Mechanizing Agriculture
Online Appendix

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1 Allocations

Preparation stage The optimality conditions for inputs across tasks are

$$p(m)a_n(m) = w + \frac{\omega}{\phi_i} w_{if}^P, \tag{1}$$

$$p(m)a_n(m) = w_{if}^P, \tag{2}$$

$$p(m)a_k(m) = r, \tag{3}$$

where $p(m)$ is the price of output for task m.

Optimality conditions for tasks

$$\alpha y^P = p(m)x(m)$$

The optimality conditions with respect to input intake are

$$\alpha(1 - M_i)\frac{y_i}{n_{if}^P + n_i^P} = w_{if}^P \qquad \text{if } n_{if}^P > 0, \tag{4}$$

$$\alpha(1 - M_i)\frac{y_i}{n_{if}^P + n_i^P} = w + \frac{\omega}{\phi_i} w_{if}^P \quad \text{if } n_i^P > 0, \tag{5}$$

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$$\alpha M_i \frac{y_i}{k_i} = r. \tag{6}$$

Harvesting stage

The optimality conditions with respect to input intake are

$$\alpha_f^H \frac{y_i}{n_{if}^H} = w_{if}^H, \tag{7}$$

$$\alpha^H \frac{y_i}{n_i^H} = w + \frac{\omega}{\phi_i} w_{if}^H. \tag{8}$$

2 Labor Decisions

To illustrate how the households' labor supply decision and their demand for hired labor change in response to mechanization we solve a simple version of the model. We parameterize the production technology as $y \equiv Z(n_f^P + n^P)^\gamma$. The impact of mechanization can be illustrated through a change in the labor share, γ, and a change in productivity Z, as in the benchmark model. To express output as a function of labor decisions at the preparation stage only, we exploit the optimality conditions for farming labor at the preparation and harvesting stages. These conditions imply that family and non-family labor at the harvesting stage are linear functions of the labor input at preparation, i.e. $n_f^H = \frac{\alpha_f^H}{\alpha(1-I)}\left(n_f^P + n^P\right)$ and $n^H = \frac{\alpha^H}{\alpha(1-I)}\left(n_f^P + n^P\right)$. Therefore, γ can be mapped to $\gamma = \alpha(1-I) + \alpha_f^H + \alpha^H$ and the level of productivity can be mapped to $Z \equiv A^P k^{\alpha I} l^{\alpha_l} \left(\frac{\alpha_f^H}{\alpha(1-I)}\right)^{\alpha_f^H} \left(\frac{\alpha^H}{\alpha(1-I)}\right)^{\alpha^H}$ proportional to land-endowments.

The optimal time allocation by the household satisfies,

$$\frac{\partial y}{\partial n_f^P} \leq \frac{c}{n_l},$$

$$\frac{\partial y}{\partial n^P} \leq w + \frac{c}{n_l}\omega,$$

$$w_o \leq \frac{c}{n_l},$$

plus the budget constraint and the time constraint. The optimal allocation has different features depending on the relative wages and the intensity of the moral hazard problem as we explain below.

Case I: no outside family labor $n_f > 0$**,** $n_o = 0$**,** $n > 0$**.** This allocation requires that the value of the outside option, w_o, be larger than the effective cost of hired labor, $\frac{w}{1-\omega}$. Note that this might be the case, even when agricultural wages are below the non-agriculture ones $w < w_o$, because of the contracting frictions, summarized by ω.

$$n_f = \left(\frac{\gamma Z}{\frac{w}{1-\omega}} \right)^{\frac{1}{1-\gamma}}$$

Whether hired labor is positive or not depends on the marginal product of labor, which scales of farming productivity, and the size of the family through the available working time, $\bar{n}$.

Case II: no hired labor $n_f > 0$**,** $n_o \geq 0$**,** $n = 0$**.** Importantly, when there is no hired labor engaged in production, the relative outside option for family labor is the wage in the non-agriculture sector. In an optimum with no hired labor, family labor on the farm satisfies,

$$n_f = \left(\frac{\gamma Z}{w_o} \right)^{\frac{1}{1-\gamma}}$$

If the wage in non-agriculture is relatively low, family labor only works in the farm.

Case III: no hired labor $n_f \geq 0$**,** $n_o > 0$**,** $n > 0$**.** When farming productivity, or the share of labor in farming is relatively high, the farmer hires outside workers. If in addition the farmer decides to work outside the farm, the equilibrium requires that the shadow value of hired labor be the same as the opportunity cost of family labor, which in this case is pin down by the outside option. In this case, there is continuum of combinations of family and hired labor that solve the equilibrium allocation, because the farmer is indifferent between hiring workers and their outside option. This case arises only when the outside option is relatively high, and therefore the farmer decides not to put its own labor on the farm (except through supervision time), $n_f = 0$.

If the wage in non-agriculture is relatively low, then the farmer chooses to work in the farm, as in Case I.

3 Additional Tables

Table 1: Mechanization Index Treatment Effects by Voucher

	(1) IHS(Mechanization Index)	(2) 1(Matched) 1(to Platform)
1050 Subsidy	-0.00194	0.262****
	(0.0857)	(0.0315)
1050 Subsidy, 1050 Cash	-0.0110	0.100****
	(0.0709)	(0.0274)
2100 Subsidy	0.114**	0.316****
	(0.0474)	(0.0218)
2100 Subsidy, 1050 Cash	0.0376	0.336****
	(0.0440)	(0.0249)
1750 Subsidy	0.169**	0.350****
	(0.0819)	(0.0478)
1750 Subsidy, 1750 Cash	0.153**	0.124***
	(0.0715)	(0.0427)
3500 Subsidy	0.0775	0.459****
	(0.0476)	(0.0361)
3500 Subsidy, 1750 Cash	0.130*	0.436****
	(0.0675)	(0.0422)
1(Large Farmer)	0.458****	0.0199
	(0.0337)	(0.0123)
Constant	-0.167****	0.108****
	(0.0171)	(0.00863)
Control Mean	-0.0500	0.100
Observations	4989	5399
1050 Subsidy=1750 Subsidy	0.136	0.124
1050 Subsidy, 1050 Cash=1750 Subsidy, 1750 Cash	0.0708	0.600
2100 Subsidy=3500 Subsidy	0.543	0.0000556
2100 Subsidy, 1050 Cash=3500 Subsidy, 1750 Cash	0.212	0.0215

Standard errors clustered at the village-level in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table 2: Balance Table

	(1)
Area Cultivated	0.0703
	(0.113)
1(Matched to Platform)	0.000240
	(0.0109)
IHS(Mechanization Index)	0.0126
	(0.0261)
Household Size	-0.0140
	(0.0556)
1(Credit Constrained)	0.00986
	(0.00761)
1(Household Head is Male)	-0.0116
	(0.00961)
1(SC/ST Household)	-0.00141
	(0.0163)
Log (Male Wage)	-0.00620
	(0.0288)
Log (Female Wage)	0.0195
	(0.0239)
Log(Nonagricultural Income)	-0.00642
	(0.132)
Log(Revenue per acre)	-0.0758
	(0.131)
Number of Family Males Working on the Farm	0.0339*
	(0.0196)
Number of Family Females Working on the Farm	-0.00560
	(0.0177)
Number of Hired Males Working on the Farm	0.335
	(0.205)
Number of Hired Females Working on the Farm	-0.1035
	(0.347)
Log (Span of Control: All Hired Workers to Male Family Workers)	0.0224
	(0.0255)
Number of Specialized Tasks: Family Males	-0.0371
	(0.045)
Number of Specialized Tasks: Hired Males	0.0567*
	(0.0281)
Number of Specialized Tasks: Family Female	-0.0144
	(0.018)
Number of Specialized Tasks: Hired Female	0.0257
	(0.024)
1(Own Any Equipment)	0.0176
	(0.0118)
Joint F-Stat	**0.29**
Observations	7235

Standard errors clustered at the village-level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table 3: Binary for Labor Use: Treatment Effects

	Land preparation			
	(1)	(2)	(3)	(4)
	Family Male	Hired Male	Family Female	Hired Female
1(Mechanization)	-0.0130	0.0250*	-0.00306	0.0110
	(0.00990)	(0.0140)	(0.0149)	(0.0116)
1(Cash and Mechanization)	0.00230	-0.0101	0.00171	-0.0248**
	(0.0129)	(0.0170)	(0.0189)	(0.0119)
Control Mean Levels	0.940	0.690	0.450	0.230
Observations	5535	5535	5535	5535
	Other stages			
	(1)	(2)	(3)	(4)
	Family Male	Hired Male	Family Female	Hired Female
1(Mechanization)	-0.00830	0.0119	-0.0144	-0.00464
	(0.0137)	(0.0100)	(0.0141)	(0.00859)
1(Cash and Mechanization)	0.00641	-0.00748	-0.0111	0.0164*
	(0.0141)	(0.0140)	(0.0176)	(0.00882)
Control Mean Levels	0.820	0.860	0.760	0.930
Observations	5525	5533	5526	5531

Standard errors clustered at the village-level in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Panel 1 reports binary variables for hiring different types of labor over the land preparation stage.

Panel 2 reports binary variables for hiring different types of labor over all stages except land preparation.

Table 4: Number of Workers During: Treatment Effects

	Land preparation			
	(1)	(2)	(3)	(4)
	Family Male	Hired Male	Family Female	Hired Female
1(Mechanization)	-0.0859****	-0.0523**	-0.0320***	-0.0160
	(0.0191)	(0.0252)	(0.0119)	(0.0156)
1(Cash and Mechanization)	0.0294*	-0.0224	0.0141	-0.0209
	(0.0172)	(0.0282)	(0.0134)	(0.0161)
Control Mean Levels	0.740	1.310	0.280	0.350
Observations	5502	5511	5484	5486
	Other stages			
	(1)	(2)	(3)	(4)
	Family Male	Hired Male	Family Female	Hired Female
1(Mechanization)	-0.119****	-0.121****	-0.109****	-0.131****
	(0.0297)	(0.0343)	(0.0274)	(0.0335)
1(Cash and Mechanization)	0.0314	0.0297	0.00158	0.0863**
	(0.0295)	(0.0463)	(0.0304)	(0.0400)
Control Mean Levels	2.190	5.390	1.700	8.330
Observations	5525	5533	5526	5531

Standard errors clustered at the village-level in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

The dependent variables are the inverse hyperbolic sine of the number of workers per acre.

Table 5: Tasks First Listed Being Performed by Types of Labor

Sno.	Task	Family Male	Hired Male	Family Female	Hired Female
1	Supervision of farm labor	67.65	16.63	26.1	7.53
2	Sourcing inputs	8.19	21.41	8.05	10.75
3	Land preparation	15.92	34.53	13.76	16.81
4	Manure application	3.76	13.36	16.98	20.78
5	Sowing seed	1.14	4.76	16.67	22.47
6	Transplanting	0.7	2.12	9.63	12.45
7	Chemical Fertilizer Application	0.28	1.59	0.84	1.46
8	Hand Weeding	0.15	0.63	3.74	5.58
9	Interculture	0.63	1.16	0.65	0.28
10	Plant protection	0.1	0.23	0.12	0.05
11	Irrigation	0.1	0.38	0.02	0.07
12	Watching	0.08	0.27	0.1	0.03
13	Harvesting	0	0.3	0.02	0.07
14	Threshing	0	0	0.03	0
15	Marketing	0.03	0	0.02	0
16	Other	1.27	2.61	3.28	1.67

A task is considered to be performed by a particular labor type if it was listed as being performed first in the profile of tasks listed for that labor type by the household.

Table 6: Crop Choice Treatment Effects

	(1)	(2)	(3)
	1(Paddy Grown)	1(Maize Grown)	1(Cotton Grown)
Cash and Mechanization	0.00494	0.00839	-0.00676
	(0.0144)	(0.0143)	(0.00882)
1(Mechanization)	-0.00388	-0.000826	0.00975
	(0.0120)	(0.0122)	(0.00751)
Control Mean	0.210	0.160	0.210
Observations	5035	5035	5035

Standard errors clustered at the village-level in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

1(Paddy Grown) is a binary variable that takes the value 1 if the farmer grows paddy and 0 otherwise.

1(Maize Grown) is a binary variable that takes the value 1 if the farmer grows maize and 0 otherwise.

1(Cotton Grown) is a binary variable that takes the value 1 if the farmer grows cotton and 0 otherwise.