Returns to mechanization through rental equipment markets *

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Abstract

This paper studies the role of the availability of formal rental equipment markets for agricultural productivity. Mechanization is one of the main inputs in modern agriculture, and the lack of it is arguably an important contributor to the low productivity observed in poor countries, and in particular, among smallholder farmers. We partner up with one of the largest equipment rental providers in India and study barriers to mechanization, and returns to it. Using administrative data from our implementation partner, we document usage patterns of equipment throughout the crop season as well as delays in service completion by plot size. We find heterogeneity in patterns of usage across plot sizes. We combine these findings with survey data on detailed farmer characteristics, including wealth and household characteristics, as well as on price and credit sensitivity to identify the population of farmers for which barriers to mechanization are more pervasive. We then build a structural model of equipment rental markets where richer farmers own and rent-out equipment, while poorer ones rent-in equipment or specialize in labor intensive farming activities. Informed by key predictions of the model we design a randomized control trial (RCT) to inform us on the magnitude of the costs associated to delays in service provision, as well as on the magnitude of barriers to adoption associated to (i) technical constraints (small lot sizes), (ii) farmer's financial constraints and (iii) information frictions. These estimates are then feed into the structural model to assess the general equilibrium effect of barriers to mechanization on agricultural productivity.

JEL codes: O13, O47.
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1 Introduction

What are the returns mechanization through (formal) rental markets and how does it vary by farm size? The objective of our analysis is to measure the impact of the availability of formal rental markets for agricultural equipment on households standards of living, farm productivity and technology adoption. We work under the hypothesis that smallholder farmers would benefit the most from access to these rental markets because they may overcome economies of scale. However, returns vary by farm size because of (a) technical constraints, where mechanization is less effective on small farms; or because smaller farmers are (b) more constrained in other ways, such as access to inputs, wealth, etc.

Agriculture remains central for the lives of a large portion of the world population in developing countries, employing nearly 800 million people in South Asia alone (World Bank, 2015). However, stagnating agricultural productivity has prevented transformational development to livelihoods of smallholder farmers. A key possible reason for this stagnation is the lack of farm mechanization. Anecdotal evidence on the path of mechanization for now rich economies suggests that equipment rental markets were a stepping stone to that process (Binswanger, 1986). Hence, this lack of mechanization is likely correlated with the absence of robust rental markets for equipment. However, there is no systematic evidence on how the presence of rental markets could benefit smallholder farmers and agricultural wage workers, or affect informal rental service providers in rural areas. Ours, will be the first paper to study the impact of the availability of formal equipment rental markets in an environment in which the cost of these goods largely surpass households' purchase capabilities.

We have partnered up with one of the biggest providers of rentals of agricultural equipment in India. Using administrative data from our implementation partner, we document usage patterns of equipment throughout the crop season as well as delays in service completion by plot size. We find heterogeneity in patterns of usage across plot sizes. We combine these findings with survey data on detailed farmer characteristics, including wealth and household characteristics, as well as on price and credit sensitivity to identify the population of farmers for which barriers to mechanization are more pervasive.

We then build a structural model of equipment rental markets where richer farmers own and rent-out equipment, while poorer ones rent-in equipment or specialize in labor intensive

farming activities. We model explicitly costs associated to moral hazard problems in renting out equipment, as well as costs associated to delays in service provision for farmers demanding the service. Informed by key predictions of the model, we construct a randomized control trial to discipline the magnitudes of barriers to adoption and potential returns.

We will conduct a two-stage clustered randomization, where the first stage of randomization is at the village and the second at the farmer-level. The latter will be implemented through various treatment arms including random subsidies to the cost of rentals, random credit line access and information access. This two-layer randomization is akin to the work of Crepon et.al. (2013). The experiment will take place in Karnataka, one of India's largest states, where agriculture is an important part of the economy. Small running scales as well as various market frictions (including the inability to borrow to finance equipment purchases) have been a major deterrent to farm mechanization. Little is known about the effect of rental markets on productivity. The main questions that we would like to address are:

1. To what extent is the availability of a formal rental market for equipment easing constraints to mechanization in the farming sector? What barriers are the most pervasive in explain lack of or low mechanization?

2. When rental services are contracted, how do technological choices shift either on the intensive of extensive margin (i.e. machinery, fertilizer, and crop selection)?

3. How does the presence of formal rental markets affect informal rental service providers?

Note that even when data on rental markets could be gathered, the effect of the availability of these markets for farm mechanization patterns can not be correctly identified due to endogeneity issues. The platform provided by our implementation partner and the experimental design we propose are a unique opportunity to properly identify these effects.

To fully assess the effect of the rental market we will feed the estimates from the RCT in terms of delay costs, the elasticity of mechanization to the cost of the service and credit constraints of the farmers into our general equilibrium model. We plan to also discipline our model predictions using the patterns of equipment by land size usage observed in our administrative data, and those generated from own surveys.

Literature Review There is a large literature on the relationship between scale and

productivity, with larger farms usually more likely to be mechanized (Foster and Rosenzweig,2017). Relative factor prices are also important in determining farm mechanization (Manuelli and Seshadri, 2014). Because capital deepening is a key driver of productivity differences across countries (Chen, 2017), and differences in capital quality alone explain about a third of the productivity gap between India and the most advanced economies (Caunedo and Keller, 2017), we believe the study of equipment rental markets is key to unlocking the development puzzle. Because the returns to accessing mechanization opportunities through rental markets as well as the barriers to adoption of these techniques are likely to vary by plot size, our analysis will have direct implications for the literature that studies distortions in land markets as driver of low agricultural productivity (Chen et.al. 2017) and in general, of input misallocation (Restuccia & Rogerson, 2017)

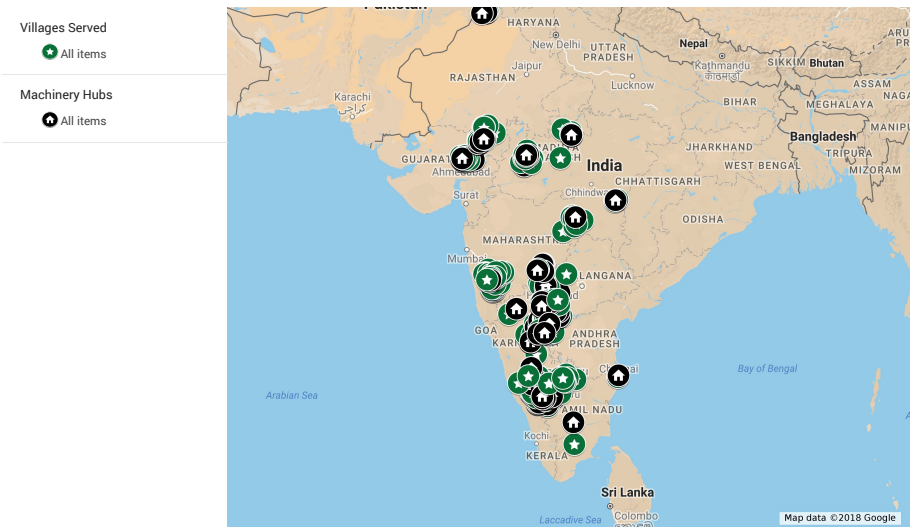
Our project will be the first to experimentally estimate the effects of rental markets on agricultural outcomes and scale. Our proposal is at the core of understanding market frictions in developing economies that may prevent the proper allocation and usage of capital intensive technologies. Rental markets for equipment have the potential to unlock those gains. Hence, by understanding market frictions that prevent private firms from providing these rental services, as well as characterizing business models that are most successful in guaranteeing service uptake we expect to benefit both market participants (firms) and policy-makers.

2 Preliminaries

Our implementation partner allows farmers to rent equipment (and a professional driver) with a phone call. Service is assured (whenever possible) to arrive to each location within two-days of posting a request - this is in stark contrast to the long waiting times that are common in anecdotal evidence during sowing and harvest seasons. Our implementation partner keeps track of farmers' request orders (including the type of service required, area to be serviced), as well as on order serviced, such as time for completion, additional hours of work required, problems with equipment, etc. While rental markets exist to some extent in rural India, the platform that our partner provides implies an enforceable contract and a quality controlled service, features that are typically unavailable in informal two-party rental agreements.

Our partner launched operations in 2016 and currently serves 1020 villages in the states of Gujarat, Karnataka, Rajashtan, Madhya Pradesh and Maharashtra (see Figure 1).

Figure 1: TRRINGO's Geographical distribution



1021 Villages Served (star, green), 70 Hubs (house, black)

Next, we present summary statistics of patterns of usage for selected hubs. Two facts stand out: a) there is substantial variation in hours of average hours of usage across hubs, even conditioning on the season; (b) revenue per hour of usage is stable across hubs.

Data from our pilot surveys conducted in October 2018 suggest heterogeneous patterns of usage across locations. On average, farmers spend about INR 23000 in rental services yearly. Villages that are served by our implementation partner spend about 25% more than villages that are not served. In addition, served villages report stronger ownership of small equipment such as sprayers and tube wells, consistently with richer farmers operating in those locations.

Finally, the two most prevalent barriers to the adoption of mechanized practices through rental markets are delays in service provision, and the inability to access credit.

Hub	Implement Name	Observations	Revenue (av.)	Hours (av.)	Peak Month
Hullahalli	Cultivator 9 Tyne	323	1311	2.6	April
	Cultivator Duckfoot	711	1313	2.4	June
	Rotavator 6 Feet	897	1740	2.3	May/June
Jayapura	Cultivator 9 Tyne	909	803	1.6	May
	Cultivator Duckfoot	1024	1015	1.8	June
	Rotavator 6 Feet	1086	1435	1.9	June/July
Kasaba(Kollegal)	Cultivator Duckfoot	230	1027	1.7	April/May
	Rotavator 6 Feet	238	1398	1.9	April/May
Talakadu	Tractor-only-744	156	1195	4.8	June
	Tractor-only-855	173	1242	4.9	June
Terakanambi	Cultivator 9 Tyne	110	2263	4.5	May
	Cultivator Duckfoot	314	2266	4	June/July
	Rotavator 6 Feet	244	2678	3.3	July/August
	Plough Disc	151	2387	4.6	August

Summary statistics administrative data, selected hubs.

3 A model of markets for equipment rental in the farming sector

3.1 Set up

Consider a continuum of farmers of measure 1 with productivity indexed by $z(i)$. Farmers are allocated a one of time and use a fraction χ to work on their farm, and supply labor to the market for the remaining fraction $(1-\chi)$. There is no disutility of labor. (In future iterations we will make the occupational choice endogenous, but for now we abstract from it).

Farmers produce an homogeneous good combining land, equipment, k and labor, n; with a decreasing returns technology so that profits are positive in equilibrium. For simplicity again let's shut down the market for land by assuming an exogenous allocation of plot size to each farmer $l(i)$ (this is easy to extend and will be meaningful once occupational choices

are endogenous). The technology for production is

$$z(i)(b_k k + b_n n)^{\alpha} l(i)^{\alpha_l}$$

Capital and labor are assumed perfectly substitutable. Hence, whether a farm uses labor or machines depends on the relative costs of capital and labor, and their productivity.

Equipment services can be rented, k^r, or provided by a farmer's own machine, k^o. Then, $k = k^o + k^r$. Suppose that there is a one-to-one mapping between a machine m and the services it can potentially provide. Hence, $k_o \leq m$. Assume that any services of the machine that are not used in the current period, can be rented out to the market at the market rental rate, k^{ro}. When a farmer rents out equipment it faces additional depreciation on the equipment than if used within her farm. This additional depreciation has to do with additional transportation of the machine, plus moral hazard issues in the use of the equipment (we will need to figure out what the additional costs are, because if the owner is operating the machine, it seems to me that the cost is mostly their opportunity cost of time, and nothing else). We just parameterize the differential cost of maintenance (in units of farm output) associated to that depreciation $\delta_r > 0$.

Because machines are indivisible, $m \in \{\underline{k}_1, \underline{k}_2, ..., \underline{k}_n\}$ a discrete set of services. Hence, farmers can own and rent in or out in a given period. In this version, I abstract from uncertainty in farms productivity, but once we introduce it, we will also have allocations where farmers own and *rent out* some the services that are slack from the machine they own. Without uncertainty, the reason for which farmers may rent-out, is that ownership of equipment is relatively cheap and their productivity (which is defined over a continuum) implies an optimal capital-service demand somewhere in between the set of machine services described above. We should characterize the conditions for ownership of slack machinery, this is not obvious because in principle, they can always buy one machine less and just rent in the remaining services. Also, if costs of delays when renting in are relatively large, ownership will be preferred (I describe those costs below).

Farmers consume, c; accumulate assets (other than equipment), a and invest in equipment, x, out of the profits derived from farming. The amount of assets a household hold can be used as collateral to purchase equipment (we can include here the value of the land they

own too). Hence,

$$x \leq \frac{\lambda^o}{p_k} a \qquad (\mu^o)$$

where p_k is the price of capital, and λ^o indexes credit available for equipment purchases. If $\lambda^o = 1$, there is no external credit available. The stock of capital owned evolves according to

$$m^o_{t+1} = m^o_t + x_t$$

Here I assume away depreciation and maintenance. Or put differently, I assume there is depreciation and costless maintenance if the machine is used in the farmer's own plot. If the machine is rented out, the farmer pays a cost of additional maintenance of unit of output and indeed keeps the full returns to the machine.

Equipment rentals should be paid upfront, which entails a standard working capital constraint on farmers demanding these services. We assume credit conditions for rentals are indexed by λ^r so that

$$k^r \leq \frac{\lambda^r}{r} a \qquad (\mu^r)$$

where r is the rental cost in the economy. Finally, we assume that the farmer incurs output costs when renting equipment, potentially associated to delays in the delivery of the rental service. We parameterize this cost by $\theta(k^r)$ and assume it is a decreasing and convex function of the amount of services demanded. Intuitively, this cost function generates higher rental costs for low-productivity farmers, that demand lower equipment services.

The problem of a farmer is

$$\max_{k,n,k^r,k^{ro},x,m^o_{t+1}} p(z(i)(b_k k + b_n n)^{\alpha} l(i)^{\alpha_l} - x - \theta(k^r) - \Gamma(k^{ro})) - w(n - \chi) - rk^r + w\overline{n} + rk^{ro}$$

subject to

$$\overline{n} \leq (1 - \chi)$$

$$k \leq m^o + k^r - k^{ro} \qquad (\kappa)$$

$$m^o_{t+1} = m^o_t + x_t \qquad (\eta)$$

and the collateral constraints, $k^r \leq \frac{\lambda^r}{r} a$ and $x \leq \frac{\lambda^o}{p_k} a$.

The optimality conditions to this problem are

$$p\alpha b_k z(i)(b_k k)^{\alpha-1} l(i)^{\alpha_l} \leq \kappa \qquad (k)$$

$$p + \mu^o \geq \eta \qquad (x)$$

$$\eta_t \geq \beta(\eta_{t+1} + \kappa_{t+1}) \qquad (m^o_{t+1})$$

$$\mu^r + r + p\theta'(k^r) \geq \kappa \qquad (k^r)$$

$$\kappa + p\Gamma'(k^{ro}) \geq r \qquad (k^{ro})$$

3.2 Allocation characterization in partial equilibrium

The key allocation dimensions that we would like to characterize are a) the choice between labor input and capital; and b) the choice between renting or owning equipment; and c) the choice of an owner to rent-out services. All these will be functions of factor prices, w, r, credit market conditions, (λ^o, λ^r) and farmer's characteristics as summarized by the distribution of (z, a).

- *Capital demand in the rental market is increasing in the productivity of the farmer and the size of its lot.*

  To see this, we need to compute the optimality conditions of the farmer with respect to capital (assuming the farmer does not use workers)

  $$p\alpha b_k z(i)(b_k k^r)^{\alpha-1} l(i)^{\alpha_l} = r + \theta'(k^r) + \mu^r$$

  where $\mu = 0$ if the credit constraint on rentals is not binding, and it is positive otherwise. Totally differentiated the above condition we obtain

  $$\frac{\partial k^r}{\partial z(i)} = -\frac{\alpha b_k (b_k k^r)^{\alpha-1} l(i)^{\alpha_l}}{(\alpha-1) b_k^{\alpha} (k^r)^{\alpha-2} l(i)^{\alpha_l} - \theta''(k^r)} > 0$$

  Because the cost of delays is convex $\theta''(k^r) < 0$ and factor shares are $\alpha < 1$, the demand for capital services is increasing in the productivity of the farm. An analogous

argument implies that capital services increase in the size of the lot $l(i)$.

- *Farmers with low asset holdings relative to their productivity and lot size are less likely to mechanize*

  This is a direct consequence of the credit constraint more likely to bind when a is low. Consider a farmer that only rents-out capital services. From the optimality condition with respect to capital and labor

$$p\alpha b_k z(i)(b_k k^r)^{\alpha-1} l(i)^{\alpha_l} = r + p\theta'(k^r) + \mu^r$$

$$p\alpha b_n z(i)(b_n n)^{\alpha-1} l(i)^{\alpha_l} = w$$

  we obtain a threshold condition characterizing mechanization. That is if

$$\frac{w}{b_n} < \frac{r + p\theta'(k^r) + \mu^r}{b_k} \tag{1}$$

  the farm is not mechanized. In general, when the cost of labor is relatively low, farmers are less likely to mechanize. Mechanization is more likely to occur when the cost of delays is low (that is, farmers that have high demand for rental services), and when the credit constraint does not bind (asset rich farmers).

- *Our experiment could be designed to pick up the relative effects of $\theta(k^r)$ and μ on mechanization (see equation 1).*

- *A farmer that holds a demand for rental services, $k^r = \underline{k}_1$, would like to own a machine if the costs of delay are relatively large, or if credit for purchases of equipment are generous relative to rentals.*

  This is a consequence of the advantage of owning relative to renting in terms of delay costs as derived from the optimality condition of the farmer

$$\alpha b_k z(i)(b_k \underline{k}_1)^{\alpha-1} l(i)^{\alpha_l} = p + \mu^o < r + p\theta'(\underline{k}_1) + \mu^r$$

  Suppose that $\lambda^o > \lambda^r$, for example because of a government policy to incentivize purchases of new equipment. Assume that intuitively, $p_k \geq r$ (this would be true in

GE) and that $\frac{\lambda^o}{p_k} > \frac{\lambda^r}{r}$. Then $\mu^r > \mu^o$ for every level of asset holdings. Hence, the farmer want to own (conditional on having enough asset for it to be feasible) if the real rental costs, $\frac{r}{p}$, are relatively high.

- *Notice that by lowering the rental cost, r, we are also making the credit constraint more slack.*

- *A farmer that holds a demand for capital services, $\underline{k}_j < k < \underline{k}_{j+1}$, would like to own $\underline{k}_{j+1}$machines and rent-out $\underline{k}_{j+1} - k$ if the costs of delay are relatively large, or if credit for purchases of equipment are generous relative to rentals.*

  To show this compare these two options given the optimality conditions of the farms. That is, at the margin, the farmer is either renting in or renting out equipment,

$$p\alpha b_k z(i)(b_k k)^{\alpha-1} l(i)^{\alpha_l} = \mu^r + r + p\theta'(k^r)$$

$$p\alpha b_k z(i)(b_k k)^{\alpha-1} l(i)^{\alpha_l} = r - p\Gamma'(k^{ro})$$

  We know that the farmer won't rent in if $\mu^r + r + p\theta'(k^r) > \kappa$ and will rent-out if $r - p\Gamma'(k^{ro}) = \kappa$, or what is the same

$$r - p\Gamma'(k^{ro}) < \mu^r + r + p\theta'(k^r)$$

  We assume that the cost of delays is decreasing in capital demand, $\theta'(k^r) < 0$ and a convex function; and that the cost of additional maintenance is increasing in the services rented out, $\Gamma'(k^{ro}) > 0$. Then, there will be rent-outs if (a) the marginal cost of delay are high (the farmer's rent in demand is low), or (b) the credit conditions in the rental market are not favorable, μ^r high (could be that the farmers is asset poor).

$$-p\theta'(k^r) < \mu^r + p\Gamma'(k^{ro})$$

  To do comparative statics with respect to the cost of renting out is tricky because if the marginal cost of renting out is large, the farm is more likely not to rent-out at all. $\kappa + p\Gamma'(k^{ro}) > r$ (costs are larger than the market return).

These decisions are all characterized at the margin, assuming that the farmer has the equipment available to him to rent-out the equipment. The costs associated to owning the equipment are sunk for these marginal decisions.