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Uber for tractors? Opportunities and challenges of digital tools for tractor hire in India and Nigeria

Thomas Daum [a,*], Roberto Villalba [a,b], Oluwakayode Anidi [a,c], Sharon Masakhwe Mayienga [a,c], Saurabh Gupta [d], Regina Birner [a]

[a] Hans-Ruthenberg-Institute of Agricultural Science in the Tropics, University of Hohenheim, Germany
[b] Department of Agricultural Economics, Technical University of Munich, Germany
[c] Food and Agriculture Organization, Rome, Italy
[d] Indian Institute of Management, Udaipur, India

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ABSTRACT

Digital tools hold great promise to promote agricultural transformation and benefit smallholder farmers in the developing world. One such tool is *Uber for tractors*, which aims to enable farmers to access tractor hire services in a way that is deemed similar to the Uber service for ride-hailing. While widely praised, *Uber for tractors* has not yet been rigorously analyzed. How does it work in practice? And what is its potential to reduce the transaction costs of tractor service provision, both for tractor owners and for smallholders who use tractor services? To answer these questions, we present case studies of two companies that apply digital tools in support of tractor hire: Hello Tractor in Nigeria and EM3 Agri-Services in India. A transaction costs economics framework was developed to identify how *Uber for tractor* tools can, in theory, influence the attributes of service hire transactions and, thus, reduce transaction costs. For the empirical analysis, a mixed-methods approach was applied involving approximately 400 respondents and comprising net-maps (a participatory mapping tool), focus group discussions, interviews with tractor owners and other stakeholders, and a survey among farmers. Our results show that the *Uber for tractor* models have indeed the potential to reduce transaction costs for service providers, in particular the owners of several tractors, by enabling the monitoring of tractors and operators through GPS devices. Farmers who access services have, so far, only indirectly benefitted from the new digital tools, because they still relied on "analog" solutions - booking agents and phone calls - rather than a smartphone app to request services. Overall, the paper shows that *Uber for tractors* is a pioneering concept, but investment in enabling conditions, such as digital literacy and network coverage, is required to harness the full potential of such digital innovations for smallholder farmers in the developing world.

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1. Introduction

During the last decade, agricultural mechanization has re-emerged on the development agenda of Africa (Baudron et al., 2019; Diao, Cossar, Houssou, & Kolavalli, 2014) and unfolded rapidly in Asia (Takeshima & Lawal, 2018; Wang, Yamauchi, & Huang, 2016). Mechanization allows farmers to overcome labor bottlenecks and expand farm production (Adu-Baffour, Daum, & Birner, 2019; Baudron et al., 2019; Diao et al., 2014). Agricultural mechanization refers to the use of animal or mechanical power along the agricultural value chain. Some tools, such as pumps, shellers, and hammer mills, have spread widely and fast throughout Africa (Malabo Montpellier Panel, 2018) and Asia (Biggs & Justice, 2015). However, the adoption of tractors, the key element of farm mechanization, has remained limited, in particular among smallholder farmers in Africa (Daum & Birner, 2020; Malabo Montpellier Panel, 2018).

While large-scale farmers can afford to buy tractors, there is a need to find technological or institutional solutions to enable mechanization for smallholder farmers, who play a key role in agricultural development. Without such options, the use of tractors can lead to the unequal distribution of land and wealth (Binswanger, 1986; Kansanga, Andersen, Atuoye, & Mason-Renton, 2018). Technological solutions focus on scale-appropriate mechanization, e.g. in the form of two-wheel tractors (Baudron

* Corresponding author: Universität Hohenheim, Wollgraweg 43, 70599 Stuttgart, Germany.

E-mail addresses: thomas.daum@uni-hohenheim.de (T. Daum), roberto.villalba@tum.de (R. Villalba), saurabh.gupta@iimu.ac.ind (S. Gupta), regina.birner@uni-hohenheim.dea (R. Birner).

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et al., 2019). However, such tractors are still too expensive for many smallholder farmers, and, as they lack the power to plow under rain-fed conditions, they have to be "earmarked towards niches" (Kahan, Bymolt, & Zaal, 2018).[1] Institutional solutions aim to help smallholder farmers to access tractors even though they cannot afford to buy them. One such institutional option is the provision of tractor services, which requires the development of service markets.

Service markets played a key role in the history of today's mechanized countries. For example, as shown by Olmstead and Rhode (1995), service markets for reaping, though far from being "completely fluid" (p.51), contributed extensively to smallholder mechanization in the United States. Service markets also play a role in some of today's mechanizing countries. In India, harvesting services are popular and in Bangladesh, only 2% of farmers own two-wheeled tractors but 72% of farmers access them (Diao et al., 2014). In Ghana, service markets contributed to the emergence of some highly mechanized pockets, where up to 80% of farmers use machinery (Cossar, 2016). In Ethiopia, markets for combine-harvesting of wheat have emerged, which are also used by smallholder farmers (Berhane, Dereje, Minten, & Tamru, 2017). In many areas, however, such markets are hampered by high transaction costs – the searching, bargaining, and enforcing costs related to setting up contracts – and tractor owners are unwilling to provide services to smallholder farmers unless transactions are facilitated (Adu-Baffour et al., 2019; Daum & Birner, 2017).

One way to facilitate transactions may be the use of digital tools, which have received much attention in the quest to solve the challenges of rural markets (Aker, Ghosh, & Burrell, 2016; Baumüller, 2018; Daum, 2018; Malabo Montpellier Panel, 2019; Nakasone, Torero, & Minten, 2014; World Bank, 2016) and have been shown to reduce the transaction costs related to service access by smallholder farmers (Deichmann, Goyal, & Mishra, 2016; Van Campenhout, 2017). For mechanization, digital tools that aim to connect tractor owners and farmers have been developed by *Hello Tractor*[2] in Nigeria; *EM3*[3], *Trringo*[4], and *farMart*[5] in India; *Trotro Tractor*[6] in Ghana; and *Rent to own*[7] in Zambia. For tractor owners, the use of such tools promises to reduce the transaction costs related to service provision, thereby allowing them to spread fixed costs and reach economies of scale. For farmers who cannot afford their tractor, such tools promise to reduce the transaction costs of accessing tractor services.

The abovementioned digital tools are referred to as *Uber for tractors* and the *Uberization of mechanization.* These phrases have been coined by the abovementioned ICT providers themselves and have been enthusiastically repeated by policymakers, donors, researchers, and the media. The New York Times headlined an article on this approach with "How do you hail a tractor in India? All it takes is a few taps on your phone".[8] The Uber comparison has generated a powerful narrative of change by suggesting that farmers can access tractors as easily as city dwellers can hail rides using Uber[9]. Uber, which owns no cars and employs no drivers, provides a digital marketplace where customers "schedule transportation with third-party providers of such services" (Henten & Windekilde, 2015, p.12). According to Henten & Windekilde (2015), Uber has significantly lowered transaction costs for searching, contacting, and contracting for both passengers and drivers.

Uber-type ride-hailing is popular in developing countries whose cities are among the most promising markets for ride-hailing. In Africa, Uber had served 5 million customers by 2019 with 150,000 drivers.[10] In India, Uber has 350,000 drivers, and a rival, Ola, has more than a million (Agrawal, 2018). However, there are differences between urban Uber-type ride-hailing services and rural Uber-type tractor hiring. In urban areas, network coverage and literacy levels are higher, and roads are more developed (GMSA, 2017). Moreover, the density of customer demand is higher, as there are more potential customers per area, and each of them may hail rides daily. In contrast, farms are spatially dispersed, and farmers demand services only a few times per season, in particular during early mechanization when mostly labor-intensive land preparation is mechanized (Binswanger & Rosenzweig, 1986; Diao et al., 2014).[11] Furthermore, farmers located in the same area are exposed to the same climatic conditions and thus demand services at the same time (Binswanger & Rosenzweig, 1986), a challenge that is less pronounced in areas with marked rainfall gradients, which allow for the migration of service providers.[12] Also unlike driving a car, operating farm machinery is a skill-intensive task and the quality of the work on the field can be highly variable. Additional challenges of agricultural markets, including various types of risks and information asymmetry, have been explained by Binswanger and Rosenzweig (1986).

As outlined above, digital tools have received much advance praise and enthusiastic media attention for reducing the challenges faced by smallholder farmers in developing countries. This has helped to cast light on the grand challenge of smallholder mechanization and potentially to attract private sector interest into an otherwise neglected market. However, while many ICT applications, such as Uber-type approaches for smallholder mechanization, have been flagged as success stories, few of them have been rigorously studied (Baumüller, 2018), which would be needed for evidence-based policy-making. This can be problematic as success stories can lead to political lethargy if they suggest that solutions for problems exist, for example, that the Uberization of mechanization has solved the problem of findings ways to enable smallholder mechanization. This may lead to the neglect of alternative solutions and complementary policy actions.

Against this background, this paper presents two case studies of two of the pioneering companies promoting ICT-based tractor hire services: *Hello Tractor* in Nigeria and *EM3 Agri-Services* in India. The paper investigates how these models address the thorny challenges of rural and agricultural markets and shows what works, where, when, and for whom. To analyze this, we draw on a framework by Sumberg (2005), which highlights that the adoption of innovations hinges on both endogenous factors (the utility of the innovation) and exogenous factors (the prerequisites to the adoption of the innovation). In the case of *Uber for tractors,* the utility of the innovation is manifested in the degree to which such models can change the transaction costs of service markets for both service providers and users. To further explore this, we combine Sumberg (2005) framework with a theoretical framework that draws on transaction cost economics (TCE) (Shelanski & Klein, 1995; Williamson, 1985; Williamson, 2010). As the main factors that influ-

[1] However, they may have sufficent power for direct seeding under conservation agriculture.
[2] https://www.hellotractor.com/home
[3] http://www.em3agri.com/
[4] https://www.trringo.com/
[5] http://www.farmart.co/
[6] https://www.trotrotractor.com/
[7] https://rtoafrica.com/
[8] nytimes.com/2016/10/18/world/what-in-the-world/trringo-app-india.html
[9] https://www.uber.com

[10] https://www.bbc.com/news/av/business-47518342
[11] The density of customer demand also depends on agro-ecological factors such as the number of seasons per year, the use of irrigation and the types of crops grown, some of which are more labour intensive, e.g. small grain cereals, than others,. e.g., root crops.
[12] Seasonal migration can be observed, for example, in China for combine harvesters (Yang, Huang, Zhang, & Reardon, 2013) and between Kenya and Tanzania for ploughing services (Bymolt & Zaal, 2015). In Ethiopia, there is a seasonal migration of combine harvesters between lowland and highland areas (Berhane et al., 2017).

ence the transaction costs such as uncertainty and asset specificity are difficult to quantify (Shelanski & Klein, 1995), a wide range of TCE studies are qualitative, an approach that the authors also follow (as further detailed in Section 2).

Because the *Uberization of mechanization* has not been studied previously, this study used an explorative, mixed-methods approach with a focus on understanding the opportunities and challenges of the models. Future studies could also assess the effects of such models on tractor owners and farmers more quantitatively, for example, by conducting randomized control trials.

The paper proceeds as follows. In Section 2, the authors present the theoretical framework, building on transaction cost economics. Section 3 shows the status of mechanization and tractor hire markets in Nigeria and India, provides background information on the case studies and presents the data collection methods. In Section 4, the authors apply the theoretical framework to analyze how the different *Uber for tractor* case studies address the challenges of agricultural markets and affect the transaction costs of tractor hire markets for both service providers and users. Section 6 discusses and concludes the paper.

2. Theoretical framework

To understand the opportunities and challenges for the adoption of *Uber for tractors*, the authors draw on a framework by Sumberg (2005). Sumberg (2005) shows that the adoption of innovations hinges on both *endogenous factors*, i.e. "the goodness-of-fit between the innovation and the targeted group of potential users" (p. 4), and *exogenous factors*, i.e. conditions that cannot be influenced by the innovation but are prerequisite to its adoption. To address the specific conditions of tractor service markets, we expand Sumberg's framework, which focuses on the adoption decision of *one* category of users (i.e. farmers). The adoption of the *Uber for tractor* model depends on the simultaneous adoption by two different types of users: the mechanization service providers and their customers, the farmers. We further expand Sumberg's framework by distinguishing two types of endogenous factors, which can be expressed in the form of the following questions:

1) is the innovation utility-increasing for potential users, i.e. the mechanization service providers and the farmers, if all prerequisite conditions are fulfilled?
2) which prerequisite conditions for the adoption can be addressed by the innovation itself or by the potential users themselves, i.e. the mechanization service providers and farmers?

For example, digital literacy is a prerequisite of the adoption of an Uber-type model. This prerequisite can be (partially) addressed by the innovation itself if the app is very user-friendly and relies on visual tools. Another prerequisite is smartphone ownership, which does not constitute a lacking prerequisite as long as users can afford to buy smartphones in principle. Regarding the exogenous factors, we follow Sumberg, who defined them as factors that are "outside the control or influence of the innovation-development process" (Sumberg, 2005, p.7). Exogenous factors are given – at least in the short term. Expressed as a question, we ask:

3) which prerequisite conditions cannot be addressed by the innovation itself or by the potential users, i.e. Mechanization service providers and farmers?

Examples of such external factors include network coverage and the general demand for mechanization, which depends on factors such as the type of farming system and the relation between the cost of capital and the cost of labor.

Sumberg (2005) framework highlights that innovations have to be utility-increasing for potential users to be adopted (see the first question). In the case of *Uber for tractors*, utility-increasing particular refers to the need to be more efficient than traditional solutions for reducing transaction costs to be adopted. Therefore, understanding how such Uber-type models affect transaction costs for mechanization service providing tractor owners and farmers accessing mechanization services is key.

To explore this systematically, we use transaction cost economics (TCE). TCE dates back to Ronald Coase (1937), who argued that market exchanges include costs other than production and transportation costs (as suggested by neoclassical economics), as the parties of the exchange need to find each other and establish whether they can trust each other (information/sorting), negotiate terms of service (negotiation) and ensure that the terms are adhered to (monitoring, enforcement, and compliance).[13] All these steps are associated with monetary costs as well as more elusive costs such as opportunity costs, which makes TC difficult to measure (Kherallah & Kirsten, 2002).

TCE argues that markets rely on contractual arrangements that minimize the overall costs of the transaction, which comprise both transaction and production/transportation costs (Shelanski & Klein, 1995; Williamson, 2010). When TC are too high, markets can fail, which can frequently be observed for developing countries' agricultural markets (Kherallah & Kirsten, 2002). Thus, contractual arrangements that reduce TC tend to enhance the participation of farmers in markets (Cuevas, 2017).

Transaction costs are determined by attributes such as uncertainty, specificity, frequency (Williamson, 1985), complexity (Shelanski & Klein, 1995), measurability (Barzel, 1982), and hold-up problems (Wander, Birner, & Wittmer, 2003). For mechanization, additional attributes play a role, as further detailed below. While TCE is often used to predict the type of contractual arrangements that companies select given these attributes (Williamson, 2010), a different approach is used here: We examine to what extent the digital devices used in the Uber for tractor model affect the attribute of the transactions involved in providing tractor services and are, thus, likely to reduce the transaction costs of tractor service provision, which would then contribute to expanding the market for tractor services and improving smallholders' access to such services. The role of the attributes in the case of tractor service provision are described in the following (cf. Wander et al., 2003):

Uncertainty relates to the risks surrounding the exchange. For farmers seeking mechanization services, uncertainties related to the punctuality and quality of the services are key as deviations from the optimal farming window and bad service can lead to large yield drops (Sallah, Twumasi-Afriyie, & Kasei, 1997). Uncertainty depends on the farming system considered (e.g. the number of cropping seasons per year, the types of crop grown, and the use of irrigation). For tractor owners, uncertainties can arise from a lack of knowledge on farmer's intention to pay and the conditions of their field (e.g., the prevalence of tree stumps and stones), among others.

Asset specificity describes whether assets can only be used for a particular exchange. In mechanization, a harvester can only be used for one activity, harvesting (sometimes only of a particular crop), while tractors can be used for a wide range of activities when

[13] TCE thus explicitly acknowledges that market actors are opportunistic and possess "self-interest seeking with guile" (Williamson, 1985, p. 47).

equipped with the respective equipment (e.g., plows, planters, sprayers).[14]

Frequency refers to how regular exchanges take place. Concerning mechanization markets, seasonality and synchronous timing of farming activities reduce the number of possible transactions between service providers and customers.

Complexity affects how elaborated the terms of the exchange have to be. For mechanization services, terms must specify not only prices and dates of service delivery, but also field conditions, plowing depth and speed, and soil erosion control, among others. Some of these parameters are difficult to monitor because of information asymmetry, which makes contractual arrangements more complex.

Measurability refers to how easily the parties can check whether the terms of the exchange were followed. For plowing services, the quality of work is partly difficult to measure objectively (e.g. consistent plowing depth is difficult to measure after the work is completed).

Spatial dispersion refers to the spread of customer demand across space. Regarding mechanization, the distances between transactions can be high given the spatial dispersion of farming, which drives up the costs for fuel and creates principle-agent problems. If the spatial dispersion is organized along with a rainfall and crop maturity gradient, however, this can also be an enabling rather than disabling factor, because tractors can be used over a larger area for the same type of farm operation.

Tractor owners have two types of contractual arrangements: with the customers and with the operators of the tractors. The latter type is prone to principle-agent problems, which can arise when tractor owners hire operators who face moral hazard problems, for example, when the operators lack the motivation to perform maintenance activities, are inclined to steal diesel and line their own pockets (Daum & Birner, 2017), which can lead to a failure to adhere to the agreed-upon services. The abovementioned attributes may be interrelated. Table 1 summarizes the attributes of the transactions in mechanization service markets.

There are ways to reduce transaction costs and protect trading partners "from the hazards associated with exchange relationship" (Shelanski & Klein, 1995, p. 336). Table 1 shows some of the traditional solutions used to reduce the transaction costs related to mechanization markets. A common disadvantage of all these methods is that they constrain the potential area of service provision. Also, while some reduce the transaction costs for service providers (such as informal demand pooling by farmers), they are associated with transaction costs for farmers (to organize themselves).

ICT tools may provide additional mechanisms to reduce transaction costs. This has been shown by Uber-type ride-hailing (Henten & Windekilde, 2015). For example, digital tools have helped to reduce uncertainties for passengers by showing digital maps with the location of the nearest service providers, by showing the waiting time until drivers arrive, by requiring drivers to be formally registered and allowing customers to rate them, and by informing passengers on the final price upfront. For Uber operators, Uber's digital solutions help to reduce uncertainties by spatially showing customer demand and using algorithms that minimize the travel time between service provisions. Following Benkler (2004), ICT applications can also reduce enforcement costs because they rely on enforcement mechanisms based on social relations and social capital (by rating service providers) rather than relying on state authorities to enforce contracts, which may be of particular relevance for countries with otherwise limited governance capacities. Similar digital solutions could also help *Uber for tractor* service providers and customers.

3. Material and methods

This paper examines Uber-type tractor hire models in Nigeria and India. Section 3.1 provides an overview of the status of smallholder mechanization and tractor hire in these countries. Section 3.2 presents background information on Hello Tractor and EM3. Section 3.3 describes the methods used for this study.

3.1. Status of mechanization and tractor hire in Nigeria and India

This section provides an overview of the status of smallholder mechanization and tractor hire in Nigeria and India.

3.1.1. Nigeria

Compared to India, which will be presented in the next section, agricultural mechanization is at a lower level in Nigeria. Takeshima & Salau (2010) find that "owning and renting a plow is not common" and "access to a tractor is even rarer" (p.1). According to them, most of the land is cultivated with hand hoes, and the uptake of mechanization is low even for power-intensive operations such as land preparation, which are typically mechanized first. Actual numbers are not available, and estimates are contradictory. According to the latest estimates of the Food and Agriculture Organization (FAO) from 2007, Nigeria has a tractor population of 25,000. In contrast, extrapolating from LSMS-ISA data, Sheahan and Barrett (2017) estimate that there are 450,000 tractors. However, compared with annual tractor imports, this estimate seems to be a gross overestimation (Takeshima & Lawal, 2018). Sheahan and Barrett (2017) estimate that 1.6% of all farmers owned tractors in 2010/11 and that 25% accessed them through various channels (see below). In contrast, Takeshima and Lawal (2018) argue that only 4% of all farmers own *or* hire tractors. Adoption rates differ by farm size: of the 10% farms larger than 3 ha, 10% own or hire tractors, and 40% own or hire animal traction according to Takeshima and Lawal (2018). In general, tractors are used for a few activities, mainly land preparation and transportation (Takeshima & Lawal, 2018).

According to Takeshima and Lawal (2018), 66% of the farmers using tractor services access them via neighbors and relatives as well as the private market, which is composed of medium-scale farmers as well as contractors and associations, both of which may own large fleets of tractors. A total of 28% of farmers hire tractors via public hire centers (Takeshima & Lawal, 2018). Such centers have been established since 1958 and became a policy priority during the 1970s. In the mid-1980s, they were "largely considered inefficient" and often abandoned (Takeshima & Lawal, 2018, p. X, referring to Akinbamowo, 2011). Since the 2000 s, such centers were revived as Agricultural Equipment Hiring Enterprises (AEHE), this time as public–private partnerships, where the state supports private entrepreneurs (such as farmers, cooperatives, and investors) with subsidized tractors (Takeshima & Lawal, 2018). By 2016, 80 AEHEs had been established, each typically owning five four-wheeled tractors and five two-wheeled tractors plus attachments and sometimes owning harvesters and processing equipment as well (Takeshima & Lawal, 2018).

3.1.2. India

In India, agricultural mechanization started during the late 1950s (Bhattarai, Singh, Takeshima, & Shekhawa, 2018; Diao et al., 2014). From then until 2010, the number of tractors rose from 37,000 to above 5 million (Singh, Singh, & Singh, 2014; Singh, 2015). In 1960, there was one tractor per 3600 ha; in

[14] Kahan et al. (2018) argue that multi-functional machinery which can be used for land preparation but also transportation, shelling and irrigation can help to make service provision more viable.

Table 1
Attributes of transactions for mechanization service markets and ways to reduce transaction costs.

Attributes	Key questions	Effect on TC	Non-ICT-based and ICT-based ways to reduce transaction costs	
			Providers	*Customers*
Uncertainty	Are transaction partners available? Will service providers and customers show up (on time) and fulfill their terms?	The more uncertain, the higher the TC.	**Non-ICT-based:** Using scouts to assess fields, relying on long term relationships, developing a "cropping calendar", requiring up-front payment, avoiding some types of customers (e.g. smallholder farmers) as a rule of thumb **ICT-based:** Software for fleet management and demand planning, using algorithms that minimize the travel time between requests, Internet of Things approaches that allow tractors to communicate and plan service provision, drone or satellite-based field assessments, requiring farmers to send pictures of fields, electronic scoring systems that allow assessment of customers	**Non-ICT-based:** Relying on long term relationships, using social capital to ensure early service, long-term planning to ensure service provision (often tractor owners operate on a first-come, first-served basis), pay only after service delivery **ICT-based:** Showing waiting time until tractors arrive, public rating of service providers, up-front price calculation
Asset specificity	For how many different production stages and crops can the machinery be used?	The more specific, the higher the TC.	**Non-ICT-based:** Diversification, sharing of implements (e.g., using "Machinenringe"[1]) **ICT-based:** Sharing of implements supported by digital management platforms	Not applicable
Frequency	How often are services provided?	The more regular services are, the more trust can build and the lower the scope for opportunism, therefore, the lower the TC.	**Non-ICT-based:** Migration to other areas, relying on long term relationship **ICT-based:** Software optimizing service provision (incl. the migration to other areas); customer management platforms	**Non-ICT-based:** Relying on long term relationship **ICT-based:** Software optimizing service provision (incl. the migration to other areas); customer management platforms
Complexity	How complex do the contractual agreements need to be?	The more complex, the higher the TC.	**Non-ICT-based:** Participate in training so that complex tasks can be executed more effectively **ICT-based:** Use of sensors in implements and automation of farm operations to "standardize" processes	**Non-ICT-based**: Participate in training to be able to better assess the quality of complex tasks **ICT-based ways:** Use of sensors in implements and automation of farm operations to "standardize" processes
Measurability	Can the service be easily measured?	The more difficult to measure, the higher the TC.	**Non-ICT-based:** Agreeing on objective measurements (such as measuring areas served with standardized ropes) and relying on objective judges to assess quality (such as extension officers) **ICT-based:** Using satellites, drones, and machinery-based sensors to measure quality and GPS to measure area served	**Non-ICT-based:** Agreeing on objective measurements (such as measuring areas served with standardized ropes) and relying on objective judges to assess quality (such as extension officers) **ICT-based:** Using satellites, drones, and machinery-based sensors to measure quality and GPS to measure area served
Hold-up problems	Does a transaction failure affect other transactions?	The higher the risk and consequences are, the higher the TC.	Not applicable because providers can cultivate their fields first	**Non-ICT-based:** Partial mechanization (i.e., only part of the land to minimize the risk), diversify crops so that services can be spread over a longer period, use of contractual penalty mechanism in case of late service provision **ICT-based:** Showing waiting time until tractors arrive
Spatial dispersion	How spread is customer demand across space?	The more dispersed, the higher the TC, unless the dispersion follows a rainfall gradient, enabling migratory service provision (see frequency)	**Non-ICT-based:** Use of brokers/agents to organize customers upfront, focus on large-scale farmers **ICT-based:** Demand pooling using smartphone applications	**Non-ICT-based:** Informal demand pooling among neighboring farmers **ICT-based:** Demand pooling using smartphone applications
Principle-agent problems	How easy is it to monitor and control operators?	The easier to supervise, the lower the TC.	**Non-ICT-based:** Performance of operations by machinery owners only, mileage recording, timed fieldwork, owner/relative follows tractor, control by the assistant operator, random field checks, limiting radius for effective oversight, fuel monitoring, customer calling, tractor owner organization to collectively refuse poorly performing operators **ICT-based:** Using GPS tracking and machinery-based sensors to monitor operators and maintenance	**Non-ICT-based:** Supervision and inspection of fieldwork, use complaint mechanisms; involve experts (e.g., extension agents) and peers in the assessment of work; participate in training to be better able to assess the quality of work **ICT-based:** Electronic complaint mechanism and checklists for quality control, send pictures of served fields to experts or peers electronically, supervise fieldwork using drones

[1] Groups of farmers (often neighbors, relative or friends) that each own machinery that they rent out to each other. An approach to shared machinery that is popular in Germany.

2013, this figure reached one tractor per 24 ha (Bhattarai et al. 2018). In 2015, alone, 550,000 tractors were sold (Bhattarai, Joshi, Shekhawa, & Takeshima, 2017). Tractor density is highest in Northern India, but it is on the rise across Southern and Western India as well: in 2012, 147 tractors were used per 1000 ha in Haryana, 124 in Punjab, 40 in Rajasthan, and 6 in Kerala (Bhattarai et al., 2017).[15] Most tractors are four-wheeled and have an average of 42 horsepower (Singh, 2015). There are approximately 300,000 two-wheeled tractors (power tillers), which are popular for wetland rice production and hilly areas (Singh, 2015).

Agricultural mechanization began with land preparation, followed by irrigation and processing. More recently, equipment for zero tillage, laser land levelers, and combine harvesters became popular (Singh, 2015). Early mechanization was driven by large farms: during the 1960s, 96% of tractor owners possessed more than 10 ha (Singh, 2015). However, farmers owning 4 to 10 ha soon acquired smaller tractors, and hire markets emerged (Binswanger, 1986; Diao et al., 2014). In the 1970s, 60% of the annual use of tractors was for service hire (Singh, 2015). By 2010, 38% of all tractors were owned by farmers with more than 10 ha, while farmers with less than two hectares owned 1% of all tractors (Bhattarai et al., 2018). Rental markets increasingly make tractors "accessible to all segments of farmers, including smallholding and marginal farmers" (Bhattarai et al., 2017, p.5). Today, although 85% of all landholdings are smaller than 2 ha, Bhattarai et al. (2018, p.1) estimate that up to 90% of farmland is prepared by tractors. Rental markets are organized around individual farmers providing services, cooperatives, and forms of joint ownership, rural entrepreneurs, big firms with large tractor fleets for custom hire as well as public–private or purely public hire centers (Bhattarai et al., 2018). There are no numbers on how many smallholder farmers access tractor services. The Economic Times (2016) argues that rental markets are still unorganized, dominated by wealthy farmers, and government-subsidized custom hiring centers with limited scale and reach as well as patchy, unsatisfactory, and often late services.[16]

3.2. Background on the case studies

This paper is based on case studies of two start-ups that have been pioneering the Uber for tractor approach: Hello Tractor in Nigeria, which was the first company to explore the potential to apply the concept of Uber to mechanization in developing countries, and EM3 Agri-Services in India, which pioneered this approach in India. Section 3.2.1 provides background information on Hello Tractor and Section 3.2.2 on EM3.

3.2.1. Hello tractor (Nigeria)

Hello Tractor was founded in 2014 in Nigeria by Jehiel Oliver, an entrepreneur with a finance background, to connect "tractor owners to farmers through a digital app" (Foote, 2018). According to its founders, Hello Tractor has received around 1.2 million US$ in startup grant funding.[17] The key components of the Hello Tractor business model are a GPS-based monitoring device that allows for the remote monitoring of tractors, costing 80 to 200 US$, and a digital booking platform that matches farmers with the nearest tractors.

The monitoring device records, for example, GPS location data, fuel efficiency, and operator activity, depending on the version chosen. The recorded data can be accessed via smartphone or computer. Having real-time data promises tractor owners easier management of tractors and operators, for example, by showing maintenance needs and controlling fraud. The digital booking platform, which shows customers' requests and can be used for fleet management, promises to ensure high machinery utilization rates. For smallholder farmers, finding the nearest tractor via a digital booking platform promises to reduce the transaction costs of accessing tractor services. Given the potential for both tractor owners and farmers, Jehiel Oliver argues that Hello Tractor is "a hybrid. An Uber-meets-Salesforce for tractors" that is "connecting farmers in need of service to tractor owners, while also enhancing a tractor owner's existing business" (Foote, 2018).

Initially, Hello Tractor sold the GPS monitoring device together with their two-wheeled tractors, which they considered their "flagship" (Foote, 2018). However, the focus on machinery sales turned out to be not viable for various reasons, including the Nigerian recession at that time, which led to currency devaluation; the limited access to credit for tractor owners; and the low reach and durability of two-wheel tractors. In 2017, Hello Tractor started to focus exclusively on its digital solution, therefore collaborating with existing machinery dealers instead of competing with them. According to Hello Tractor founder Jehiel Oliver, 75% of all tractors sold in Nigeria are fitted with Hello Tractor devices (Foote, 2018).

The actual tractor hire process works as follows: The service can be requested via a smartphone application, but most farmers rely on the help of a booking agent because few Nigerian smallholder farmers own smartphones. In 2018, approximately 13% of the population across urban and rural areas owned smartphones (Newzoo, 2018). Moreover, those owning phones often do not trust them to make transactions (Foote, 2018). Realizing this challenge, Hello Tractor has established a network of booking agents, a model that is also used by some traditional service providers. These agents create awareness about tractor availability and pool the demand from several smallholder farmers in a particular geographical for a 10% commission (Jones, 2018). The agents work with individual farmers or farmer cooperatives.

3.2.2. EM3 Agri-Services Pvt. Ltd., India

EM3 was founded in 2014 by Rohtash Mal, a former executive in the telecommunication industry, and his son Adwitiya Mal, who has a background in finance. They had the aim to "uberize" agriculture (Katz, 2016, para 3). At first, EM3 operated custom hire centers with their machines, an approach that was later replaced by an "asset-light strategy": a franchise model where franchisees own the machines, and EM3 provides support functions. EM3 has received considerable start-up capital, including a 1.25 million US$ equity capital by Aspada (Empea Institute, 2017). EM3 started operating in Madhya Pradesh, and in recent years, it has extended its work to Rajasthan, Uttar Pradesh, and Gujarat.

In Rajasthan, which is the focus of this study, EM3 operates under an agreement with the state government, signed in 2016. Under this agreement, EM3 has to establish 300 custom hiring centers in 28 of the 32 districts of the state. The EM3 centers are based on a franchise model where EM3 provides know-how on service provision to the franchisees and helps them to acquire customers. To achieve this goal, the franchisees pay 5% of every transaction to EM3 monthly. The machines have to be acquired by the franchisee, but the government of Rajasthan subsidizes the equipment with 40% of the purchase value upon approval of the franchisee's application. In exchange, franchisees need to prove a minimum of 650 annual hours of service provision. By the end of the data collection for this study in September 2018, 29 out of the planned 300 centers had been established. By the end of 2019, 275 centers were established.

Before opening a franchisee, EM3 analyzes the frame conditions in the respective area, focusing on current levels of mechanization as well as projected demand; crops grown (i.e., whether crops are

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[15] Tractor densities are higher with higher cropping intensity, larger farm size and higher per capita income in the respective state (Bitsch, 2017).

[16] https://economictimes.indiatimes.com/small-biz/startups/how-startup-em3-agri-services-is-tackling-farmers-distress-the-uber-way/articleshow/53133968.cms

[17] Personal communication with Jehiel Oliver on January 16th 2020.

entitled to government minimum prices); levels of irrigation; average land size; operating costs for maintenance, diesel, and electricity; and customers' willingness to pay. Potential franchisees need to meet the following prerequisites: a good bank repayment history; access to a network of more than 500 farmers; knowledge of local geography, agriculture, machinery use, and maintenance; a local trustee; and 200,000 rupees capital (approx. 2500 Euros).

3.3. Methods and sampling

This paper uses a mixed-methods design, including qualitative and quantitative data collection methods (see also Table 2). In each of the countries, stakeholder mapping exercises were conducted to identify the stakeholders who determine the functioning of the business models. For this purpose, a participatory technique called "Net-Map" (Schiffer & Hauck, 2010) was applied. "Net maps" are well suited to exploring the structure and functions of complex systems and to identify how different stakeholders influence these systems. "Net-Maps" were created with representatives of the companies Hello Tractor and EM3. During the "Net-Map" sessions, participants were first asked to discuss which stakeholders influence the success of the Uber-type models and to identify the challenges on the business model on the ground. The answers were drawn on a large sheet of paper. Second, participants were asked how these stakeholders are linked to each other (e.g., through flows of money, services, information, or commands). These linkages were drawn on the paper with different colored arrows. Participants were then asked to identify the most important stakeholders in making the ICT-based approach work. The answers were indicated using so-called "influence towers" built with checker game pieces. Respondents could place checker game pieces ranging from none (indicating no influence) to six (indicating high influence). Finally, bottlenecks to service provision were identified, and solutions to overcome these bottlenecks were discussed.

Based on the "Net-Maps", interviewees for qualitative in-depth interviews were identified, including representatives of the companies, tractor owners, and other actors in the value chain, tractor dealers, tractor operators, mechanics, and government officials. In the case of EM3, 15 franchisees were interviewed. In the case of the Hello Tractor, seven booking agents were interviewed. With some of these stakeholders, additional "Net-Maps" were created. In addition to the "Net-Maps" and the in-depth interviews, focus group discussions were organized. The use of qualitative methods allowed for an in-depth exploration of the cases while also permitting the discovery of unexpected findings that emerged during the research. During the collection of the qualitative data, the authors followed the rigorous evaluation standards of qualitative research, including data collection until a point of saturation was reached (persistent observations), discussions with research peers (peer debriefing), and research participants and experts (member checks). Also, using different data sources and methods helped to triangulate the collected data, thereby ensuring credibility and confirmability (cf. Bitsch, 2005). Most interviews were tape-recorded and transcribed for analysis.

The qualitative data were supplemented with a quantitative survey administered among farmers who hire tractors. In India, the survey was conducted in Rajasthan, and the sampling was performed as follows: 1) two districts (Bundi and Kota) were purposefully selected based on the criteria that the EM3 franchisees had been in operation for one farming season; 2) EM3 users were sampled using snowball sampling and corresponding non-EM3 users were selected randomly from the same or neighboring *gram panchayat* (village) using cluster sampling based on lists provided by the districts' Agricultural Departments, resulting in a total of 101 tractor users.

In Nigeria, the survey was conducted in the Federal Capital Territory, and the sampling was performed as follows: 1) three of six farming communities where tractor owners provide services using the Hello Tractor device were randomly sampled; 2) in each community, a list of households willing to access mechanization services was obtained, thereby avoiding self-selection bias. The list had been previously collected by Hello Tractor booking agents. From this list, a total of 220 households were sampled. The final sample comprised 104 households who eventually decided to access mechanization via Hello Tractor and 116 who decided to rely on conventional, pre-existing ways to access services. A multiple regression analysis was performed with the average price and the waiting time and price for mechanization services as dependent variables while controlling for other factors.[18] These factors, which may equally affect the average price and the waiting time, were selected based on economic theory (e.g. Binswanger & Donovan, 1987; Daum & Birner, 2017) and are shown in table 3. The covariates include farmers' characteristics (such as gender and age), factors that may influence the time and ease of service provision (such as the share of plots with stones), and factors that may facilitate access to the providers (such as having a previous exchange relation). The models were estimated with ordinary least squares (OLS) using robust standard errors to account for heteroscedasticity. Pairwise correlation coefficients were used to avoid multicollinearity.

4. Results

This section presents empirical findings on the implementation of *Hello Tractor* and *EM3 on the ground* (see 4.1) and examines how the models affect the attributes of transaction costs for service providers as well as customers (see 4.2).

4.1. Uber for tractors – case studies

4.1.1. Hello tractor (Nigeria)

The results reveal that not all machines that are fitted with the Hello Tractor GPS monitoring device are used to offer services to others; for example, farmers may use the machines only on their farms, especially if they have large farms. Additionally, some service providers use the tracking device but not the Hello Tractor booking platform. At the time of this study (October 2018), there were twelve contractors and or tractor owners' "association groups"[19] who applied Hello Tractor's Uber model, including the booking platform. These twelve contractors and association groups owned in total approximately 800 tractors, out of which approximately 600 were equipped with the GPS monitoring device.

The results reveal some challenges related to the use of booking agents. Booking agents are not always trusted by farmers, which is a challenge because the Hello Tractor model requires farmers to pay a commitment fee before the service is delivered. Farmers, however, prefer to see the tractor first. One booking agent reported:

> *"Farmers are always scared. They say we (the agents) just make promises but at the end of the day we do not bring the tractors to them".*

[18] Such an approach was not undertaken in the case of EM3 due to the small sample size.

[19] In Nigeria, the term "contractors" refers to mechanization service providers who are not farmers themselves. "Contractors" can be individuals (managing between 5 and 10 tractors) or groups of investors that manage dozens or hundreds of tractors. Many tractor owners also register in "association groups". These tractor owners are typically farmers themselves, and most of them provide hire services. In such "association groups", which exist for each state, they coordinate service provision and often also agree on service prices.

Table 2
Data collection methods and sample size.

Methods		EM3 India	Hello Tractor Nigeria	Total
Qualitative Methods	Net-Maps	2	12	14
	Focus group discussions	2	3	5
	Interviews with stakeholders	11	29	40
	Interviews with franchisees or tractor owners	15	7	22
Quantitative Methods	Interviews with farmers	101	220	321
Total		131	271	402

Table 3
Description of the variables used in regression analysis.

Variables name	Variables description
Outcome variables	
Waiting time	Average waiting time in days before requested service is delivered
Price	Average price per ha (in NGN) for the service
Explanatory variables	
Use of Hello Tractor	Households served by service providers using Hello Tractor; 1 = yes, 0 = no
Gender	Gender of household head; 1 = male, 0 = female
Age	Average age of household head in years
Community role	Does household head play a major role in the society (e.g. as village headmen); 1 = yes, 0 = no
Phone ownership	Does the farmer possess a mobile phone; 1 = yes, 0 = no
Land mechanized	Average land size mechanized in hectares
Share of plots with stone	Prevalence of stones in the percentage of plots as a proxy for land quality
Share of plots with tree stumps	Prevalence of tree stumps in the percentage of plots as a proxy for inaccessible plot surface
Mechanization group	Does the farmer pool demand and request services as a group; 1 = yes, 0 = no.
Previous exchange relation	Does the farmer have an existing exchange relationship with the service provider; 1 = yes, 0 = no
Internet access	Access to the internet as a proxy for the remoteness of the farm; 1 = yes, 0 = no

Table 4
Socioeconomic characteristics of surveyed farmers. Values rounded. Differences between Hello Tractor and others based on Welch 2 sample t-tests and chi-square test (for categorical variables) and shown with *, **, and *** to indicate the significance of mean differences at the 10%, 5%, and 1% level.

Variable	Hello Tractor (n = 104)	Others (n = 116)	Difference
Gender (female) (%)	11	0	0.0010***
Age (years)	38	43	0.0044***
Community role (yes) (%)	11	19	0.1281
Phone ownership (yes) (%)	95	83	0.0106**
Land cultivated (ha)	6.5	7.1	0.4765
Land mechanized (ha)	4.6	5.3	0.3949
Share of plots with stone (%)	8	15	0.0983*
Share of plots with tree stumps (%)	28	36	0.1222
Off-farm income (yes) (%)	40	42	0.8444
Mechanization group (yes) (%)	24	19	0.4522
Previous exchange relation (yes) (%)	0	60	0.0001***
Internet access (yes) (%)	47	34	0.0855*

Levels of trust are particularly low when booking agents come from outside the farming community, which is a problem because most live in nearby towns and cities, and only a few are located within the farming communities. The location of the agents also means that they incur a high cost of transportation in accessing farming communities, which sometimes discourages the agents from going to areas with limited infrastructure. However, because booking agents come from outside the communities, often from urban areas, they are less constrained by social norms and rules. This has an advantage in that they seem to be more likely to accept requests from female farmers. Among the farmers accessing services interviewed for this study, 11% of those that relied on the Hello Tractor model were female, while the farmers using existing traditional methods were all male, as shown in Table 4.

Once a sufficiently large number of requests is accumulated, the booking agents can submit a request for service through a Hello Tractor booking app. However, not all booking agents use this option. Although Hello Tractor claims to adequately train their booking agents, three out of seven booking agents interviewed for this study complained that they lacked adequate knowledge to use the booking app and thus preferred to have their supervisors enter the request data.

As seen in Fig. 1, the pooled requests include information on the farmer's details, the location, the type of service requested, the land size to be serviced, and the nature of the farm plot (such as whether it has trees, stumps, or stones). Once requests are transferred, Hello Tractor pairs the request with the nearest tractor owner. In cases where the demand in one location is not sufficiently large, that farming community is paired with nearby farming communities by a booking agent so that tractor use can be maximized and travel time minimized. Thus, the booking agent is an integral part of the digital platform. So far, the application software does not help to optimize tractor use and service provision. For example, it does not use any algorithms to optimize travel routes or the sequencing of requests – these decisions are still made by the tractor owners and operators.

If the tractor owner agrees to provide the service, after pairing (see also Fig. 1), he or she either provides the service directly or sends a tractor operator to provide the service. Tractor owners do not agree to provide services in all cases, as most of the farmers are located in rural areas, with bad roads affecting accessibility for both booking agents and tractor operators. According to the stakeholder interviews, operators sometimes refuse to deliver services in areas with bad roads, even when prearrangements have been made, as this can destroy the tractor equipment. In addition to reports of tractors that did not arrive for such reasons, there were also reports of tractors arriving late or breaking down during service delivery. In some cases, farmers also default: despite a commitment fee, customers reportedly may switch to other service providers if they are available earlier.

During service provision, the abovementioned Hello Tractor GPS monitoring device helps tractor owners to supervise their operators. While having GPS records of their movements generally does ease supervision, this approach is also confronted with some challenges. For example, one of the interviewed tractor contractors reported a case where operators destroyed the device while being in the field so that they could not be monitored. Additionally, while the GPS device works offline, the transfer of data to the tractor owners requires good connectivity. This is not always guaranteed: 43% of the tractor owners complained about "blind spots" where there is limited internet access, which prevents them from monitoring their operators – a problem highlighted in the following quote:

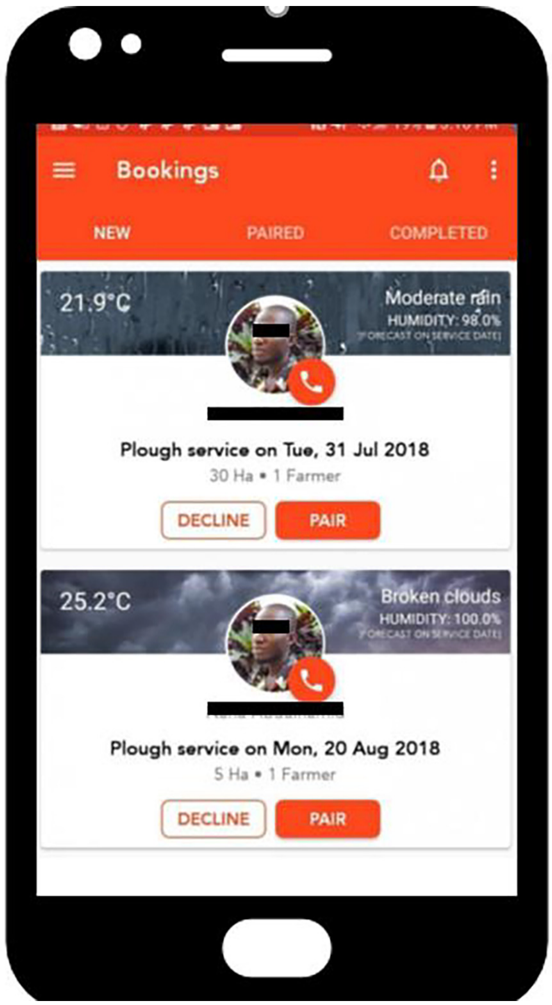

Fig. 1. Hello Tractor application for tractor owners showing requests from booking agents.

”*There are certain blind spots from the tracking (...) and this sometimes prevents us from monitoring the operators properly or to know what they are doing*”.

Because smallholder farmers, so far, do not use a smartphone app to book tractor services and instead engage with Hello Tractor indirectly through booking agents, the focus group discussions with the smallholder farmers showed that they were mostly not aware that they were customers of Hello Tractor. This unawareness is not surprising because the prices and waiting times are similar to those of traditional service providers. As shown in Table 5, there is no significant price difference at the 5% confidence level. There is a significant difference at the 10% level but this disappears when controlling for additional covariates (see Table 6).[20] When looking at Table 6 it is important to be aware of the relatively small sample size. Also, Hello Tractor service providers are mostly large contractors and part of large associations. Thus, any difference may also occur because service providers are larger and potentially better organized than owners of one or few tractors.

[20] Land mechanized (ha) was dropped from the regression since it can be affected by the outcome variables (e.g., with a high service price, farms may want to prepare less land using machinery). Ideally, one would use lagged values for land mechanized (ha) during the previous year to address this problem but this data was not collected. No suitable instrumental variable could be identified. Land mechanized (ha) was not significant in the first place.

Table 5
Differences in mean costs and waiting time for plowing service. 1 NGN is 0.0028 USD. Thus, Hello Tractor users pay, on average, 79 USD, while customers of other service providers pay 89 USD. Values rounded. Differences between Hello Tractor and others with *, **, and ***, indicating the significance of mean differences at the 10%, 5%, and 1% level.

Variable	Hello Tractor (n = 104)	Others (n = 116)	Difference
Price per ha (NGN)	28,490	32,078	0.0764*
Waiting time (days)	5.48	6.47	0.0824*

Table 6
Correlation between Hello Tractor and waiting time and price for mechanization services. Note: Waiting time and price were estimated with OLS. Parentheses show robust standard errors. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively.

Explanatory Variable	(1) Waiting Time	(2) Price
Use of Hello Tractor (dummy)	−0.83078 (0.89886)	−3268.78 (2406.24)
Female household head (dummy)	−0.64497 (1.17788)	3917.99 (2820.36)
Age (years)	−0.07832 (0.02988)**	−63.09 (121.80)
Community role (dummy)	1.35845 (0.97642)	10686.05 (5187.24) **
Phone ownership (dummy)	−0.66585 (1.41058)	–
Share of plots with stone (%)	0.96281 (1.42415)	6024.90 (6930.76)
Share of plots with tree stumps (%)	0.31263 (0.84293)	−7816.39 (2878.24)**
Request service as group (dummy)	0.65344 (0.77020)	544.89 (2742.90)
Previous exchange relation (dummy)	0.16910 (1.06958)	578.07 (3329.91)
Internet access (dummy)	−0.35839 (0.63903)	−2643.54 (2231.38)
Constant	9.61153 (2.46221) ***	35406.40 (5989.93) ***
Number of observations	*220*	*220*
R^2	*0.09*	*0.14*

Direct benefits for farmers using tractor services are thus not apparent. However, if Hello Tractor contributes to creating a larger supply of tractor services, this may indirectly benefit smallholder farmers. For example, 30% of the interviewed tractor associations/contractors reported that the use of the GPS device helped them generate tractor use data, which helped them access loans from banks. Moreover, while 60% of the farmers using conventional service providers had a previous relationship with them, 0% of the Hello Tractor users had. This may be either due to the newness of Hello Tractor – there was no time yet to establish relations – but it may also indicate the use of existing relations (a tool to reduce transaction costs) becomes less important when using Hello Tractor. It is important to point out that the average land size served by both Hello Tractor and the conventional service providers in the sample was well above the level of two hectares that is often used as a threshold to define smallholder farming (see Table 4).

One needs to take into account that the benefits for service providers may differ depending on the type of provider. For individual tractor owners and small associations who own few tractors and operate within their community, the advantages of participating in Hello Tractor's model, where the booking agents receive a 10% commission, may be limited. This is because they do not travel far and often have well-established relations with their customers, which are both ways to minimize transaction costs. According to some stakeholders, some such tractor owners and small associations who own a few tractors also already have their networks of booking agents as part of their tractor owner organizations. However, as mentioned above, the Nigerian mechanization market is also characterized by the existence of large contractors and associations, which own large fleets of tractors (in some cases several hundred) and migrate across agro-ecological zones. Such large contractors and associations are not able to use the same strategies pursued by individual tractor owners to reduce transaction costs, e.g., working within the community and establishing longstanding customer relations. Thus, for large contractors who use their tractors in different regions, Hello Tractor's technology may help to manage their tractor fleets, supervise operators and schedule demand upfront with the help of booking agents – without which it may be difficult for them to coordinate and operate at a profitable scale.

4.1.2. EM3 Agri-Services Pvt. Ltd., India

The empirical research revealed that EM3 franchisees are typically already well-established service providers: 80% of the interviewed franchisees were working as private contractors before working with EM3. Others are agro-business dealers and medium- and large-scale farmers. The on-the-ground research also showed that digital solutions are less important to the EM3 business model than portrayed. Farmers request services most often by contacting the franchisees directly – simply by walking in or calling – as most franchisees have been service providers before and already have trusted working relationships: 36% of the EM3 customers had a previous relationship with the EM3 franchisee.

In addition to contacting the franchisee directly, farmers can also call an EM3 call center that then forwards the request to the closest franchisee using a digital platform. If local franchisees do not have the requested equipment, the call center contacts other EM3 franchisees or contractors from other areas, an approach that is common for more expensive equipment such as rice transplanters, laser land levelers, and harvesters (i.e., equipment that not all franchisees own). While service providers and customers often have longstanding working relations, there are also first-time customers. In such a case, EM3 field staff visits the farms to validate location, topography, accessibility, and field sizes using GPS devices – a process that can, reportedly, take much time.

At the time of the study, farmers couldn't request services using a smartphone application, as the app that is supposed to match farmers with service providers was still being developed. Whether there will be demand for such an application remains unclear. Among the surveyed households, 56% had access to a smartphone, with a large variation depending on the farm size (see Table 7). Phones have thus far been mostly used for calling, taking pictures, and social media. Only 6% of the interviewed farmers reported having experience with applications for farming services.

While there was no smartphone app for farmers yet, service providers could use a digital platform for managing tractors, service requests, and accounting (see also Fig 2). Using the digital platform, they see requests that come in through the EM3 call center. They can also enter requests that come from farmers who personally visit the franchisee or from the franchisee directly. The franchisee will then enter the customer's name, type of service requested, date, and farm size. The franchisees use the digital platform despite the abovementioned 5% fee, which has to be paid to EM3 for every transaction. Due to the subsidy offered by the state government, the franchisees need to prove that they have fulfilled 650 annual hours of service provision to qualify for the subsidy. At the time of the study, this could only be done by entering information on service provision on the platform provided by EM3. In the meantime, this data can also be verified with tracking devices on the tractors. If more than 50% of the subsidized tractors fail to meet the minimum requirement of hours, EM3 deducts a percentage as a security deposit, which is equivalent to 1–2 percent of the total investment in the machinery.

Table 7
Smartphone ownership rate among tractor users (n = 101).

Land size (ha)	Smartphone ownership rate (%)
< 1	23
1 – 2	27
2 – 4	60
4 – 10	79
>10	83
Overall	56

After the service is completed, farmers pay in cash, but they could also transfer the money via their banks to the franchisee, which can be done on the spot or within 15 days. All of the EM3 users interviewed for this study paid for the service in cash. Farmers can give feedback about the services provided to the franchisee directly or by contacting the EM3 call center. In the first case, franchisees may not forward complaints to EM3. In the absence of an application that is available to farmers, no application can be used for feedback purposes.

Similar to the case of Hello Tractor, benefits for smallholder farmers seem to be mixed. For 36% of the customers who had trusted relationships with the service providers before they became EM3 franchisees, little has changed (other than having access to more expensive types of machinery). They continue to directly engage with the service provider without any reliance on EM3 services. Moreover, EM3 customers pay similar service prices as customers who use other contractual arrangements. While the transaction costs for accessing tractors may be lowered through call centers, the verification of such requests takes a long time for new customers. On the upside, less upfront trust seems to be needed to access EM3 services compared to other service providers: while 65% of all farmers highlighted the importance of having a previous relationship with the service provider when choosing a contractual arrangement (other categories were price and quality, among others), only 15% of all EM3 users reported that this was a key criterion. However, this may be the case because EM3 users own more land and therefore have easier access to hire markets. Moreover, some types of machinery are more easily available to EM3 customers because each EM3 center has access to the machinery pool of the entire EM3 network. In some cases, the providers offer services with better machinery and reportedly lower prices because they have access to subsidized machinery as the following quote of a franchisee shows:

> *"Thanks to the subsidy i can offer a lower price than my competitors."*

Finally, while EM3 advertises that it makes tractors more accessible to smallholder farmers, across the tractor customers interviewed, EM3 was most popular with large farmers (see Table 8).

Similar to the case of Hello Tractor, the benefits of joining the model are mixed for the tractor owners, partly because many were well-established service providers already. Generally, it is important to keep in mind that the business model may hinge on continuous government support: 33% of the interviewed franchisees declared that they decided to work with EM3 only to access the subsidy, and 53% had doubts about whether the EM3 business model would be sustainable if it was not a prerequisite to accessing the machinery subsidy. However, it is important to keep in mind that these views reflect the state of mind at the beginning of EM3's presence in Rajasthan. In the meantime, EM3 has started to provide additional services to its franchisees such as selling inputs and procuring farm produce via them, which may have changed their views.

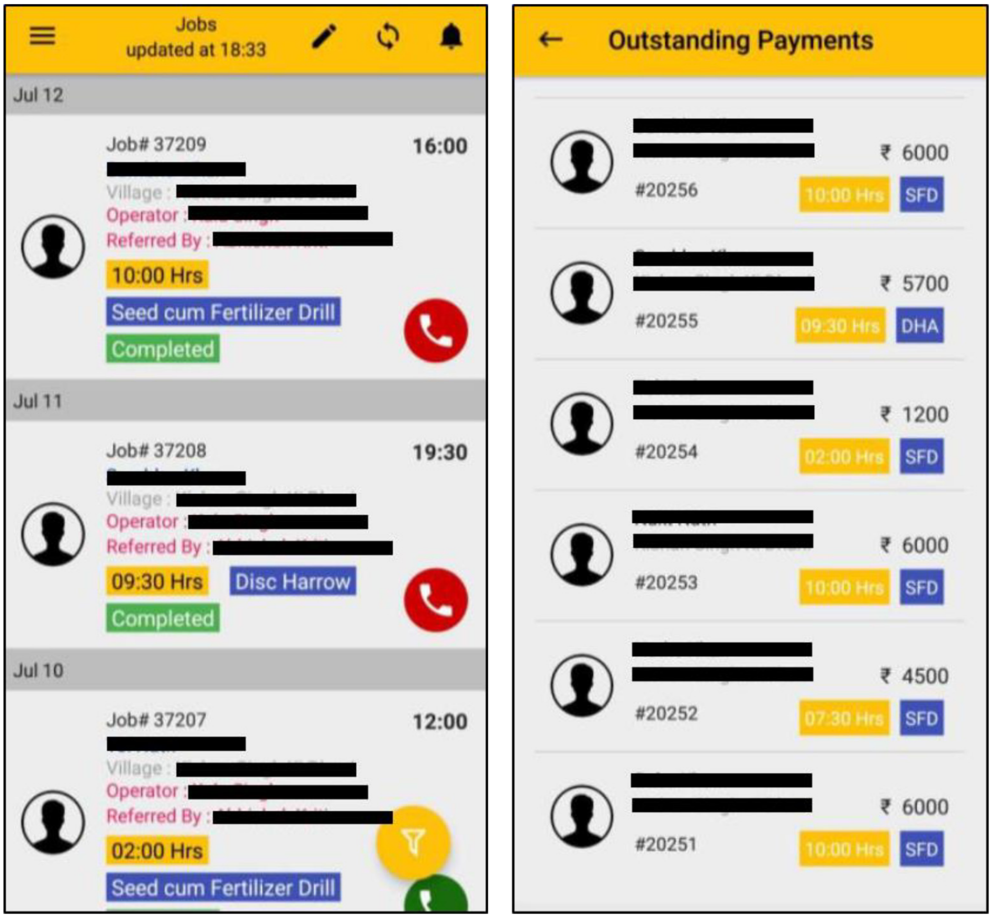

Fig. 2. EM3 digital platform for managing tractors, service requests, and accounting. On the interface to the left, franchisees can see customer requests, both outstanding and completed. On the interface to the right, they can see outstanding payments.

Table 8
Source of mechanization among tractor users (n = 101).

Land size (ha)	Own (%)	Contractors (%)	Farmer groups (%)	EM3 (%)	Others (%)
< 1	26	50	8	5	8
1 – 2	37	28	29	1	3
2 – 4	43	40	2	9	2
4 – 10	74	17	1	3	1
>10	75	8	0	17	0

4.2. Effects on transaction costs

This section assesses how the digital models promoted by Hello Tractor and EM3 address the attributes of transaction costs (see Section 2). Table 9 provides an overview. Table 9 suggests that both Hello Tractor and EM3 affect the attributes of the transactions in ways that reduce transaction costs. Only the complexity and hold-up problem attributes are not affected, as the tools do not include sensors or other equipment that would facilitate the farm operations. Table 9 also shows that Hello Tractor and EM3 mainly affect the transaction costs arising for tractor service providers and to a lesser extent the transaction costs of tractor users (smallholder farmers). They are therefore mainly benefiting indirectly (e.g. as such tools can help to reduce supply-side constraints to mechanization).

In the following sections, the effects of the two digital models on the different attributes are discussed in more detail. It is important to keep in mind that this paper examines the transaction cost effects of the *Uberization of mechanization* as currently implemented by Hello Tractor and EM3 (focusing on tractor supervision and customer matching, see Section 4.1.1 and Section 4.1.2) and that the transaction cost effects of the ideal "Uber" model (which also includes quality assurance through ratings and algorithms to optimize matching, see section 1) may differ.

4.2.1. Uncertainty

Hello Tractor and EM3 reduce the *uncertainty* regarding the fulfillment of the transaction for service providers. Hello Tractor uses booking agents to check whether fields are serviceable (accessible by roads and without tree stumps and stones) and organize customers upfront (see 4.1.1.). The use of booking agents deviates from the approach of the original *Uber* but helps to reduce uncertainty for service providers. This is particularly useful for large-scale migratory service providers who face high uncertainty as they operate across large areas, often crossing agro-ecological zones, and have to work with unknown customers. For such service providers, having booking agents assessing fields and scheduling demand with easy-to-access farms greatly reduces uncertainty. Moreover, as farmers have to pay a commitment fee upfront, the financial risks of a transaction failure are reduced (see Sec-

Table 9
Effects of Uberization of mechanization on attributes of transactions. Green cells mark aspects that reduce transaction costs; yellow cells mark aspects that are not affecting transaction costs.

Attributes	Hello Tractor		EM3	
	Providers	*Customers*	*Providers*	*Customers*
Uncertainty	*Reduced* through field checks by booking agents, up-front payments *Reduced* for migratory service provider through up-front customer pooling	Not affected	*Reduced* through field checks for first-time customers	*Reduced* by sharing of machinery across franchisees, which makes machinery more available
Asset specificity	Not affected	Not affected	*Reduced* by implement sharing across custom hire centers	Not affected
Frequency	Not affected	Not affected	*Increased* through the introduction of inputs and procurement through franchisees, which may increase contact frequency	*Increased* as sharing of machinery across franchisees widens the range of machinery available to customers. *Increased* as the introduction of inputs and procurement through franchisees may increase contact frequency
Complexity	Not affected	Not affected	Not affected	Not affected
Measurability	*Increased* by using GPS devices for land measurements	*Increased* by having access to GPS data from land measurements by providers	*Increased* by using GPS devices for land measurements	*Increased* by having access to GPS data from land measurements by providers
Hold-up problems	Not affected	Not affected	Not affected	Not affected
Spatial dispersion	*Reduced* by demand pooling with booking agents (similar to traditional markets), GPS matching	Not affected	*Reduced* by demand pooling with booking agents (similar to traditional markets)	Not affected
Principle-agent problems	*Reduced* by GPS-based monitoring device	Not affected	*Reduced* by GPS-based monitoring device	Not affected

tion 4.1.1). Small-scale, locally-operating service providers may rely more on other means to reduce uncertainty such as focusing on customers within the community and having longstanding customer relations (see Section 4.1.1). Similar to Hello Tractor, EM3 reduces uncertainty for service providers as EM3 field staff validates the location, topography, accessibility, and field sizes of first-time customers. However, in the case of EM3, no upfront commitment fee has to be paid.

While the demand pooling by the booking agents can help customers who may otherwise have too little land to access mechanization services, the uncertainty for customers increased because the transaction requests must go through different actors – first through Hello Tractor, who then pairs them with a nearby tractor owner; and then, the tractor owner also has to decide whether or not to carry out the transaction. Moreover, the chances of the transaction being carried for the customer depends on the successful aggregation of requests from other farmers by the booking agent (see Section 4.1.1). Also, compared to requesting services from well-known service providers within their community, farmers using Hello Tractor have limited control and knowledge about who will provide the service (and the reliability and quality of its services) (see Section 4.1.1 and Section 4.1.2). This is different in the case of EM3 when farmers approach the custom-hires centers directly (see Section 4.1.2). Neither Hello Tractor nor EM3 explicitly addresses some key aspects of uncertainty for farmers seeking mechanization services such as punctuality and quality of the services. However, in the case of EM3, relying upon a large network for franchisees reduces the risk related to machinery being unavailable for farmers. (see Section 4.1.2).

4.2.2. Measurability

Hello Tractor and EM3 enhance measurability through the GPS monitoring device. Using GPS devices allows to accurately measure the field sizes served by the tractor operators. This helps to reduce a longstanding source of conflicts between tractor owners and operators (who may "underestimate" field sizes to line their own pockets) and customers and tractor owners (who may "overestimate" field sizes to obtain higher service charges). However, the digital approaches offer no clear solution to objectively measure the quality of the work.

4.2.3. Spatial dispersion

As noted above, the distances between transactions (i.e. customers) can be high given the spatial dispersion of farming. Through demand pooling by the booking agents, Hello Tractor and EM3 help to address the spatial dispersion of farming for service providers, reducing travel time and costs. Moreover, in the case of Hello Tractor, these clusters of requests are matched with the nearest tractor owner, further reducing travel time and costs. However, it is important to note that such booking agents are also used as part of traditional, non-digital tractor service markets and that the digital tools do not help to optimize tractor use and service provision (e.g. travel routes or the sequencing of requests) (see Section 4.1.1).

4.2.4. Principle-agent-problems

As noted above, the relation between tractor owners and the operators of the tractors is often riddled with principle-agent problems (see Section 2). For example, operators may try to steal diesel and line their own pockets and lack the motivation to perform maintenance activities. By using GPS-enabled monitoring, Hello Tractor and EM3 reduce these principle-agent problems, thus affecting this attribute of the transaction for service providers. For example, Hello Tractor's monitoring device records GPS location data, fuel efficiency, and operator activity, which makes it more difficult – but not impossible – for tractor operators to take advantage of being difficult to monitor (see Section 4.1.1). While such principle-agent problems affect all types of service providers, they are particularly high for large-scale, migratory service providers whose tractor operators work across large territories outside of the direct supervision of the tractor owners.

4.2.5. Other attributes

Other attributes that are of relevance for transaction costs are frequency, asset specificity, complexity, and hold-up problem. EM3 hopes to affect the attribute of frequency through the marketing of inputs and procurement of farm produce through the franchisees, a strategy that was recently adopted. This strategy may increase the frequency of contacts and help to increase customer trust. Also, by being able to request machinery from a larger machinery pool of other centers, the attribute of frequency may increase in the case of EM3 (see Section 4.1.2). The EM3 network also allows for the sharing of implements across franchisees, which reduces the asset specificity for service providers (see Section 4.1.2). Neither Hello Tractor nor EM3 affect the attribute of complexity, nor do they reduce hold-up problems related to mechanization service provision.

5. Discussion

This paper aimed to explore the *Uberization of mechanization* narrative and to disentangle what, so far, works, where, when, and for whom. The paper has assessed whether the digital approaches referred to as *Uberization* have the potential to reduce the transaction costs related to tractor service markets, thereby leading to higher utilization rates of tractors and enhancing smallholder farmers' access to mechanization. The results make clear that the image of smallholder farmers themselves using Uber-type apps to access tractor services is not accurate – at least not yet. Newspaper headlines indicating "all it takes is a few taps on your phone"[21] are thus misleading. Instead of farmers, the tractor owners are the ones using ICT applications for monitoring and managing their tractors – to a higher degree in Nigeria and a lower degree in India. Importantly, smallholder farmers may benefit indirectly because Uberization helps tractor owners achieve higher utilization rates, thereby relaxing supply-side constraints to mechanization, which are prevalent in Nigeria (Diao, Takeshima, & Zhang, 2020). The results have shown that different challenges affect the *Uber for tractor* approach on the ground, some of which are endogenous, thus addressable by the models, while others are exogenous. As noted in Section 2, two questions can be asked to classify endogenous factors (1 and 2) and one question to characterize exogenous factors (3).

1) Is the innovation utility increasing for potential users, i.e. mechanization service providers, and farmers, if all prerequisite conditions (3) are fulfilled?

The tools enhance utility for tractor owners who possess several tractors and migrate across agro-ecological zones to unchartered territories. Uber-type solutions help them to monitor tractors and achieve higher utilization rates by reducing the transaction costs related to organizing new customers. The Uber-type ICT application studied here may even be improved by using algorithms for the optimization of service provision (e.g., optimizing for travel time), thus moving beyond the mere aggregation of customer demand. Importantly, the ICT-enabled emergence of large contractors, owning dozens of tractors in the Nigerian case, may have implications for the market structure in service markets (e.g., it may lead to market concentration). Policymakers should monitor such markets to ensure that there is sufficient competition.

In contrast, the utility effects seem limited for tractor owners who possess few tractors and offer services within their communities to well-known customers. Tractor owners with one or a few tractors can reduce transaction costs and risks by limiting the radius of customers and focusing on trusted customers. When owning a few tractors, this may suffice to reach high utilization rates while avoiding the commission fees attached to digital solutions (10% for Hello Tractor; 5% for EM3). Farmers and contractors with few tractors in industrialized countries often continue to rely on such techniques as well.[22] In such a scenario, the traditional way of organizing services offers lower transaction costs than digital tools, supporting the argument of Shelanski and Klein (1995, p.338) that "exchange relationships observed in practice can be explained in terms of transaction cost economizing".

The results also showed mixed utility effects for farmers, so far. Most farmers seemed indifferent on whether to access services through Hello Tractor, EM3, or traditional service providers. However, one reason for this is that neither Hello Tractor nor EM3 offered a digital interface for the farmers at the time of the study.

2) Which prerequisite conditions for the adoption can be addressed by innovation itself or by the potential users themselves, i.e. The mechanization service providers and farmers?

Section 4.1 showed that several factors are constraining the adoption of *Uber for tractor* services. Many of these constraints are already addressed by the innovation itself. For example, both business models use analog intermediaries (such as booking agents in the case of Hello Tractor and call center agents in the case of EM3) to address the lack of digital literacy. A lack of digital literacy could also be addressed (partially) with the help of easy app design using visual elements.[23] Uber-type ride-hailing, for example, does not hinge on the literacy of its users, however, Uber-type ride-hailing requires only limited data to be entered by customers (i.e., only the destination), whereas tractor hiring requires the recording of additional data (i.e., plot sizes, type of equipment, land conditions), some of which cannot easily be aided by visual tools. Another addressable prerequisite condition is the limited smartphone ownership rate. Both business models address this problem with the help of analog intermediaries.

The results showed that patchy connectivity constraints the use of GPS tracking devices in some areas. A (partial) lack of connectivity can be addressed, for example by enabling offline tractor tracking in "blind spots" and using analog intermediaries. However, a full lack of connectivity turns this challenge from a constraint into a lacking prerequisite (3). The use of ICT applications can also depend on risk attitudes and the level of trust held by potential customers (Baumüller, 2018), which can hamper the use of Uber-type tools for tractors. As noted by Foote (2008) and supported by our study, few smallholder farmers in Nigeria trust mobile services sufficiently to make business transactions, such as hiring tractors, via an application if this includes an up-front payment. Such a lack of trust to use digital tools for market exchanges such as tractor hire can be addressed partly within the innovation-development process. For example, ICT applications could also allow for the anonymous rating of service providers by tractor users – and by showing the results, create an accountability mechanism based on social capital (Benkler, 2004). However, a more general lack of trust cannot be addressed within the innovation-development process.

3) Which prerequisite conditions cannot be addressed by the innovation itself or the potential users, i.e. mechanization service providers and farmers?

[21] nytimes.com/2016/10/18/world/what-in-the-world/trringo-app-india.html

[22] For an overview of different contractors in Germany, see https://lu-web.de/redaktion/reportage-des-monats/

[23] It can also be addressed by the users, for example, when they take training courses on the use of digital services.

One important exogenous factor is the demand for mechanization. The case studies focused on areas where there is, in principle, strong demand for mechanization. Another example of such frame conditions, which neither the innovation nor the users can address in the short term, maybe network coverage. As shown above, some blind spots of connectivity are addressable by the innovation, however, a certain level of connectivity has to be guaranteed. The last example of prerequisite conditions is the general trust to use digital tools for business, which can only partly be addressed by the innovation. With a better legal framework and law enforcement, this could change. As noted by Birner, Daum, and Pray (2021), Deichmann et al. (2016), and Toyama (2015), technologies cannot address all barriers faced by farmers, and digital solutions need to be backed up by complementary infrastructure investments, including electricity and literacy.

The two case studies show that the *Uber for tractor* approaches are not exact copies of the well-known Uber for ride-hailing. Potentially, the Uber narrative has emerged driven by the desire to demonstrate that ICT solutions offer exciting new options for smallholder farmers, a strategy that is tailored to raising funds from development and philanthropic organizations. *Uber for tractors* captured the imagination of a wide audience, leading to a cycle of positive reporting and the appearance of success (Hunsberger, 2014). In their quest to make their digital business work amidst the challenges of rural and agricultural markets, the two providers studied here turned to focus on technologies for tractor owners that help them to monitor and manage their tractors. Thus, while not providing a direct interface for smallholder farmers yet, both companies are nonetheless digital pioneers.

Our case studies suggest that it is important to disentangle what the powerful narrative of *Uber for tractor* stands for from what it does not stand for. Otherwise, development organizations, governments, and the general public may consider *Uber for tractors* to be the long-awaited "silver bullet" that can resolve all obstacles facing smallholder farmers in accessing mechanization services. It cannot. Agriculture will never depend on software alone; it will remain dependent on the "hardware" – tractors and implements that are suited to local agronomic conditions, financial systems that make it possible to acquire them, and the human skills required to use them well in sustainable production systems (Adu-Baffour et al., 2019; Daum & Birner, 2017; Daum, Huffman, & Birner, 2018).

One also needs to acknowledge that the contracting models studied in this paper are not the only institutional arrangement that enables smallholders to access machinery services. Digital tools can also support cooperative arrangements among farmers, which are widespread in agriculture, for example, associations of farmers that each own machinery that they rent out to each other.[24] Such solutions may also be supported by digital management platforms as well as data sharing arrangements (Griepentrog, Weis, Weber, & Schneider, 2019). Other alternative solutions are already digital. In Kenya, for example, Village Twitter, a bulk SMS-based version of Twitter requiring no smartphones, invented by a local chief and Safaricom, has been gaining momentum. Village Twitter allows tractor owners to send SMS messages advertising their service to up to 15,000 recipients for as little as one Kenyan shilling (Mayienga, 2019). These examples, as well as the two case studies presented here, show that digital agriculture tools have a unique potential to overcome the challenges of mechanization in smallholder agriculture.

The case studies of Uber for tractor presented here underline the role of local entrepreneurship in unlocking this potential. *Uber for tractors* was not invented by the large-scale digital companies that dominate the cyber world nor was it invented by the large-scale tractor manufacturers that dominate the world of agricultural machinery – it was invented by individual entrepreneurs who had the vision of bringing innovative ICT solutions to a business sector where the challenges of making such solutions work are greater than anywhere else: the poverty-stricken smallholder agriculture sector in developing countries – and this is perhaps the most promising dimension of *Uber for tractors*.

[24] In Germany, such associations (known as "*Maschinenringe*") are widespread (Gripentrog et al., 2019).

6. Conclusion

The findings highlight the theoretical appeal of the *Uberization of mechanization* approach to reduce transaction costs. In practice, the case studies on Hello Tractor and EM3 suggest that such models face the thorny challenges of rural markets, which hinders the ideal application of the *Uber of mechanization* approach. Given the stark difference in conditions faced by rural tractor hire markets compared to urban ride-hailing markets, this is not a surprise it has to be expected. A direct comparison with Uber ("all it takes is a few taps on your phone") therefore does not yet reflect the way such approaches work on the ground – at least not yet. In both case studies, farmers relied on "analog" solutions to access tractor hire services, such as booking agents and phone calls, approaches widely used by "non-uberized" tractor owners as well. As a result, the findings suggest limited effects on the transaction costs for farmers. Transaction cost effects are also limited for service providers owning few tractors. However, such tools seem to reduce the supervision and marketing costs of large-scale migratory tractor service providers who operate across large distances and face unchartered territories and unknown customers. Overall, the advantages of ICT-based models – as currently implemented - over more traditional ways of organizing service markets are more mixed than commonly assumed. This is both due to endogenous and exogenous factors. To address the latter, governments have to focus on the creation of enabling conditions, such as digital literacy and network coverage. This will enable entrepreneurs to harness the full potential of digital tools, which can help to reduce market failures for smallholder farmers in the developing world.

Credit authorship contribution statement

Thomas Daum: Conceptualization, Methodology, Formal analysis, Writing - original draft, Supervision, Project administration. **Roberto Villalba:** Methodology, Formal analysis, Writing - review & editing. **Oluwakayode Anidi:** Methodology, Formal analysis, Writing - review & editing. **Sharon Masakhwe Mayienga:** Methodology, Formal analysis, Writing - review & editing. **Saurabh Gupta:** Methodology, Writing - review & editing, Supervision. **Regina Birner:** Conceptualization, Methodology, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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