Agricultural mechanization in Ethiopia: enabling policy, suppliers and inter-regional heterogeneity

Yared Deribe (yared.deribe@gmail.com)
Ethiopian Institute of Agricultural Research (EIAR) https://orcid.org/0000-0002-9053-7105

Bisrat Getnet
Ethiopian Institute of Agricultural Research (EIAR)

Research Article

Keywords: Agricultural mechanization, enabling policy, machinery suppliers, hiring services, heterogeneity, hiring cost

Posted Date: April 30th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-478878/v1

Abstract

Background: Agriculture in Ethiopia heavily relies on traditional farm power sources and is characterized by the lowest access to farm machinery in contrast to other places in SSA. The study analyzed the factors and gaps in the delivery of mechanization inputs through the qualitative survey of the supply chain actors. Furthermore, the study involved the crossectional survey of the producer households in the major crop production areas of Oromia, SNNPR, Amhara, and Tigray regions.

Results: The recent policy amendment resulted in a reduction in the price of farm machinery while it excludes spare parts in isolation and raw materials for manufacturing. The counter influence of the simultaneous depreciation of the exchange rate has undermined the likely impacts of the tax benefits. The major deterring issues in the machinery supply system include the high shortage of foreign currency, the upsurging price of spare parts, and shortage of trained machinery operators. A formal survey tells that a significant proportion of the areas have no access to mechanization while in some parts of the country, utilization of the combine harvester reached full coverage and a large proportion of the farmers use tractor power.

Conclusions: Maintaining a healthy business competition among imports and the manufacturing sector remained an important policy gap. The mechanization hiring costs, service transactions, and coordination have shown significant variability across the crop potential production areas. Resolving of the supply side encounters, development of the hiring service market, and reduction of transaction cost are the key areas of interventions in the mechanization supply and demand systems.

1. Introduction

Agricultural mechanization is generally defined as the use of hand tools, implements, and machinery for farm activities in all stages of agricultural production (FAO, 2016; Van Loon et al., 2020). A vast body of literature emphasized that mechanization contributes to efficient utilization of resources and increased factor productivity due to the benefits of higher precision, timely operation, reduced drudgery, and saving of labor (Clarke, 2000; Clarke & Bishop, 2002b; Sims & Kienzle, 2016). Mechanization is an important element of agricultural growth (Daum & Birner, 2020) and the factor for the transformation of agricultural production or the rural communities at large (Schmitz & Moss, 2015). Traditional farms that are predominantly dependent on the productivity of agricultural labor were not able to meet the dynamic food and nutrition security needs of the society (Fuglie & Rada, 2013). Donors and policymakers granted continued support for the sector though the efforts come up with less fruitful results (Mrema et al., 2008; Pingali et al., 1988b; Mrema, 2014; FAO, 2008). A large mass of land is brought under cultivation in Sub-Saharan Africa, Latin America, and South Asia but utilization of mechanical power and tractors, in particular, is considerably low (Baudron et al., 2015; Mrema et al., 2008).

The discrepancy of the economies of scale of mechanization and small farm size characterized by dispersion and crop diversity is the major impediment for the wider adoption. The proposed solution of consolidation of small farms to harmonize with large machines was also not successful in many countries. The literature and policy suggestions are in favor of reversing the approach and state that scale-appropriate machinery is the alternative taking into account the resource endowment factors (Sims & Kienzle, 2016; Van Loon et al., 2020). Enhancement of the demand and adoption of mechanization technologies requires a system perspective beyond the plot and farm level situations, which encompasses the supply chain processes, local manufacturers, dealers, and repair and maintenance centers (Kahan et al., 2018). The past perception towards the mechanization of agriculture where it is feasible only under large-scale farming is misguiding and rather mechanization should be customized to the circumstances of small farms (Diao et al., 2014).

In developing countries, the state interference through the direct support to farmer cooperatives while ignoring the need for maintaining a conducive environment to the suppliers involved in manufacturing, imports, distribution and sales, and

after-sales services has constrained the growth of the sector (Mrema et al., 2008; Clarke, 2000; Pingali et al., 1988). Concurrently, the factors of farmers' know-how, skills in operation, maintenance and repair, and access to spare parts have not been well considered (Diao et al., 2018). The importance of the catalyzing role of the public through the building up of an enabling financial and infrastructural environment is emphasized (Mrema, 2014; Sims & Kienzle, 2016).

Agricultural mechanization in Ethiopia has undergone a structural change from the state of government-subsidized provision of hiring services in the 1980s, which experienced a collapse in similar ways to other Asian and African countries. After the market liberalization, the majority of the farmers in the Arsi area obtain services from private service providers whereas there has been a limited role of the government and state farms (Hassena et al., 2000). The relatively free market operation at least permitted the involvement of the private sector, however, farm machinery and the hiring service became too expensive (World Bank, 2014). The government posed no clear direction for maintaining favorable institutional and infrastructural facilities that are important for the success of mechanization service through the involvement of private operators. Due to the underdevelopment of agricultural mechanization in Ethiopia, agriculture remained largely dependent on draught and human sources of farm power.

The demand for mechanization in the country has gained a revival in the recent decade. Recognizing the benefits of agricultural mechanization and the ongoing dynamics, the formulation of the Agricultural Mechanization Strategy (AMS) and amendment of import duty on machinery are the steps taken to encourage the development of mechanized farming in Ethiopia. For transformation of the agricultural production through the promotion of crop and livestock technology packages, the extension system further incorporated row planters, threshers, and post-harvest technologies (MoANR & ATA, 2014). Various public and private institutions nowadays have shown interest to make the necessary interference for the development of the sector. The paper characterizes the policy opportunities and gaps that are affecting the functioning of the agricultural mechanization system and the machinery supply chain, which encompasses the import, manufacturing, and mechanization hiring services. Moreover, it traces the existing variability in connection to the access, hiring service costs, and behavior of the mechanization service transactions.

2. Literature Review

2.1 Mechanization of small farms

Small farms have limited capacity to invest in large farm machinery through own funds or else they are much constrained by the lack of access to formal financial services (Mrema et al., 2008; Mottaleb et al., 2016; Pingali, 2007). The appropriate mechanization discourse is in favor of the hiring service models that smallholder farmers can access mechanization through the low-cost hiring services despite assumed transaction cost (Diao et al., 2018; Mrema, 2014; Sims & Kienzle, 2017). As reports indicated, not only technological solutions but also institutional approaches are essential for the enhancement of smallholder mechanization, for example, cooperative exchange and rental markets have played key roles (Olmstead & Rhode, 1995). For enhancement of linkage and information sharing among farmers and service providers, digital-based Hello Tractor service has been introduced in Nigeria (Daum & Birner, 2020).

The farmer to farmer mechanization hiring service (often medium-scale farmers) is the alternative supply model (Chapoto et al., 2014; Diao et al., 2014; Houssou et al., 2015), which offers diversified opportunities due to off-farm and on-farm income streams (Mottaleb et al., 2016; Van Loon et al., 2020). Despite farmer to farmer service is imperfect, it will be more competitive in terms of reduction of administrative costs and related inefficiency in contrast to specialized hiring services. The collective ownership service approach requires mobilization of resources, effective governance, and enhancement of skills. The direct provision of mechanization hiring services by the government is practiced in some countries (Diao et al., 2016; Zhou, 2016) and specialized private operators are alternatives for supplying mechanization hiring services to small farms.

Dictated by the inherent ago ecological diversity and farm productions, the demand for mechanization might not have a similar pattern across locations. The spatial variability of the hiring cost is correlated with per area machinery density, constraints of mobility, shipping of machines, road condition, and efficiency of the service market (Houssou et al., 2016; Diao et al., 2016). For instance, the lower tractor density in Nigeria and Ethiopia is associated with the higher tractor-hiring cost in contrast to other locations (World Bank, 2014). The tractor density in Ethiopia is only four tractors per 100 square kilometers of arable land, which is the lowest in SSA (Fig. 1). As empirical studies concluded, the availability of road infrastructure and proximity to urban centers favor both the supply and use of mechanization (Stifel & Minten, 2008). Due to localized demand and transaction cost factors, there is a variation of the service cost within the same country and across districts. It seems that migratory service would be profitable, however, it is not attractive for most of the hiring operators (Diao et al., 2016).

Due to the exogenous pushing factors of agricultural intensification, rising rural wages, urbanization, population pressure, and better market access emerging demand for mechanization is observed (Diao et al., 2012, 2014; Cossar, 2016). The rapid migration of the youth from rural to urban areas has a consequence of shortage of farm labor and increased pressure on remaining household members (Biggs & Justice, 2015; Baudron et al., 2015; Goldsmith et al., 2004; FAO, 2018; Rosegrant et al., 2014). A similar study indicated that the cost of labor and draft animals is the push factor for the changing pattern of mechanization in Ethiopia (Berhane et al., 2017).

2.2. Trends in agricultural mechanization and structural change

The expansion of private large-scale commercial farms during the 1960s, which later on handed over to the state-owned farm enterprises were the earlier adopters of agricultural mechanization practices in Ethiopia. Notably, the mechanization hiring schemes that came into existence have laid down the foundation in the promotion and use of mechanical technologies by peasant households. The Agricultural Mechanization Service Corporation (AMSC) was established in 1985 under the Ministry of Agriculture (MOA) with the primary purpose of rendering mechanization services to the small-scale sector (Clare, 1991). Two service modalities were designed in parallel to differing production systems i.e., the fully subsidized services access to the tsetse fly affected areas whereas the cost-recovery brand to producer cooperatives and farmers predominantly in southeast, northwest, and central regions. The hiring rate was set by the government in such a way that it covers the full cost of variable costs while only 10–15% of fixed costs.

The rural technology centers simultaneously targeted the establishment of mechanization services along with the dissemination of farm technologies, for example, maize shelling hiring schemes have been started, which have an output capacity of 4–5 tons/hr (Kelemu, 2015). The ambitious rural settlement program and the expansion of smallholder mechanized farming is the other scenario that has undertaken during the 1980s (Dessalegn, 2003) through the program experienced little success.

A major structural change was devised during the subsequent regime, the policy argument positioned in favor of labor-intensive agricultural production while against the allocation of scarce capital resources to smallholder farming (MoFED, 2010). The below figure illustrates the evolvement of tractor imports during the two periods, 1975–1991 and 1994–2018 (Fig. 2). The UN COMTRADE data evidence that the structural change had an impact on agricultural mechanization, which is explained by thereafter reduction of tractor imports. The value of import (World Bank data) is correlated with the quantity while it only captures the post-liberalization period (1994–2018). For about 16 years in the second lapse of time, tractor imports stood largely lower than the import quantity demand during the previous regime. However, this has shown a surpassing growth lately from 2010 through 2014.

2.3. Renewed attention to mechanization

The emerging interest in mechanization has led to the formation of the Agricultural Mechanization Strategy in 2014. The strategy has a mission for raising the current mechanical power uses from 0.13 kW/ha to 1 kW/ha, improving

smallholders' access to mechanization by 30%, and reduction of animal power by 50% (MoANR & ATA, 2014). A policy appraisal raises an agenda of the mechanization policy that guides and sets full-fledged targets and priorities at various levels. The import policy gives a special advantage to investors while cooperatives and smallholder farmers hardly get any of the benefits (Deribe & Jaleta, 2019). On this account, the advocacy and ongoing dialogue has induced a re-examination of the circumstances and currently, the policy has waived import taxes on agricultural machinery, irrigation technologies, and livestock feed ingredients.

The agricultural development program has targeted to enhance agricultural productivity through integrated support and access to complimentary services to selected Agricultural Commercialization Clusters (ACC) (ATA, 2019). Cluster farming is expected to be attractive for mechanization hiring service providers as compared to fragmented plots. The rural job creation schemes have introduced youth-based hiring services and access to credit for the purchase of tractors, threshers, and water pumps. The first private capital goods lease financing company has entered the market, which could enhance the access to finance in the mechanization supply system.

3. The Research Methods

3.1. Description of the study area

Ethiopia is geographically located in extension from 3^0 to 15^0 N and longitude 33^0 to 48^0 east. The country has a total surface area of 1,104,300 square kilometers and is sub-divided into nine administrative regional states. Ethiopia is endowed with wide varying agro-ecologies and socioeconomic scenarios that nurture agricultural production and productivity in different ways. As a result, the wide variation of the natural phenomenon dramatically over relatively short distances gives the chance for growing a large variety of crops (Simane et al., 2016; Taye et al., 2018).

Considering crop productions, arable land takes up about 362,590 square kilometers, i.e., 14.3% of the land area, whereas the access to land per person is declared to be 0.15 hectare. The size of agricultural land expressed in terms of the percentage of the total land area is 33.6. Statistical figures also indicate that the land under cereal production is equivalent to 10,352,596 hectares and cereal yield is about 2,538.2 kg ha^{-1} (World Bank, 2015). The land allocated for the production of cereals takes the largest share of 81.39%, followed by 12.73% for pulses and 5.88% for oil crops (CSA, 2018).

3.2. Design and data sources

About 33 machinery import dealers and large manufacturers are in operation in the country and the study is designed in such a way that both the newly entering and experienced major machinery suppliers are considered. Then, the selection of the firms was performed using the non-probability sampling approach and principally meant to capture the market characteristics and gaps in qualitative terms. About six import only and five firms in both import and manufacturing activity category have participated. Studies show that the majority of the mechanization hiring businesses are located in the wheat-producing Arsi and Bale areas. The hiring services were contacted mainly in those areas but they are also operating migratory services in different parts of the country. With the same approach, the survey addressed each of the hiring service provider categories i.e., cooperatives, specialized private operators, commercial farms, and farmer-owned hiring services.

The mechanization access, hiring costs, and the perspective of the hiring service transaction were examined at the household level through the crossectional survey of producers in the major cereal growing regions of Oromia, Southern Nation, Nationalities and Peoples Region (SNNPR), Amhara, and Tigray. The sampling design involves the multistage selection of the study units, which proceeds with the random selection of the districts, *kebeles* in the second stage, and producer households at the final stage. To apprehend the mechanization supply circumstances and policy issues, a

separate instrument was designed for machinery suppliers and hiring service providers for the final implementation of the expert interviews. Moreover, supplementary secondary data was collected from databases and web-based sources. For the formal survey, a structured questionnaire was converted into electronic formats through coding, programming, and testing for final use.

4. Results And Discussion

4.1. Machinery import, manufacturing and policy

The growing demand for mechanization attracted new import dealers, which have joined within the past 2 years while the older firms stayed in the business for more than 40 years. The export promotion policy gives special advantages to the export-oriented firms that give them the entitlement of 70% of the foreign currency they have generated. The recently amended import policy further has given a tax incentive for farmers and farmer cooperatives during 2019. The old custom practice was allowing for keeping machines in stock for only about 4–6 months but the current procedure has improved the limitations. It also reduced the bureaucracy in the import and distribution of the machinery. The tax exemption resulted in a reduction of the import and value-added taxes that accrue up to 35% of the sales value of the machine.

The price of farm machinery has shown an increase which is mainly attributed to the depreciation of the exchange rate. For instance, 130 horsepower John Deere tractor costs 1.7 million birr before 5 years but the current sales price has shown an increase of 76–85% over the previous one. The same horsepower Massey Ferguson tractor was worth 1.53 million birr about 5 years ago. Exclusive of the tax duty, this has shown an increase of 83% in 2021. Despite so, the machinery import dealers indicated that the actual sales demand for machinery at different stages of mechanization has shown growth (bar label stands for the number of firms) over the recent five-year or two-year period. Other than planter and grain cleaner, the change in the machinery sales quantity ranges from 20–50% over the five-year time and even more than 20–73% in the nearest two years (Fig. 3).

The policy exempts taxes to only 35% and a higher stage of the Semi-Knocked Down (SKD) manufacturing process. As a result, the immature manufacturing sector will not be competent in a situation where there is a better advantage of merely importing the machinery and ancillaries. For instance, a manufacturing firm loses a margin of 100–120 thousand birr in the fabrication of trailers domestically in contrast to direct import. It appears that a detailed diagnosis of the situation on the grounds of comparative advantages, maintaining a healthy competition, import replacement roles, and the growth of the sector is important. Perhaps, the pitfall is that the existing firms might fully shift to sole importation or they do little effort for improving capacity for the quality of the small to medium manufactured products.

The current mechanization services supply and utilization are restricted in some areas of the country. The potential for mechanization includes widening the services to demanding but unaddressed parts of the country such as Benishangul, Gambella, Somali, Afar, Amhara, and the western part of Oromia. In terms of crop commodities, other than the wheat crop, the potential demand is declared to be for the crops of sesame, maize, barley, *teff*, sorghum, rice, haricot beans, and cotton. The introduction of a grass cutting kit for *teff* harvesting and exchangeable blade (header) of combine harvester for the maize crop has proved positive results. As the feedback from the hiring service providers indicates, it is convenient for operating medium-sized or clustered service users.

One of the major deterring factors for the current import and manufacturing supply chain is the severe shortage of foreign currency, which exacerbates the continuous upsurge of the price of machines and spare parts. Furthermore, spare parts are still subject to taxes unless imported altogether with the machine. For the manufacturing of small-medium machinery, the time-to-time rising price of raw materials makes the price of good quality products expensive.

The recent ambitious importation and dumping of farm machinery has affected the market and resulted in tied-up capital or competition woes for some of the firms. Despite the emergence of the machinery lease financing system, other firms become afraid of credit repayment due to depressed combine-harvester hiring rates. Roughly, the return on investment is approximated to be in the range of 40–50%, which also took only 2–3 years in the earliest time. There is a gap of coordination among the supply chain actors, backup by the support institutions, and access to reliable mechanization information. For the expansion of the mechanization services to the new places, simply looking at the tractor density or else the low level of mechanization is misleading unless the demand factors and the supply models are systematically identified in each production system and location.

4.2. Mechanization hiring services

About five categories of mechanization hiring service providers are currently identified viz., private operators, private commercial farms, farmer cooperatives, medium-scale farmers, and recently emerging, youth-based models. The farmer service provider and the private commercial farms own farmland that ranges from the lowest of 2 hectares for small-scale farmers and up to 1000 hectares for the commercial farms. The mechanization hiring service is a seasonal business, in most cases, the operators do engage in related value chain activities such as grain trading, flour milling, transport, and other businesses.

The most common mechanization services offered are tractor plowing and combine harvesting practices. In some areas, the hiring services of threshing, shelling, harrowing, sowing, planting, and baling of crop residue are existent. The tractors owned by the hiring service providers are between 90–130 hp. Unlike tractors below this range including single-axle tractors are in use in many parts of the Asian countries, these might not be very functional under difficult soil conditions. According to the service providers, the lowest area expected for a profitable business is 4–20 hectares for services offered in the vicinity (below 50 km). Regarding the migratory services to places above 60 km, a land size of at least 30 hectares is expected and even more than 100 hectares for other providers.

The cooperative service has become vibrant justified by the expansion of the service by the earlier groups or the emergence of new providers. The combine harvesting service coverage has proved an outreach to the high altitude areas of Arsi (Bekoji and Asella) and the lowland places in East Shewa (Ziway, Meki, and Alemtena) where the hiring of combine harvester was less common before five years. The changing paradigm of the simultaneous switch in crop choice in East Shewa mainly towards the wheat crop, which possibly has attracted mechanization in return, is an open research topic in the farming system diagnosis. The consecutive rural roads development scheme is the other visible stimulator particularly in those places or else across the countrywide change in the quality of the rural roads that triggers both the supply of hiring services and utilizations.

The mechanization hiring services also encounter the major challenges of getting trained machine operators, the high price of spare parts and machines, and the absence of rural maintenance services. The breadth of the cooperative service is growing so that limitations of investment capital and the capacity for managing multiple services are important.

4.3. Variability of the mechanization hiring service

4.3.1. The access to mechanization and hiring service cost

The hiring service market needs to have favorable competition for improved efficiency of the service and a conducive business environment for the involvement of the private sector. The private operators informed that they are members of the Mechanization Association, which has offices at Shashemene, Asella, and Bale-Robe. The association revises the hiring service rate each year taking into account the changes in operational costs and farm productions. When the service providers enter new areas or in case of migration, intermediaries will play facilitation roles. For tractor plowing and combine harvesting services, the farmer cooperatives demand up to 50% lower hiring costs than the going market rate.

Despite the mechanization service of the cooperatives is growing, they reach only some parts of the country and are limited on the extent of market stabilization.

The service providers often fix the combine-harvesting rate per *quintal* (100kg) of production and even it may have high variation within a single *kebele*. Distance from asphalt and all-weather roads, quality of rural feeder roads, and topography factors are reasons for addition over the baseline hiring rate. They are not willing to give the service if the land has rocks or if it became very steep. The cooperatives have adjusted the rate of combine harvesting alternatively on an area basis to widen the service coverage to the relatively less productive areas. On this account, the private operators have started to negotiate extra payment if production is below 2 tons/ha and sometimes, they also have set a hectare-based minimum threshold rate.

The demand side variations of physical and infrastructural circumstances explain the heterogeneity of the mechanization supply in the country. The mechanization hiring services access and utilization is much concentrated in the major wheat-producing areas of Arsi and Bale. In contrast, the Oromia region has the highest proportion of tractor users as indicated by the density of the spikes in (Fig. 4a) while the Amhara region has the lowest utilization. A large proportion of about 40.3% of the crop potential areas have no access to tractors, combine harvesters, and threshers. The mechanization status represented by the typical *kebeles* shows that there is high dissimilarity across the districts, for example, 55.6% of the major crop-producing areas have no or insignificant tractor users. Among all the sample areas, the study finds that tractor utilization is higher in wheat-growing districts of Asasa (West Arsi), Sinana (Bale), and Dalocha (Silte) with a proportion of 71.8%, 63.3%, and 53.3%, respectively.

The utilization of combine harvesters is even more restricted in some parts of the country (Fig. 4b). Similarly, Asasa and Sinana have a large proportion of users that reach up to 100% in both areas followed by Dalocha (Silte) with a rate of 96.7%. Combine harvesters have shown better acceptance than tractors within the highly mechanized areas. The shortage of labor is more prominent at peak harvesting time and family labor may not be sufficient to accomplish the activity on time. The combine harvesting cost is roughly lower by 40% in Asassa and 25% in Asella in contrast to the labor cost of harvesting. This tells that there is overtime change in the cost advantage which was reported to be 20–30% about 20 years ago (Hassena et al., 2000).

The mechanization hiring service rate as indicative of the availability of mechanization is plotted by the relative position of the cost incurred by the farmer over the mean rate for each region (Fig. 4). The earlier describes the existing variations within the same location whereas the distance in between the horizontal mean hiring rates captures the interregional divergence.

Considering the specific locations, Asasa district (West Arsi) positions on the downside of the aggregated mean where the hiring service cost is 41.3% lower than the total mean (Fig. 5a). Farmers in Asasa area enjoy the lowest rates perhaps this relates to the relatively flat nature of farmlands, light soil, mono-cropping of wheat, and the large size of the hiring market. The mechanization service is found to be more expensive in Mecha (West Gojjam), the tractor hiring rate is 86.6% higher in contrast to the mean. When it comes to the combine harvester, again Asasa district has the lowest cost with the reduced rate of 45.3% while Lemo (Hadiya) has an addition of 59.8% over the mean (Fig. 5b).

The variation of the mechanization hiring service cost has been further examined statistically with the mean comparison test. The violation of the assumption of homogeneity of variance is confirmed so that the standard test has undergone contrasting with the simulation technique. There is significant variability in the hiring cost of tractor plowing and combine harvesting services across the major crop potential areas. In contrast to Oromia, the mean hiring rate of plowing is 7.3%, 81.0%, and 82.8% higher in SNNP, Amhara, and Tigray regions, respectively (Table 1). The combine-harvesting rate is also much higher in Amhara and SNNP regions, i.e., more than two-fold of the rate in Oromia. The major wheat and other

cereal growing areas in Tigray have no significant adoption of the combine harvesting practice. The mechanization hiring transaction cost is partly represented by the commission payment for agents and machine operators.

Table 1
Mean comparison test on the tractor and combine hiring rates and commission payment

Region	Tractor hiring rate (birr/ha)				Combine harvester hiring rate (birr/ha)				Commission (birr/farmer)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Oromia	1687.35	406.04	800	2400	49.25	11.73	30	80	169.21	154.95	50	1000
SNNP	1738.09	519.11	1200	3600	115.94	29.19	75	160	190.24	158.12	50	700
Amhara	2925.00	547.93	2000	3800	111.60	14.05	100	150	96.67	44.57	20	160
Tigray	2950.53	382.76	2200	3600	-	-	-	-	150.00	70.71	100	200
Total	1983.04	679.10	800	3800	75.08	36.28	30	160	168.90	150.55	20	1000
F-values	65.69 (P < 0.01)				171.40 (P < 0.01)				2.76 (P = 0.1519)			
** 1$=40.22 ETB*												

The limited availability of the hiring service nearby and involvement of high cost in shipping of the combine harvester from the central part of the country is the major reason for the variation. For instance, the large-sized combiner harvester is transported on a truck to Mecha (West Gojjam) which is about 640 kilometers from Addis Ababa. The cost of transporting the combine harvester is declared to be over 30 thousand birr, which is the major factor for increased hiring cost or barrier to mobility.

4.3.2. The hiring service transaction and relationships

The transaction cost theory underpins the unbounded rationality and capability of the service business whether the mechanization-hiring firm chooses intermediation for the delivery of the service. The private operators explain that the nature of the business and uncertainty is the inducing factor for the intermediation of the service. The local brokers provide necessary information on the viability of the business i.e., the expected size of demand, the distance of plots, and the access to feeder roads. Farmers may underestimate the distance of their plots or appreciate the quality of roads. The recruited agents will negotiate the hiring rates in uncertain conditions and are managing arguments in connection to queues and payments.

In the supply of the mechanization hiring services, it is observed that the direct transaction is more common while transaction cost-induced intermediated relation is outweighing in other places. The chi2 test indicates that the difference in the type of transaction, behavior of the transaction relationship, and coordination among users have shown much variation across locations. The effect size is determined to be high (strong as to Cohen's definition) whether the service providers do choose intermediated transactions and trend to build relational hiring transactions in the mechanization service market (Table 2). Clustered farming as the means of access to the mechanization hiring services in itself and the future tendency for cooperation among farmers also have shown association (small-medium) with the place of transaction.

Table 2
The characteristics of the mechanization hiring service transaction

Service transaction (relative frequency)	Oromia	SNNP	Amhara	Tigray	Total	Chi^2 values
Direct transaction[a]	81.08	34.21	61.76	95	72.08	40.06
Relational hiring [a]	45.83	21.43	77.42	66.67	49.24	21.26
Cluster-based access [b]	30.51	42.86	58.62	58.82	39.06	11.25
Cooperation [b]	24.66	39.71	33.77	37.68	31.16	8.48

[a] $p < 0.01$, effect size (phi) 0.41 & 0.33, [b] $P < 0.05$, phi-0.24 and 0.16, respectively

The scanty mechanization service in Amhara and Tigray regions is characterized by relatively more direct and relational transactions with the horizontally coordinated demand for the service. The farmers access the mechanization services on a cluster basis, and the size of the group ranges from 4–10 members. The future tendency for cooperation among farmers might involve discarding borders of fences, trees, grasses, and stones that demarcate the adjacent plots. In Oromia, the large size of existing demand, mono-cropping, and relatively suitable land possibly explain the lesser tendency for clustered farming or cooperation.

To expand the mechanization services to small farms, a hybrid or complementary approach to the low-cost hiring service model could be the alternative through building up relationships among farmers that have related household and market objectives and tailoring the small farm situations with a sense of mutual benefits. Clustered farming has its own challenges despite the mechanization advantages of reduced operational and transaction costs, which encourage the proliferation of efficient and lucrative hiring businesses.

5. Conclusions

The antagonism of the scale advantages of mechanization and small plot circumstances led to a view that mechanization is only appropriate for large-scale commercial farming. Literature and policy rather emphasized that mechanization should be customized to fit the smallholder farming. The low-cost hiring service is the alternative to small farms that could not afford farm machines on their own funds or are constrained by access to the formal credit sources.

In Ethiopia, the state-subsidized mechanization hiring schemes have laid down the foundation in the utilization of mechanization in some parts of the country. The market liberalization later abandoned any public direct supply of machines and hiring services but also lacked a clear strategy and an uphold towards the efficiency of the mechanization hiring services. Over two decades times, agricultural mechanization remained underdeveloped as evidenced by the decline of imports of farm machines. The country has the lowest tractor density in contrast to other countries in SSA with only 4 tractors per 100 square kilometers of arable land and also associates with the high tractor-hiring cost.

Induced by raising rural wages and agricultural intensification, emerging demand and renewed attention to mechanization are observed. As the evidence from the machinery dealers indicates, the actual sales demand for different agricultural machiners has shown important growth during the recent 2–5 years. The farmers' factor substitution decision relates to the comparative merits in the cost of production. For instance, the combine harvesting cost is found to be much lower in Asasa and Asella areas in contrast to the labor cost of harvesting.

The recently amended import policy included farmers and cooperatives, which resulted in a reduction of import duty and value-added tax that accrues up to 35–40%. It has significant implications on the price of the machine; however, the counter effect of simultaneous depreciation of exchange rate constrained the maximum gain. Moreover, spare parts are still subject to taxes unless imported altogether with the machine and remain to be too expensive. The policy exempts taxes to only 35% and the higher stage of the semi-knocked down manufacturing process; the drawback is that the

immature manufacturing sector will remain incompetent. The machinery supply chain is facing the challenges of a severe shortage of foreign currency, well-trained operators, and maintenance services.

The access and utilization of mechanization in the country has wide heterogeneity and is much concentrated in the major wheat-producing areas. A significant proportion of the crop potential areas have no access to large mechanization such as tractors, combine harvesters, and threshers. However, the prevalence of full coverage of combine harvesting service and a large proportion of tractor users in the wheat-growing districts in the Oromia region evidence existing wide heterogeneity. The cost of the mechanization hiring service is characterized by high interregional divergence across the crop potential areas.

Notwithstanding the free supply market, on and off the state involvement and special treatment for some of the firms will have a distortion impact on the market. Unveiling the potentials and comparative merits in contrast to import and maintaining a healthy business competition creates a favorable environment for the manufacturing sector. In gearing hiring services to small farms, enhanced access to reliable mechanization information, coordination among the supply chain actors, and systematic scrutiny of alternative supply models are important for reducing the involved transaction cost. Improving the access to foreign currency, spare parts delivery system, and establishment of mechanization maintenance centers are areas that seek meaningful interference.

Abbreviations

ACC: Agricultural Commercialization Clusters; AMS: Agricultural Mechanization Strategy; AMSC: Agricultural Mechanization Service Corporation; ATA: Agricultural Transformation Agency; CSA: Central Statistics Agency; ETB: Ethiopian Birr; hp: horsepower; kW/ha: kilowatt/hectare; MoFED: Ministry of Finance and Economic Development; MoANR: Ministry of Agriculture and Natural Resources; SKD: Semi-Knocked Down; SSA: Sub-Saharan Africa

Declarations

Acknowledgment

The authors acknowledge financial support from the Rural Development Administration of South Korea (RDA) through the funding of the Korea Africa Food and Agriculture Cooperation Initiative (KAFACI), the Agricultural Mechanization Project, and the Ethiopian Institute of Agricultural Research (EIAR) - Melkassa Agricultural Research Center (MARC).

Authors’ contribution

The first author contributed to the design and implementation of the research proposal, data collection, analysis, and preparation of the manuscript. The second author contributed to the formulation of the research proposal, data collection, and preparation of the manuscript.

Funding

The Rural Development Administration of South Korea (RDA)-Korea Africa Food and Agriculture Cooperation Initiative (KAFACI) and the Ethiopian Institute of Agricultural Research have financed the research project.

Availability of data and materials

The authors declare that the interview feedback and dataset used for the manuscript will be available from the corresponding author on reasonable request

Ethics approval and consent to participate

The research has been implemented through the official communications and institutional cooperation between the Ethiopian Institute of Agricultural Research, and the Regional and District-level Bureau of Agriculture and Natural Resources. The authors further declare that the subjects of the research provided the information upon informed consent.

Consent for publication

Not applicable

Competing interests

The authors would like to confirm that there are no conflicts of interest in the communication of the manuscript work.

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Figures

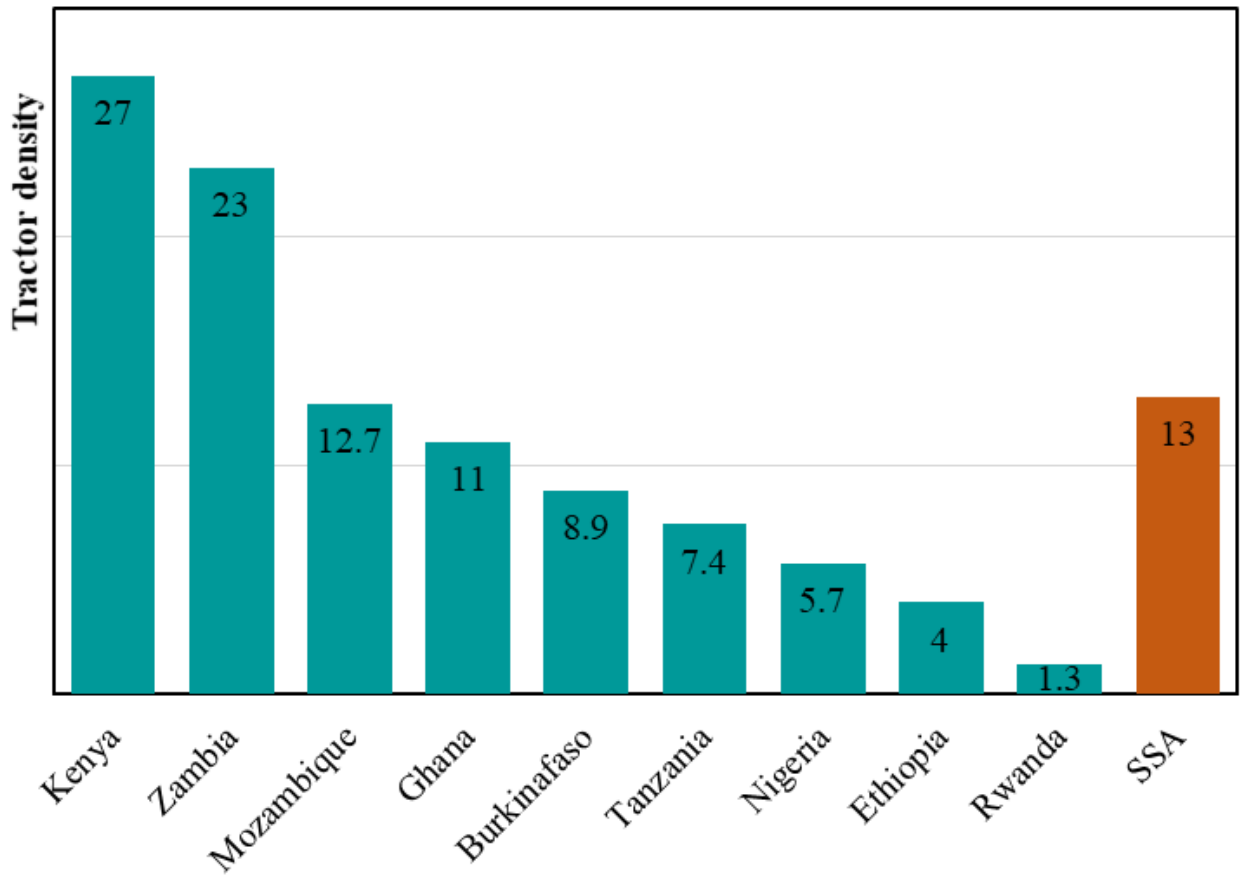


Figure 1

Number of tractors per 100 km2 (Source: World Bank, 2014)

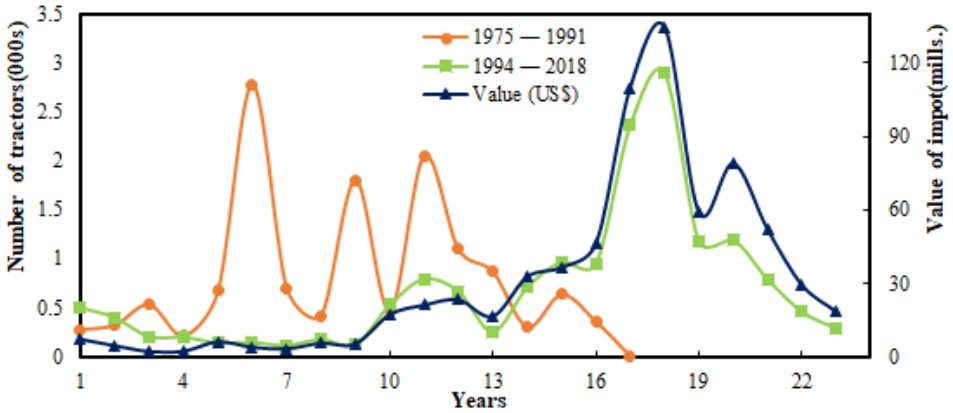


Figure 2

Tractor import demand over time-periods (Source: UN COMTRADE and World Bank, 2020)

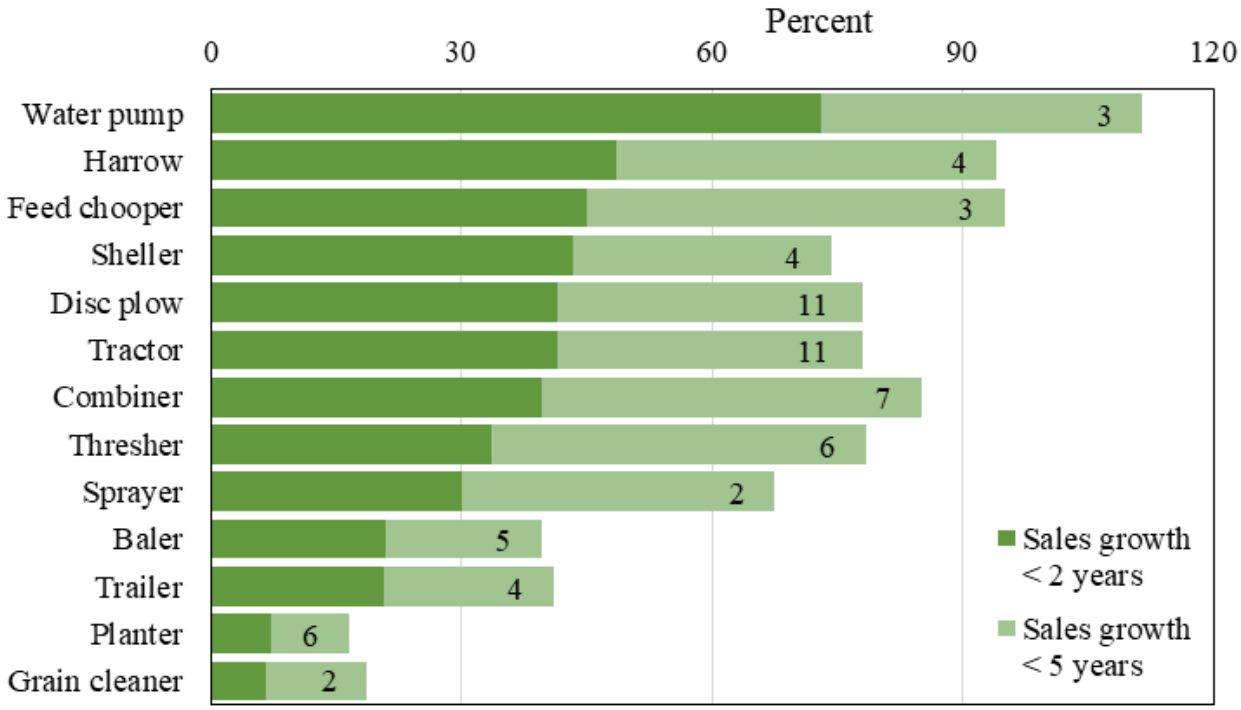


Figure 3

Farm machinery sales demand growth

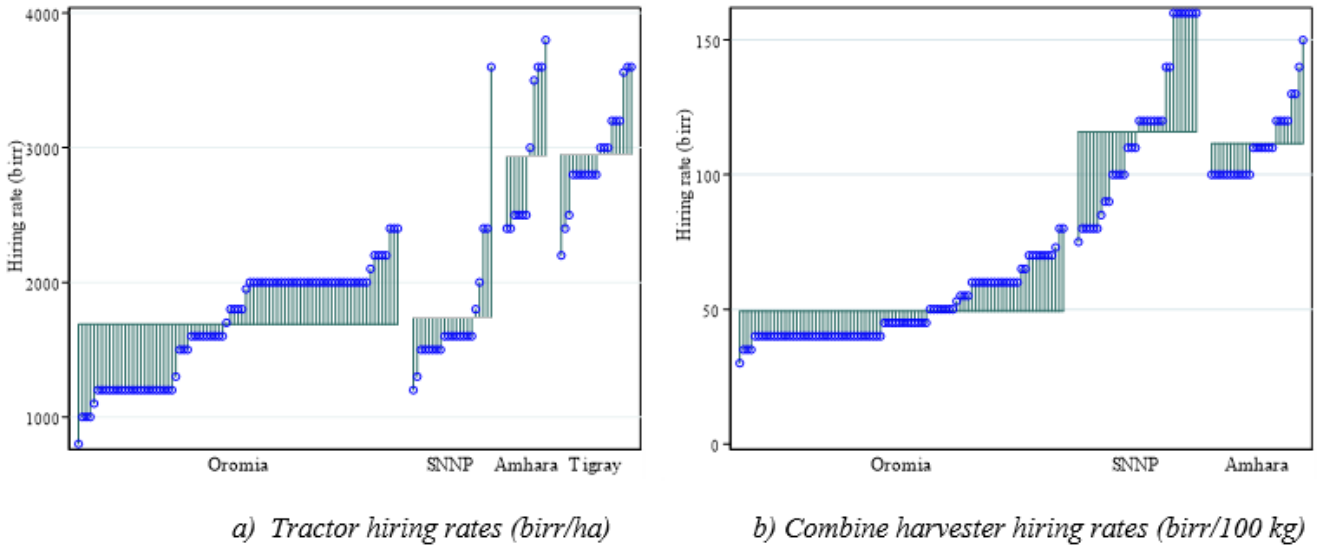
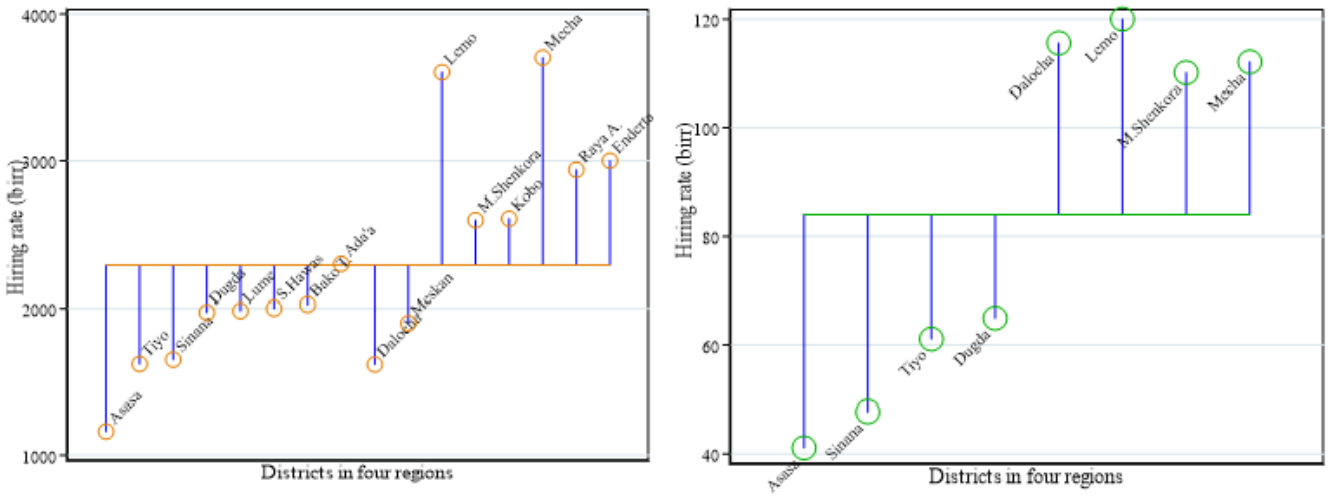


Figure 4

The variation of mechanization service access and hiring costs



a) Tractor-hiring rate (birr/ha) *b) Combiner-hiring rate (birr/100 kg)*

Figure 5

The mean mechanization hiring cost over districts