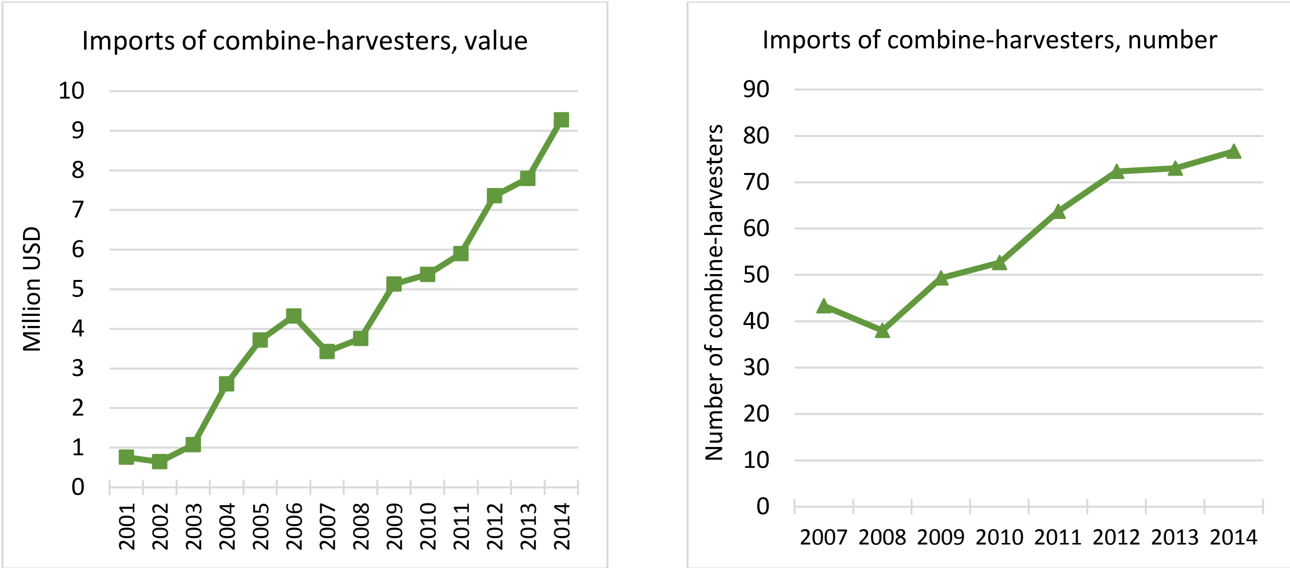
[12] Large-scale farmers include especially state farms. For example, the Oromia Seed Enterprise (one of the biggest state farms) that cultivates almost 25,000 hectares in the Oromia region, reportedly owns 150 tractors and almost 40 combine-harvesters. Also, sugar farms that the government is increasingly investing in are important in this category (World Bank 2015a).

[13] Claas, the biggest importer of combine-harvesters, reported that they had imported 800 combine-harvesters in the country since the start of its operations in the beginning of the 1990s. It estimated that 500 of their combine-harvesters were still functional. It was further estimated that New Holland would service about 50 to 100. John Deere reported that they had 75 functional combine-harvesters in the country. There were further reported imports by Massey Ferguson (100 over the last ten years), Deutz (10) and Sambo (10).

[14] Using wheat area cultivated by smallholders (1.6 million hectares) and commercial farms (0.08 million hectares) in 2014/15, there was nationally about 1.7 million hectares of wheat planted (exactly 1,774,420 hectares). Relying on statements of key informants and assuming that combine-harvesters harvest 8 hectares a day, are functional for 120 days (our stakeholders mentioned that some were active for 150 days), and that there were 500 functional combine-harvesters, this would imply a harvested area by combine-harvesters of 480,000 hectares.

[15] We get lower numbers from our survey as commercial farmers are not included, the major Arsi-West Arsi-Bale area is underrepresented, and a random sample of farmers was used (not focusing on area cultivated).

Figure 4.3: Imports of combine-harvesters into Ethiopia, three-year moving averages



Source: Authors' calculations based on Comtrade data

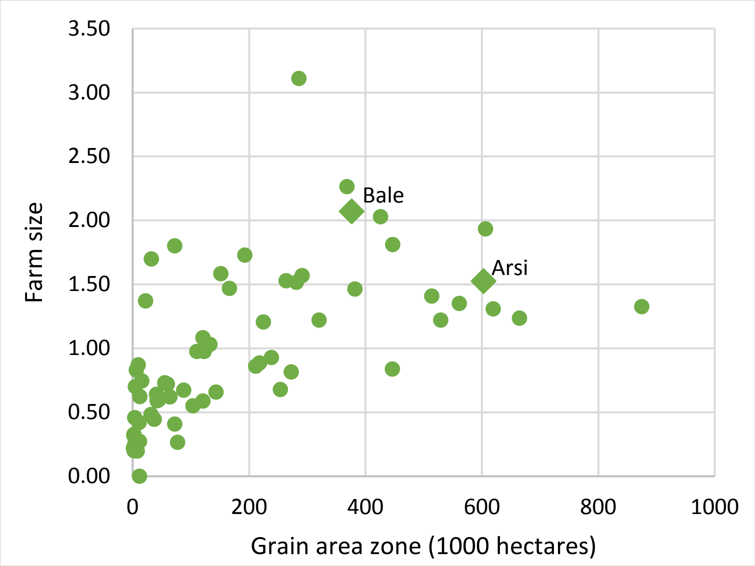
Our survey data and focus group interviews indicate strong spatial differences in the use of mechanization. These data indicate that mechanized services of tractors and combine-harvesters have especially been taken up in major wheat-growing areas in the southeast of the country (the zones of Arsi, West Arsi, and Bale, in particular). That area seems to be unique for a combination of factors.

- First, commercial farms and smallholders co-exist, and the smallholder population is relatively large compared to the rest of the country (Figure 4.4).
- Second, there has been a history of interventions by projects to stimulate mechanization uptake and farmers have been exposed to mechanized services for a longer period, seemingly facilitating its adoption by smallholders at a larger scale.[16]
- Third, in those zones where mechanization is taking off, we find terrain that is contiguous and relatively flat and stone-free, and plots are larger and soils are more fertile, making the adoption of mechanization easier (Table 4.6).
- Fourth, rural wages are on the higher side in these areas. This matters as mechanization is a substitute for agricultural labor. For example, Berhane et al. (2016) show the strong link of wages with use of mechanization in the Ethiopian context (Figure 4.5).
- Fifth, in some of these highland areas within these zones, there are two harvests – rather rare in Ethiopia – and there is significant time pressure between harvesting and threshing the output of the Meher, and the consequent plowing of the fields for the upcoming Belg. As mechanization reduces the time needed to complete these agricultural processes, it might have contributed to further successful adoption.

It is however important to highlight that, while all these factors might have contributed to the success of mechanization in that part of the country, it is hard to pinpoint one specific driving force from the feedback provided by several key informants.

[16] The Arsi zone was exposed early on to agricultural mechanization technologies due to priorities set in the Arsi Rural Development Unit (ARDU) and the Chilalo Agricultural Development Union (CADU), financed by a Swedish International Development Agency (SIDA).

Figure 4.4: Farm size and grain area, by zone



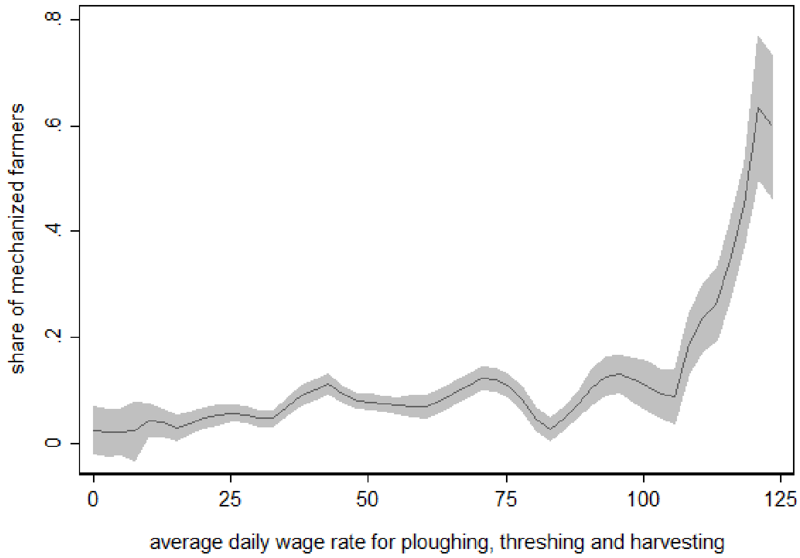
Source: Authors' calculations based on CSA's commercial farm survey

Table 4.6: Comparison of some characteristics of mechanization-intensive zones to other zones

Zone	Avg. plot size, ha Mean	Median	Soil fertility, % Fertile	Semi fertile	Infertile	Slope of the plot, % Plain	Hilly	Valley
Mechanization-intensive zones								
Arsi	0.39	0.25	73	24	3	76	23	1
Bale	0.51	0.41	71	24	6	79	21	0
West Arsi	0.38	0.25	73	25	3	79	19	1
Jijiga	0.57	0.33	62	29	10	97	3	0
W/Tigray	0.75	0.38	89	8	2	90	9	1
Other zones								
All other FTF zones	0.25	0.15	64	30	6	71	28	2
Total	0.28	0.19	65	29	6	72	27	2

Source: Authors' calculations based on the household data from the FTF survey

Figure 4.5: Mechanization and daily wage rates, Birr/day



Source: Berhane et al. (2016)

In brief, the results indicate that the demand for mechanization in land preparation and in harvesting in the case of wheat has grown to a level whereby there is a large enough demand from smallholders to warrant a hiring market. We estimate that a quarter of the smallholder farming area under wheat in Ethiopia is harvested by combine-harvesters. We also find that there is a strong spatial component to agricultural mechanization.

5. SUPPLY SIDE ANALYSIS

There are no manufacturers of tractors or combine-harvesters in Ethiopia, all are imported from abroad. Taxation of agricultural machinery is treated in a similar way to other investment goods, and, therefore, they are exempt from taxes and excise duties (World Bank 2012). Spare parts have similar privileges if they are imported at the same time as the machinery. If they are imported separately, the import duty is between 10 and 25 percent and VAT is charged at 15 percent (World Bank 2012). While the taxation of agricultural machinery is relatively lower than for other commercial imports, an important hurdle to scale has been access to foreign exchange for dealers to import machinery. This clearly has lowered the availability of agricultural machinery and, therefore, its use. For example, this hurdle resulted in situations where people had the resources to pay for agricultural machinery, yet had to wait for months – or even years – before the foreign exchange could be obtained and the final hurdle preventing importation of agricultural machinery could be resolved. However, this constraint has been (partly) alleviated recently as agricultural mechanization has been declared a priority area with preferential access to foreign exchange. Also, AAMI enjoys a special institutional status and, so, suffers less from such import constraints.

Different types of payment facilities have been established to assist in the acquisition of agricultural machinery. First, AAMI offers credit facilities. Tractors of 30 horsepower or less can be bought with only a 30 percent down-payment, while tractors of 40 horsepower or higher require a 50 percent down-payment. The rest of the payment can be made over a two-year period. This access to credit was reported by several focus groups to be among the main attractions for purchasing tractors from AAMI. Second, the Oromia International Bank provides loans for agricultural machinery purchases from private dealers. Interest rates, however, have been relatively high – current annual nominal interest rates are 16 percent, increasing from 8 percent three years ago. In the case of commercial banks, a 50 percent down-payment is often the norm, and loans have to be paid back in 2 to 3 years.

While there are no local manufacturers of tractors and combine-harvesters, there are, however, local assembly plants of tractors. In particular, AAMI is engaged in assembling machinery, but other dealers are planning to do likewise.[17] AAMI mostly imports tractor parts from Poland, China, and Belarus in “knocked down (KD)”, “completely knocked down (CKD)”, and “semi-knocked down (SKD)” form. Other importers deal with completely build up units (CBU). The most important private dealers include GEDEP, ADEP, AMNIO, Caleb, and Ries Engineering. Combined, it is estimated that they import 100 to 200 tractors a year (World Bank 2012). The tractors they provide are more expensive than those provided by AAMI, but they are also reported to be of a higher quality.[18] This higher quality means that for the same horsepower in a tractor, AAMI assembled tractors reportedly took more time to complete the work undertaken than similar tractors from other dealers. However, at farm level, no distinction is made for pricing of service provision between AAMI tractors and tractors from other dealers. Most of the private companies also have good post-sales service provision, while AAMI is reported to fall short in service provision due largely to the frequency in which it makes changes in the brands of tractors it imports.[19]

In the case of tractors, ownership appears to lie more in the hands of commercial farmers and state farmers than with service providers. One importing company estimated that 60 percent of tractors are owned by farmers and 40 percent by service providers. However, in the case of combine-harvesters, ownership is mostly by mechanized service providers. The chairman of the Mechanized Service Provider Association estimated that about 50 of the 700 functional combine-harvesters in the country are owned by commercial farmers and parastatals (such as the Oromia Seed Enterprise and the Agricultural Equipment and Technical Services Share Company), while the rest are operated by commercial providers of mechanized services. It is estimated that there are 200 such private service providers nationally, implying that each provider owns on average three combine-harvesters.[20] Providers of these services typically live in areas where mechanized services are widely used.[21] Most service providers are often involved in other businesses, such

[17] The advantage of doing local assembly is that it is cheaper to bring tractors into the country. While one can fit three complete large tractors in a shipping container, the components for up to eight unassembled tractors can fit in a single container.

[18] For example, one informed stakeholder put the current price of a 120-horsepower John Deere tractor at 1.8 million Birr. This compares to 1.2 million Birr for a similarly powered tractor from AAMI.

[19] However, AAMI provides 10-day training courses in the use of its tractors to buyers and provides repair and maintenance services for tractors in the field.

[20] The largest provider was reported to own 14 combine-harvesters. Bigger service providers existed earlier, but they have divested out of harvesting.

[21] The chairman of the Association of Mechanized Service Providers estimated that five percent of service providers were based in Addis Ababa, 17 percent in Bale; 16 percent in Dodola, 12 percent in Assosa, 5 percent Shashemene; 5 percent in Arsi Negele; 20 percent in Nazareth/Assela; 5 percent in Jijiga and the rest scattered in rural towns.

as in cereal trade, consumer shops, or flour factories. The provision of mechanized services is a largely seasonal activity and other activities are required to fill the slack period in their business. However, there is limited integration of their other economic activities with their mechanization service provision – for example, few reported also buying harvested wheat as part of their trade activities.

Table 5.1 shows to what extent farmers in the FTF survey use machine rental services for land preparation, harvesting, and threshing. As discussed earlier, machine use in agriculture is low, and the majority of farmers employing agricultural machinery in their farming rely on such rental services – very few farmers use their own tractor, combine-harvester, or thresher. Own machines only make up 19 percent of machine use for land preparation, 22 percent for harvesting, and 2 percent for threshing. Results from the ESS survey show higher own tractor use than in the FTF survey. Nonetheless, the ESS survey estimates are that almost 70 percent of farmers rely on rental agreements to assure the plowing of their fields, again illustrating the importance of the provision of rental services for mechanized farm operations for these smallholder farmers.

Table 5.1: Importance of machine rental services, by farm size

		Farm size (by quintile)				
	All	Q1	Q2	Q3	Q4	Q5
FTF areas, percent of households						
Land preparation by machine	1.79	0.56	1.49	1.68	1.45	3.76
Of these,						
Own	19.5	0.0	42.3	23.6	12.0	14.0
Rented	71.9	88.1	50.2	68.8	73.6	79.1
Share-owned	0.7	0.0	0.0	0.0	4.6	0.0
Government	7.9	11.9	7.5	7.5	9.9	6.9
Observations	*162*	*16*	*28*	*25*	*25*	*68*
Harvesting by machine	3.69	2.24	3.09	3.6	2.86	6.71
Of these,						
Own	21.6	9.8	23.8	12.5	26.9	27.1
Rented	58.7	52.5	54.8	66.5	47.9	63.1
Share-owned	5.0	11.0	2.5	8.4	8.3	1.2
Government	14.6	26.6	18.9	12.7	17.0	8.6
Observations	*253*	*33*	*45*	*45*	*35*	*95*
Threshing by machine	2.13	1.22	1.88	1.88	1.66	4.03
Of these,						
Own	2.0	0.0	0.0	0.0	4.5	3.5
Rented	95.9	100	96.2	100	90.6	94.8
Share-owned	0.8	0.0	0.0	0.0	4.9	0.0
Government	1.4	0.0	3.8	0.0	0.0	1.7
Observations	*161*	*19*	*31*	*28*	*23*	*60*
National level (ES survey), percent of plots						
Plowing with tractor	0.9	0.4	0.6	0.5	0.8	2.8
Of these,						
Own	31.4	69.0	54.1	44.8	40.0	16.1
Rented	68.6	31.0	45.9	55.2	60.0	83.9

Source: Authors' calculations based on the household data from the FTF and ES survey

Rental arrangements and prices of mechanized services depend on the kind of activity undertaken and on location.[22] Tractor service rates in the southeast of the country in Bale and Arsi in 2016 were typically fixed at 1,200 Birr (60 USD) per hectare for plowing. These rates are higher than for harrowing and for covering up of seed for which 650 Birr and 500 Birr, respectively, per hectare was typically charged. In some vertisol soil areas in Arsi, farmers reported that a second plowing would be required by tractor operators just before sowing. The costs of the second plowing would be lower, at about 900 Birr per hectare.[23] The differential costs reflect the effort entailed, as plowing a hectare would take about 2 to 2.5 hours during the first plow, compared to 30 minutes for the second plow. In areas where the soil is more difficult to plow, this is also reflected in costs. For example, plowing in the Ginir area – located in the lowlands – could

[22] The increasing emphasis on tax collection by the government has had an important impact on charges made to farmers. While a number of these activities previously, e.g., 3 years ago, were done informally, this is not the case anymore. Service providers usually pay 15 percent VAT on services provided. Service providers also pay 35 percent profit tax.

[23] Second plowing might also be needed following abundant rain, not enough rain (and soil is hard), or when fields are cultivated after being left fallow.

cost between 1,800 and 2,000 Birr per hectare as soils are harder and more difficult to till than in the Bale area, for example. Plowing costs are also higher after fallow periods, given the greater effort and longer time required for this operation. Moreover, distance to major towns is an important determinant of prices, as tractors must travel farther and extra costs, therefore, are incurred. Focus groups in Bale estimated that, depending on distance traveled, prices for plowing could range from 2,000 to 3,000 Birr per hectare.

In the case of combine-harvesting, the price is commonly fixed per quintal harvested.[24] Strong differences are noted in the price setting over space and time depending on several factors.

- The type of soil influences the time needed for harvest. In sandy soils, machines have greater difficulty to maneuver and harvesting therefore takes longer. Hence, charges for harvesting in these conditions are higher.
- Yields from specific areas are strongly related to the prices charged. In areas where yields are typically low – yields are often significantly lower in lowlands – farmers operating combine-harvesters spend more time to achieve specific quantities of harvest. Prices charged in these areas reflect these lower yields.[25]
- The dominant religion of an area matters, as this can influence the working days of the operator of the combine-harvester. While workers operating machines in Muslim areas face no particular taboos on days worked, the situation is very different in Orthodox dominated areas, which is practiced more widely in the north of the country. In such areas, there are usually several specific days a month that fields cannot be worked. There are also fields that are close to churches that cannot be cultivated on days that the saint of that church is celebrated. These taboo days result in a higher number of days that combine-harvesters are not used. This in turn drives up prices.[26]
- The temperature in some regions, especially in lowland Somali region, is prohibitively high during parts of the day. Combine-harvesters therefore typically only operate during the morning. As machines and operators are not fully used, this also raises the price.
- The location of the farms matter. The further away the farms are from towns and from a road, the more expensive it becomes to fuel the combine-harvesters. If the farms are really far away, combine-harvesters are partly dis-assembled and the machine is transported on trucks. This further increases the cost.
- Harvesting costs are higher on sloped land rather than on flat areas as there is a higher risk of overturning a combine-harvester.

These different factors lead to a wide range of charges for harvesting of wheat. Indicative charges – as reported by focus group interviews and by key informants for the year 2015/16 are shown in Figure 5.1.[27]

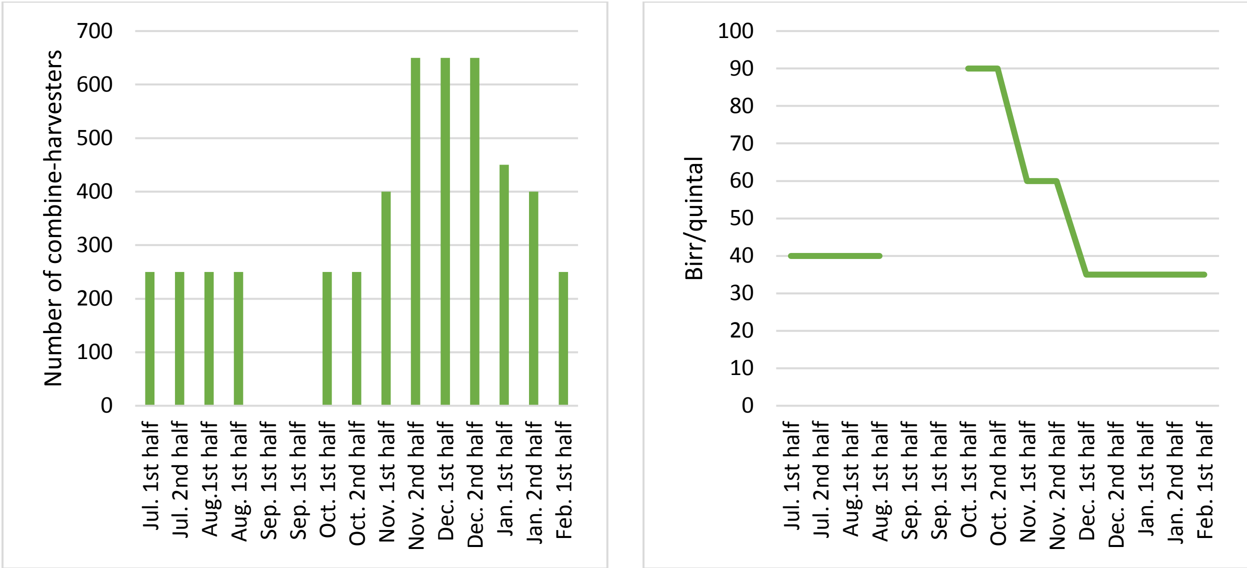
[24] On top of harvesting costs, providers typically offer transport costs services from the field to the farm. An extra charge of 5 to 10 Birr per quintal is usual for this extra service. Service providers typically rent trucks for this purpose – the amount paid varied in 2015 between 35,000 and 40,000 Birr per month.

[25] In some of these low-yield areas, a pricing system per hectare might be used, instead of per quintal prices.

[26] It was estimated that combine-harvester could only work for 15 days on average in the Gojjam area. There have been negotiations in the last year between church leaders and representatives of the Ministry of Agriculture and Natural Resources. As a result, the number of workable days has now increased in that area to between 20 to 22 days per month. In the Bale and Arsi area, combine-harvesters typically operate all days of the month.

[27] Several focus group interviews were held to explore the economics of mechanization. The following costs and benefits associated with the use of combine-harvesters as against traditional methods of harvesting and threshing were reported in a village near Assela in the Arsi/Bale area. In the case of traditional methods of harvesting and threshing a quarter hectare of wheat: Five person-days of labor would be required for harvesting. The costs of these workers would be 80 Birr per day per person, for a total of 400 Birr. In addition, the costs of food and drink for the harvest workers would amount to 220 Birr. The total labor costs for harvesting are 620 Birr. Ten oxen would be required for threshing. These would be rented at a total cost of 300 Birr. Threshing labor would require four persons at 50 Birr/day for a total cost of 200 Birr, but food and drink would also need to be provided for the threshers at a cost of 150 Birr. The total costs for threshing the harvest from a quarter hectare of wheat are 650 Birr. The total cost of traditional harvesting and threshing is therefore about 1270 Birr per quarter hectare. In contrast, the costs for using combine-harvesters are about 50 Birr per quintal times 15 quintals that is typically harvested off a quarter hectare plot, or 750 Birr per quarter hectare.

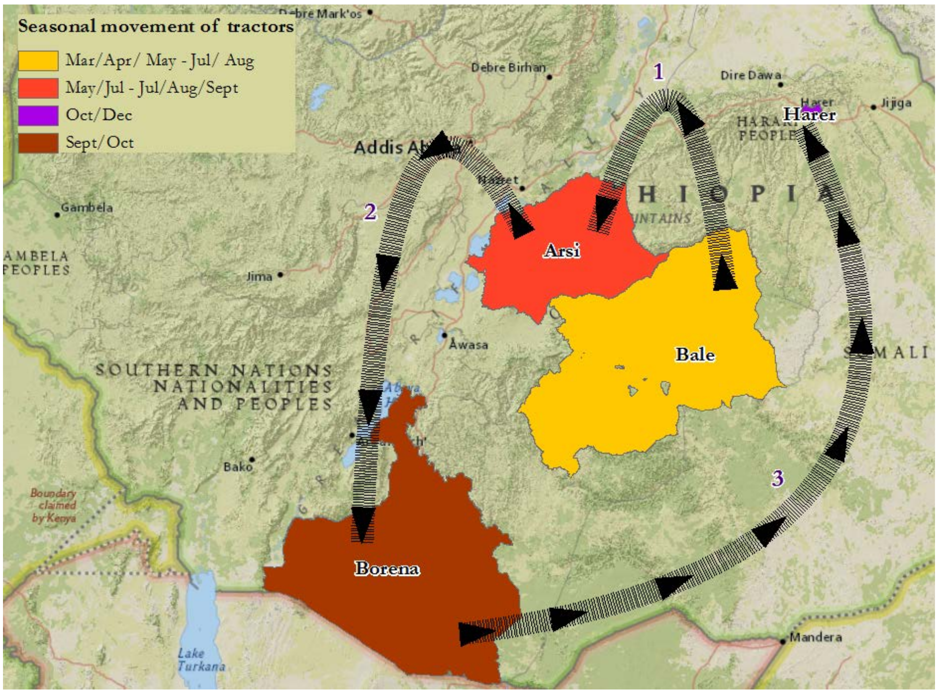
Figure 5.1: Seasonal changes in use of combine-harvesters and in harvest charges



Source: Authors' calculations based on key informant interviews

The possibility of two harvests as well as spatial differences in timing of land preparation lead to variation in the timing of service provision. Figure 5.2 illustrates the movement of tractors that perform plowing and harrowing services in the main wheat areas in Bale and Arsi. Between March and May, tractors are used to prepare fields for the Belg period. In July and August, 200 tractors might be used in that area – especially in Bale – in preparation for the Meher season. Many tractors are used in Arsi between May and September in preparation, first, for the Belg harvest and, second, for the Meher harvest. During the period September and October, some tractors move to Borena while others might be transported to Harar until December. In January and February, all tractors are idle and are serviced during that period. Tractor owners are mostly based in local areas and it is especially the larger, more expensive tractors that travel around. Tractors are typically less influenced by seasonal movements than combine-harvesters. This is for two reasons. First, tractors perform more tasks than combine-harvesters – plowing, second plowing, harrowing, covering of seeds, and sometimes sowing – and are, therefore, needed longer in the same place.[28] Second, tractors cost less than combine-harvesters. Relatively richer farmers can afford them, in contrast to combine-harvesters.

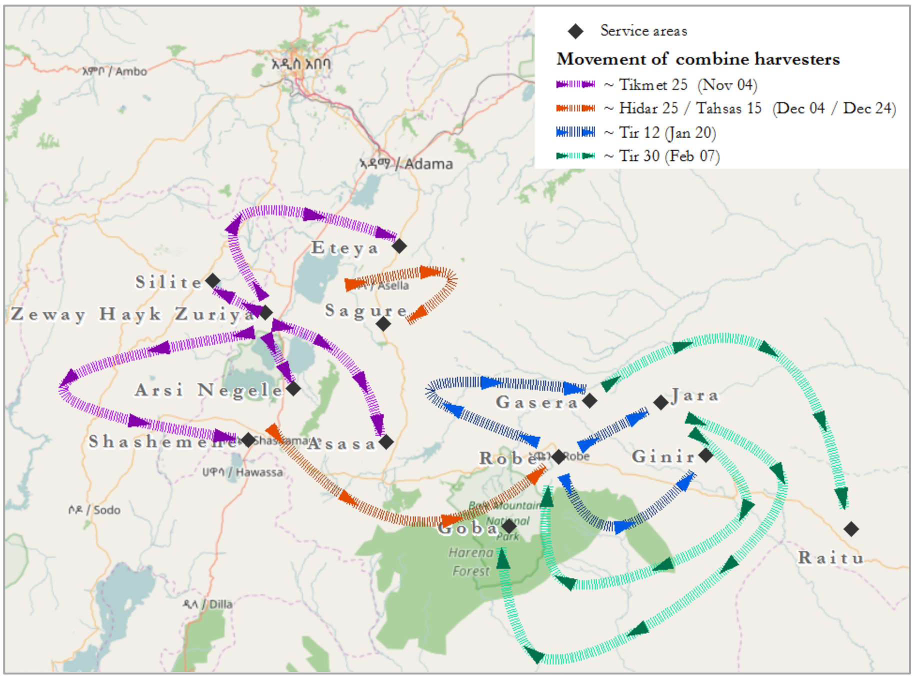
Figure 5.2: Seasonal movement of tractors between the Arsi, Bale, Borena, and Harar zones



Source: Authors' calculations based on key informant interviews

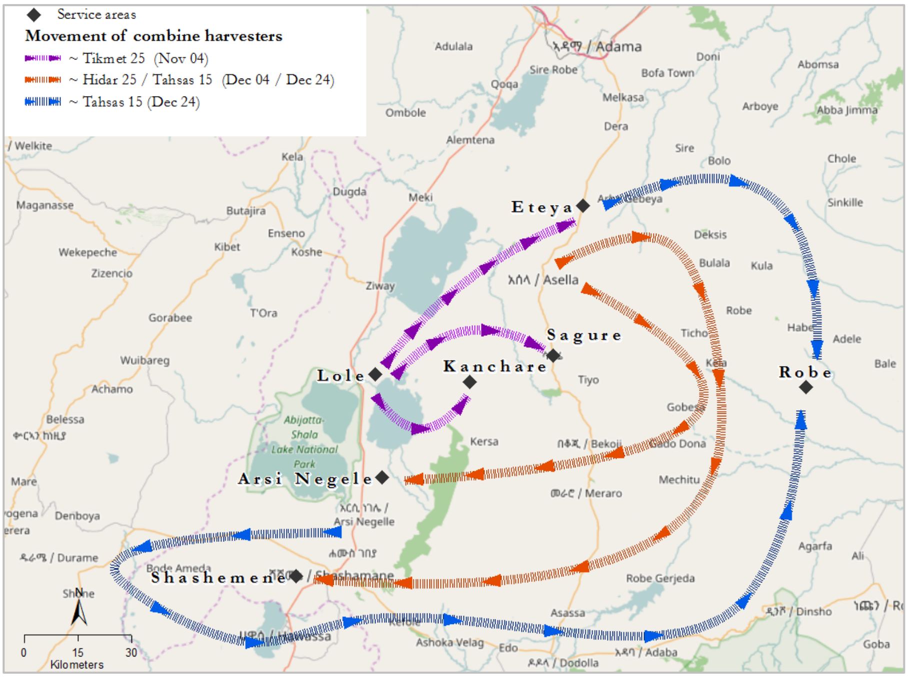
[28] For example, one stakeholder indicated that tractors that are not characterized by seasonal movement, could stay active for 5 months for all these different activities.

Figure 5.3: (a) Seasonal movement of combine-harvesters in Arsi, Bale, and neighboring areas, November to February – Route 1



Source: Authors' calculations based on key informant interviews

Figure 5.3: (b) Seasonal movement of combine-harvesters in Arsi, Bale, and neighboring areas, November and December – Route 2



Source: Authors' calculations based on key informant interviews

We also see regional movements of combine-harvesters that reflect spatial differences in harvesting periods. The two maps in Figure 5.3 illustrate this pattern of movement of combine-harvesters during the Meher harvest season, as explained by different key informants. Two main routes are taken by these combine-harvesters. The first is along the southwestern part of the wheat production belt (Figure 5.3 (a)), the second along the southeastern part (Figure 5.3 (b)). In each of the routes, the service providers begin their service in areas where the wheat harvest comes in early, due mainly to the semi-arid (or humid) agro-ecology – typically at the beginning of November. Providers along the first route begin their activities in woredas on the Rift Valley floor around Lake Ziway and Silite. Only a limited number of combine-harvesters are active (75 approximately), mainly due to the relatively lower level of wheat production in these lowland areas. Starting from mid-November, when the harvest of the relatively lower parts of the Eteya, Arsi-Negele, and Asasa woredas comes in, the number of active combine-harvesters rises. In addition to the combine-harvesters from Lake Ziway and Silite areas that move to these areas, new (previously idle) combine-harvesters enter these areas. Depending on altitude, the harvests in these areas continue until the end of November.

Combine-harvesters on the second route begin providing their service in the Lole and Kanchare areas where wheat is harvested in early November. At the end of November, providers along the second route gradually move to the productive lowlands of Sagure and Eteya. In December the combine-harvesters from the two routes head to the high wheat producing areas. These areas include Assela, Sagure, Arsi-Negele (the upper part), Asasa, and Shashemene. According to the chairman of the Mechanized Service Provider Association, given the high production, yield, and large area, between 400 to 500 combine-harvesters are estimated to be active there until the end of December.

From late December until the end of February, the combine-harvesters from the first route spread out over different areas. Some stay behind and work in the relatively higher highlands of Assela, Sagure, Arsi-Negele and Asasa where the harvest comes in later. These combine-harvesters stay in these areas until the last week of January and afterwards head to other wheat producing areas. A significant number of combine-harvesters also move to the other high wheat producing woredas of Gasera and the upper parts of Jara and Robe. They typically work there until the first week of February. Including some that arrive late form other areas, about 300 combine-harvesters are estimated to be active in these areas. Then, combine-harvesters from the two areas join and move to the lower parts of Robe, Jara, Goba, and Ginir areas where they are deployed until the end of February. In contrast, immediately after the last week of December, almost all the combine-harvesters from the second route directly head to the eastern side of Robe and its surrounding woredas, The machines, depending on demand, could stay in these areas until the end of February. After these harvests and until the Belg season, the combine-harvesters remain idle for about six months. When the Belg harvest of the Bale area comes in, 500 combine-harvesters might be in use during that period. On top of the southeast areas (especially Bale), it is estimated that 75 extra combine-harvesters might be needed in the Jijiga area. Additionally, 200 combine-harvesters might be sent to the Borena area as well.

The combination of two harvest periods during which combine-harvesters can be used as well as differences in harvesting periods between the warmer lowland and the colder highland regions contribute to a smoothening of the seasonal harvest labor peak that is typical of other crops in Ethiopia. This has contributed to the successful take-off of combine-harvesters in this area.

The coordination of journeys required for moving combine-harvesters (and to a lesser extent tractors) is usually done by local brokers, unless owners of combine-harvesters live in the area. Brokers can oversee several kebeles, and they typically coordinate with different farmers in a village to assess whether there is enough work for a combine-harvester for at least a day (about 15 and 10 hectares in flat and sloped areas respectively). Brokers commonly assess quantities of harvest and the time when areas are ready to be harvested and then coordinate with mechanized service providers. These brokers charged about 2 Birr per quintal in 2016 for this service. As they might have a stake in assuring good harvests, some of the brokers were reported to also advise farmers on improved crop management practices before harvest.

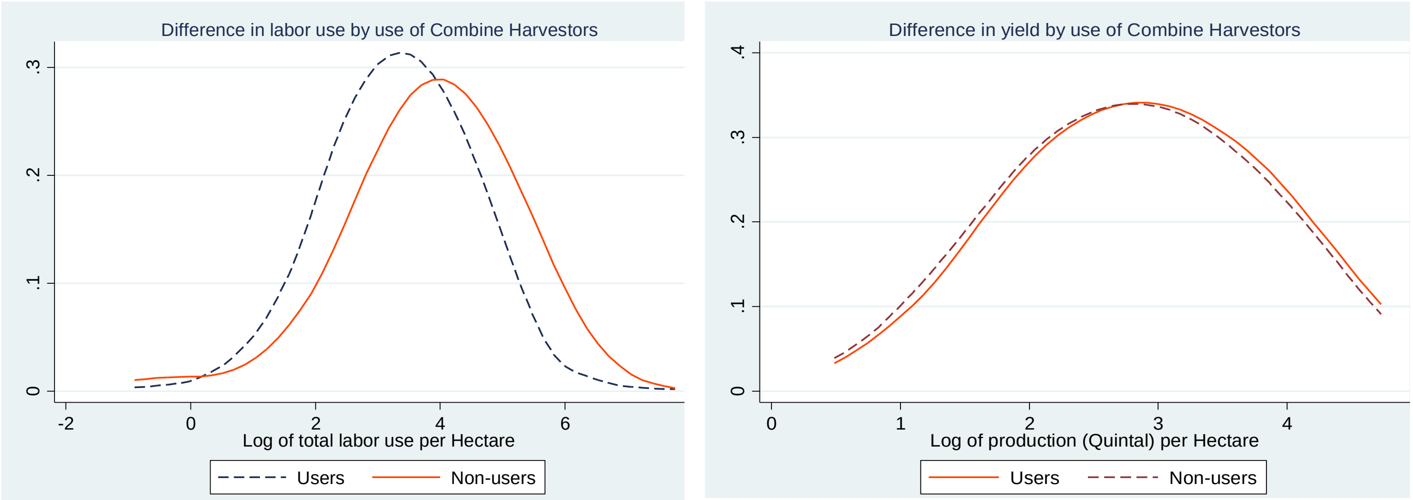
Finally, the maintenance of combine-harvesters and tractors is crucial. AAMI, as well as private dealers, normally provide warranties for their machines for up to 1,000 hours of operation. Moreover, two types of maintenance services are additionally offered in the field. First, AAMI and private dealers often have teams that travel to specific areas where many tractors are present. For example, Claas has a mobile workshop with two mechanics per workshop that services combine-harvesters during these harvest periods. They also have branches in different areas where agricultural machines are being used, such as Shashemene. Second, maintenance is provided by independent mechanics. They service different types of machines and travel to areas where tractors and combine-harvesters are functional. In the Bale-Arsi area, there are currently two such mechanics for combine-harvesters. Notably, the mechanics from companies are mostly used during the warranty period of the machines, but there is commonly a switch to independent mechanics afterwards. This switch is seemingly driven by a price difference between these two types of maintenance service providers.

6. ROLE OF MECHANIZATION IN AGRICULTURAL TRANSFORMATION

Mechanization can play an important transformative role in agriculture (Binswanger 1986). Important impacts of mechanization include increasing labor and land productivity, which are desired objectives for development and poverty alleviation. Relying on FTF data from the highly mechanized zones of the country, we test to what extent farmers that use tractors and combine-harvesters obtain higher labor and land productivity. The advantage of limiting the sample to those areas is that we have farmers that are rather similar in climatic and agro-ecological conditions and we have a reasonable number of adopters and non-adopters of mechanization in our sample.

Table 6.1 and Figure 6.1 show that wheat farmers from southeast Ethiopia who rely on combine-harvesters use only 55 percent of the labor applied by farmers who do not use combine-harvesters. Moreover, we also note differences in yield, indicating that land productivity is higher in the case of farmers using combine-harvesters, although it is not significant at conventional statistical levels, as measured by a t-test.

Figure 6.1: Density functions on association of combine-harvesters with labor productivity (left) and crop yields (right)



We also compare to what extent the farmers that use combine-harvesters are adopting different technologies and factor markets (Table 6.1). First, we look at the association with modern inputs. We note that there are no strong differences between farmers who adopt mechanized and non-mechanized practices. Furthermore, the adoption of chemical fertilizers, agro-chemicals, and improved seeds are at similar levels between both types of farmers. Second, we also look at the extent to which farmers using mechanized practices rely on land rental markets. One might hypothesize that when farmers have excess labor at their disposal, this would allow them to rent-in and cultivate more land. However, we do not see such an association in the use of combine-harvesters with the share of rented-in or sharecropped-in land in these settings. This lack of association of mechanization with land rental markets might be linked to regulations that might inhibit the development of active and efficient rental markets, as shown by other authors (e.g., Ghebru and Holden 2016).

Table 6.1: Labor and land productivity in the wheat cluster in southeast Ethiopia

	Adoption of combine-harvester		T-test	
	yes	no	t-value	sig.
Labor use, days/ha				
Mean	50.1	78.0	3.63	***
Median	32.2	56.0		
Land productivity, quintal/ha				
Mean	20.1	18.5	-1.61	
Median	20.0	16.0		
Modern input use				
Di-ammonium Phosphate (DAP), kg/ha	99.1	97.3	-0.22	
Urea, kg/ha	20.6	29.4	1.60	
Herbicide, l/ha	1.5	1.1	-1.61	
Fungicide, l/ha	0.3	0.7	0.61	
Pesticide, l/ha	0.0	0.2	2.39	**
Other chemicals, l/ha	0.11	0.04	-1.00	
Improved seeds, kg/ha	103.0	76.3	-1.59	
Improved seeds, % of plots	41	47	1.32	
Land rental				
Share rented-in, %	3.9	2.9	-0.64	
Sharecropped-in, %	1.5	4.7	2.20	**
Observations	*221*	*298*		

Source: Authors' calculations based on the household data from the FTF survey

To better understand associations between mechanization and productivity, we run simple regressions of combine-harvester use on wheat yield, controlling for several household and plot-level characteristics, as well as input use and location differences. Table 6.2 presents the results for five different specifications iteratively controlling for input use and demographic characteristics. We find a strong positive association between yield levels and use of machines for harvesting and threshing (mostly combine-harvesters). Given that the traditional methods of harvesting and threshing in Ethiopia use rudimentary technology, this may be attributed to reductions in yield losses during and after harvesting and threshing using such traditional methods. This is also consistent with our findings from interviews with key informant in which they reported that combine-harvesters reduce expected losses. These losses include those due to crop consumption by livestock during threshing using animals, to wind when winnowing and during transportation from the field to the farm or from field to the threshing floor, to crop damage because of untimely rain during harvesting, and to theft while storing unthreshed crops in the field.

Table 6.2: Regressions to examine the association of the use of machines for harvesting and threshing on wheat yield in southeast Ethiopia, quintal/ha

	Model 1	Model 2	Model 3	Model 4	Model 5
Use of machines for harvesting and threshing (yes=1)	0.204***	0.234***	0.212***	0.186***	0.202***
	(3.361)	(3.845)	(3.581)	(3.092)	(3.303)
Log (plot area)		-0.548***	-0.488***	-0.473***	-0.478***
		(-3.914)	(-3.595)	(-3.490)	(-3.407)
Log (number of plots)		0.002	-0.004	-0.031	-0.036
		(0.024)	(-0.051)	(-0.371)	(-0.436)
Log (total household land size)		0.033	0.045	0.061	0.110
		(0.348)	(0.495)	(0.667)	(1.103)
Log (plot distance from home)		0.016	0.022	0.021	0.018
		(0.621)	(0.886)	(0.854)	(0.720)
Semi-fertile soil (yes=1)		0.207	0.307*	0.319**	0.343**
		(1.177)	(1.827)	(1.968)	(2.103)
Fertile soil (yes=1)		0.256	0.362**	0.374**	0.414**
		(1.465)	(2.156)	(2.322)	(2.533)
Flat plot (yes=1)		0.087	0.073	0.051	0.037
		(0.999)	(0.828)	(0.593)	(0.429)
Modern input use	no	no	yes	yes	yes
Distance from nearest town	no	no	no	yes	yes
Demographic characteristics	no	no	no	no	yes
Zonal dummies	yes	yes	yes	yes	yes
Constant	2.876***	2.688***	2.296***	2.539***	3.084***
	(66.64)	(12.63)	(10.55)	(10.87)	(6.943)
Observations	482	481	480	480	480
R-squared	0.033	0.093	0.141	0.147	0.160

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

We perform a similar exercise in the case of tractor use. In Table 6.3, we present simple comparisons of wheat yields in mechanization intensive zones (West Tigray, Jijiga, West Arsi, Arsi, and Bale) for those farmers that used tractors with those that did not. As in the case of combine-harvesters, we find strong effects on labor of the use of tractors. Farmers that rely on tractors use half of the labor that non-users of tractors use (also Figure 6.2). In contrast with combine-harvesters, we do not find an effect on yield in a simple t-test. If anything, we find higher yields for non-adopting farmers in the case of wheat and maize. When we control for other factors (Table 6.4), we do not find a significant association between tractor use and yield levels. This is a finding consistent with other studies from other parts of the world (Pingali et al.1987), as well as with evidence from our key informant discussions in these areas. Finally, when we compare modern input use between farmers that use tractors and those that do not, we do not see an increase in modern input use for those that adopt tractors. In fact, often the opposite is seen.

Figure 6.2: Density functions on the association of tractor use and labor productivity

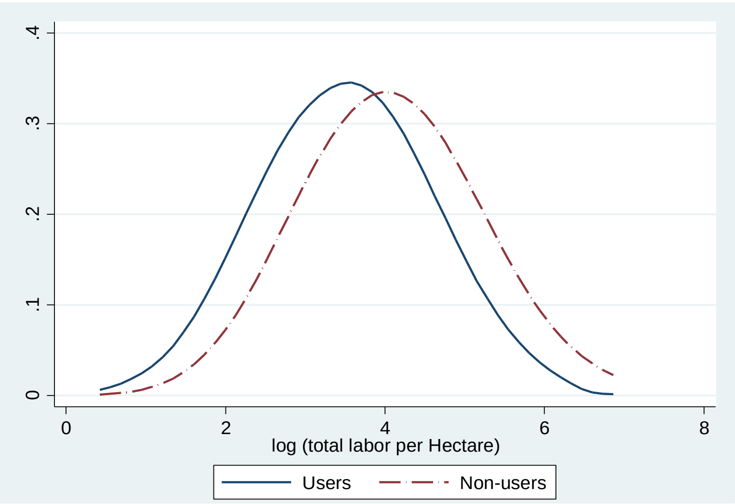


Table 6.3: Labor and land productivity by tractor use in mechanization-intensive zones

	observations	% using tractors	Tractor use? yes	no	T-test t-value	sign.
Labor use, days/ha						
Mean	1,894	13	45.8	97.0	4.65	***
Median	1,894	13	32.0	56.0		
Land productivity, quintal/ha						
All						
Mean	1,926	13	8.3	15.5	10.64	***
Median	1,926	13	5.9	13.5		
By crop						
Barley	458	4	11.7	15.4	1.86	*
Wheat	506	9	14.0	19.3	3.29	***
Maize	634	14	6.1	16.2	8.38	***
Sorghum	224	36	8.4	7.3	-1.44	
Sesame	104	25	2.2	2.7	1.37	
Modern input use						
Di-ammonium Phosphate (DAP), kg/ha	2,162	14	7.1	58.4	10.51	***
Urea, kg/ha	2,162	14	1.0	15.8	4.76	***
Herbicide, l/ha	2,162	14	0.1	3.9	0.98	
Fungicide, l/ha	2,162	14	0.0	0.3	1.19	
Pesticide, l/ha	2,162	14	0.0	0.1	2.15	**
Other chemicals, l/ha	2,162	14	-	0.0	1.32	
Improved seeds, kg/ha	2,162	14	14.7	42.3	3.47	***
Improved seeds, % of plots	2,162	14	13.4	32.4	6.82	***
Land rental						
Share rented-in, %	2,162	14	1.2	2.8	1.85	*
Sharecropped-in, %	2,162	14	1.0	2.1	1.43	

Source: Authors' calculations based on the household data from the FTF survey

Table 6.4: Regressions to examine the association of the use of tractors on wheat yield in mechanization-intensive zones, quintal/ha

	Model 1	Model 2	Model 3	Model 4	Model 5
Use of tractor (yes=1)	-0.150***	-0.045	-0.031	-0.029	-0.015
	(-2.792)	(-0.927)	(-0.632)	(-0.574)	(-0.302)
Log (plot area)		-0.667***	-0.663***	-0.664***	-0.665***
		(-10.520)	(-10.400)	(-10.360)	(-10.420)
Log (total household land size)		0.073**	0.073**	0.073**	0.076**
		(2.044)	(2.062)	(2.074)	(2.052)
Log (number of plots)		-0.080*	-0.096**	-0.095**	-0.107**
		(-1.868)	(-2.233)	(-2.204)	(-2.449)
Log (plot distance from home)		0.050***	0.044***	0.044***	0.042***
		(4.458)	(4.005)	(4.004)	(3.814)
Semi-fertile soil (yes=1)		0.053	0.087	0.087	0.092
		(0.759)	(1.251)	(1.259)	(1.314)
Fertile soil (yes=1)		0.258***	0.288***	0.289***	0.291***
		(3.749)	(4.264)	(4.272)	(4.263)
Flat plot (yes=1)		0.077**	0.054	0.056	0.052
		(2.049)	(1.411)	(1.436)	(1.339)
Crops (Barley=base)					
Wheat	0.199***	0.214***	0.165***	0.166***	0.160***
	(5.134)	(5.683)	(4.379)	(4.392)	(4.253)
Maize	0.013	0.051	0.104**	0.103**	0.106**
	(0.280)	(1.109)	(2.179)	(2.148)	(2.213)
Sorghum	-0.300***	-0.196***	-0.149**	-0.150**	-0.146**
	(-4.886)	(-3.354)	(-2.520)	(-2.551)	(-2.485)
Sesame	-1.131***	-0.836***	-0.760***	-0.761***	-0.773***
	(-14.21)	(-10.49)	(-9.196)	(-9.178)	(-9.360)
Modern input use	no	no	yes	yes	yes
Distance from nearest town	no	no	no	yes	yes
Demographic characteristics	no	no	no	no	yes
Zonal dummies	yes	yes	yes	yes	yes
Constant	2.322***	2.124***	2.047***	2.018***	2.106***
	(27.83)	(14.62)	(14.05)	(11.27)	(8.048)
Observations	1,926	1,914	1,913	1,913	1,913
R-squared	0.340	0.410	0.423	0.423	0.428

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As Ethiopia is still at an early stage of agricultural mechanization uptake, widespread effects of mechanization are not yet obvious. However, one could speculate what further impacts might be achieved from higher adoption levels.

- Tilling and harvesting activities – these are more frequently undertaken by men than by women, while women have a relatively larger role in weeding (Hailu et al. 2016). More mechanization would therefore seemingly imply that women would become relatively more important in the agricultural production process.
- Land rental markets might become more active with better access to mechanization in the country, as it would allow more area cultivation by single owners. While rental markets are still relatively little used in Ethiopia, a more active market that allows allocation of land to the most efficient cultivator – possibly those with access to mechanization – might possibly contribute to further transformation of the agricultural sector in the country.
- Labor demands are significantly higher during the harvesting period and wages show a slightly upward trend during that period. We use CSA wage data over the last ten years to check the extent of seasonality in rural wages, likely driven by seasonal changes in demand (Figure 6.3). We find that wages are indeed slightly higher at the end and the beginning of the year, around the harvest period of the main agricultural season in Ethiopia (meher), and lower in the middle of the year, usually referred to as the slack season. However, the differences are not very large (an amplitude of 5 percent) and they are not significant at conventional statistical levels. The release of labor during that period might therefore lead to downward pressure on wages during that period. This

is also the period when there is a significant demand for hired labor, and increasing mechanization might lead to lower demand for such labor. That labor could possibly be used more efficiently in the off-farm sector, although opportunities in that area are still limited in Ethiopia (Bachewe et al. 2016).

Figure 6.3: Seasonal movements in real rural wages in Ethiopia, monthly wage index (average yearly wage is 1.00)

Source: Authors' computation using CSA wages data for July 2004 to June 2014 (CSA 2015)

7. CONCLUSIONS AND IMPLICATIONS

The use of agricultural mechanization is low in Ethiopia. However, the number of tractors imported in the country was five times higher in 2014 than five years earlier, and the annual import value of combine-harvesters is now more than ten-fold the value of fifteen years ago with currently about 700 combine-harvesters active in the country. A significant number of tractors are being used by larger commercial farmers and state farms. However, we also observe increasing uptake of mechanization by smallholders, especially so in the wheat sector, with many making use of growing numbers of commercial agricultural mechanization service providers for plowing, harrowing, and harvesting. We estimate that a quarter of the area under wheat, the fourth most important cereal in the country, is currently harvested by combine-harvesters.

Mechanization, especially combine-harvesters, has been rapidly adopted in wheat growing areas in the southeast of the country. Several factors have contributed to the rapid uptake of agricultural mechanization in this area.

- Many commercial farms are in the southeast, which has encouraged machine rental markets to develop, since these larger farms often had excess capacity for the machines that they owned. However, non-farmer commercial service providers have rapidly emerged as well, especially so for combine-harvesters.
- There are large clusters of farms growing wheat in those areas which are suited for mechanization, given the economies of scale that could be achieved.
- The area is relatively flat, a rather exceptional situation in Ethiopia.
- Most of the southeast receives a bi-modal rainfall pattern with two harvests in the year. This results in higher rates of returns to investments in tractors and combine-harvesters.
- Soils are not as sandy as in other parts of the country, allowing faster plowing and harvesting.

These special conditions in the southwestern wheat producing areas of Ethiopia should be taken into consideration when planning for scaling-up of agricultural mechanization in other farming zones of the country. The case of wheat in the southeast of the country shows that mechanization uptake and appropriate institutions that offer rental services can rapidly develop when conditions are right.

Several challenges face efforts to upscale mechanization in other parts of the country, as well as with other crops than wheat. First, not all plots are well adapted to mechanized plowing in Ethiopia. Physical constraints might be linked to the type of soils, i.e., soils with too much moisture or too sandy are considered prohibitive for mechanization. Stony fields are also not suited for mechanized plowing as stones might damage plows. Sloped and steep fields also are often an important deterrent for mechanization in Ethiopia. Second, given the preference for large machines, since smaller machines might not have the required power, land fragmentation and the small farm plots in many parts of Ethiopia further complicate the use of agricultural machines. Most Ethiopian farmers have plots smaller than the minimum plot size in which combine-harvesters seemingly can operate effectively. This implies that policies which promote consolidation of land – such as through land rental markets, for example – would be needed to mitigate this issue.

Several interventions could be implemented to stimulate further agricultural mechanization uptake in the country. These include the following:

- **Improved access to foreign exchange for commercial dealers to import agricultural machinery**. This problem has lowered the availability and, therefore, the use of agricultural machinery. However, this now may be less of an issue since AAMI recently came into the market. AAMI has ready access to foreign exchange because of its special status. Moreover, the agricultural mechanization sector has been declared a priority sector with consequent priority access to foreign exchange.
- **Interventions in the financial markets.** For example, a policy where repayment periods for machines could be extended should be explored, given that the risks to investments in machinery are usually larger than in other investment domains and returns on investment are slower.[29] For example, the drought in 2015 reduced the harvest and led to some machines being underused. Moreover, while most banks require collateral on loans of about 50 percent, seeking ways to possibly reduce this amount might encourage greater uptake of agricultural machines. Further stimulation of an active leasing market might also encourage more entrants.
- **Improved knowledge by extension agents** on possible benefits and challenges with innovation in the use of agricultural machinery on farm might allow for more rapid and more widespread take-up. The agricultural extension system is not yet geared towards farm mechanization, with extension agents receiving no training on the topic.
- **Access to spare parts and maintenance for tractors**. The provision of timely maintenance services and the lack of spare parts remain key bottlenecks to mechanization. While the entry of AAMI in the market has made the acquisition of tractors more accessible because of the lower prices and the credit facilities they offer, these tractors are perceived to be less sturdy than the more expensive tractors from private dealers, break down more often, and complaints about access to spare parts because of regular changes in models and makes are common. Ready access to repair services and spare parts is required to further enable sustainable use of the AAMI machines.
- **Access to investment licenses**. Importing machines is only allowed to commercial farmers that can present investment licenses. These licenses permit access to duty free machines imported by privileged dealers. Without such licenses, smallholders can only purchase imported machines at higher prices set by dealers or else are restricted to locally assembled machines – seemingly not the first preference for most farmers. Given Ethiopia's focus on smallholders, such a restrictive import policy undermines progress in smallholder mechanization.
- **Using more adapted technologies**. While the use of combine-harvesters in other crops than wheat is currently under experimentation (maize, barley, and teff), the profitability of use of combine-harvesters is higher in the case of wheat compared to maize, for example. The risks associated with the use of combine-harvesters on maize are perceived to be much higher than for wheat, and the life of combine-harvesters with the technologies that are currently available is seen to be lower when used on maize than for wheat. The use of more adapted technologies for such other crops should therefore be further explored. Moreover, it is not well understood what are the constraints to uptake of cheaper two-wheeled tractors – which are widespread in Asia. More studies are needed to better understand these constraints.

[29] For trucks, which operate full-time, investors can repay any purchase credit in a period of 3 to 4 years. However, combine-harvesters are active only for 3 to 4 months during a year. Therefore, payback within a period of 3 to 4 years may challenging for investors in combine-harvesters.

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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; http://essp.ifpri.info/; or http://www.edri-eth.org/.

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