Robotic Harvesters or Migrant Workers? A Mechanization Adoption Model

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Background

▪ Labor shortages have been threatening the sustainability of U.S. agriculture, particularly the labor intensive fruit and vegetable industry.

▪ The urgency of developing robotic harvesters has been increasing due to labor shortages.

▪ An understanding of robotic harvester adoption decision is important for policymakers and relevant stakeholders.

Objectives

▪ This study aims to model farmers' robotic harvester adoption decisions and identify a series of conditions for adoption.

Method

▪ The decision of hiring robotic harvester and/or using manual labor is modeled using a framework of farm profit maximization.

▪ Two scenarios when robotic harvesting profit is higher or lower than labor harvesting profit are considered.

Model Framework

A representative grower is to make adoption decisions in a two-period setup to maximize the expected "harvesting profit"

▪ Harvesting profit = revenue - harvesting costs.

▪ Yield $Y_t = g_t + e$, e ~ Uniform [-b, b]

▪The unharvested acreage in the first period will not be harvested (not harvestable) in the second period, either.

▪The grower chooses the optimal contracting amount of times of robotic harvesters (M_{tm}) to maximize the cumulative expected profit by solving the problem

$$\pi = \max_{M_{tm}} \left\{ E \sum_{t=1}^{2} [p_t(Y_{tl} + Y_{tm}) - w * S - r * M_{tm}] \right\}$$

- where p is product price; w is wage; and r is the rent of hiring robotic harvesters.
- The volume harvested by labor (Y_{tl}) and robotic harvesters (Y_{tm}) are determined by harvesting efficiency (θ_l and θ_m) multiplied by their working time (S and H_{tm}), respectively.
- H_{tm} is bounded by a maximum contracting time M.

▪ Crop abandonment may occur if the total yield is more than the total volumes harvested by labor and robotic harvesters.

- The expected amount of abandoned crops in the first period is

$$K = \int_{-b}^{u1} 0 * f(e)\, de + \int_{u1}^{b} (Y_t - Y_{tl} - Y_{tm}) f(e) de$$

where e is the yield shock, *f(.)* is the error distribution; and $u1$ is the cutoff point where abandonment occurs, which a function of yield, harvesting time and efficiency.

Results

Scenario A: Robotic harvesting profit > labor harvesting profit

$$E[pY_{tm} - rM_{tm}] > E[pY_{tl} - wS]$$

The condition for adopting robotic harvester is

$$\theta_m > \frac{(g_t - S)r}{(g_t p - 2pS + wS)} \text{ and } r < \frac{(g_t p - 2pS + wS)\theta_m}{(g_t - S)r}$$

Scenario B: Robotic harvesting profit < labor harvesting profit

The optimal contracting time of robotic harvesters in the first and second periods are :

$$M_t^* = f(g, b, p_1, p_2, w, r, S, \theta_l, \theta_m)$$

Analysis shows that:

$$\frac{\partial M_t^*}{\partial p_1} > 0, \frac{\partial M_t^*}{\partial p_2} > 0, \frac{\partial M_t^*}{\partial r} < 0, \frac{\partial M_t^*}{\partial S} < 0, \text{ and } \frac{\partial M_t^*}{\partial \theta_m} < 0$$

Conclusions

▪ A grower's decision to replace labor with robotic harvesters is determined by the relative profits of machine and labor harvest.

▪ The adoption of robotic harvesters is affected by crop yield, crop price, labor supply, wage, labor efficiency, machinery efficiency, and machine rental price.

▪ The use of robotic harvester increases with crop prices, but decreases with labor supply, machine efficiency, and rental price.