Climate-Robust Seeds RCT: Impacts on Adoption and Farmer Earnings

Josahn Oginga Helen Wang Marilyn Rutecki
Samantha Rudravajhala Cassie Zhang

May 8, 2025

Abstract

This study evaluates the causal impact of adopting climate-robust wheat seeds on household earnings among farmers in a randomized controlled trial (RCT) across 283 towns. Farmers were randomly assigned to treatment groups where varying shares (25%, 50%, 75%) were offered access to the new seeds, while a control group received no offer. Using individual-level data on household demographics, seed adoption, and earnings, we assess the direct treatment effects, peer spillovers, and potential sources of bias such as attrition. Results show that the treatment significantly increased seed adoption, and adoption, in turn, was associated with a 25% rise in log household earnings. Notably, even untreated farmers benefited through peer effects in higher-treatment towns. Despite minor imbalances in observed covariates and differential attrition by treatment intensity, the findings provide strong evidence that climate-robust seeds can deliver meaningful economic gains and highlight the importance of social dynamics in the diffusion of agricultural technology.

Keywords— Climate-Robust Seeds, Randomized Controlled Trial, Agricultural Technology, Farmer Earnings, Peer Effects, Impact Evaluation

1 Introduction

Climate change poses increasing risks to agricultural livelihoods, especially in regions that are vulnerable to the increasing frequency of extreme weather events. Despite these challenges, global crop and food production must keep pace with a growing global population. As Singh et al. (2014)[2] emphasize, the increasing frequency of extreme weather events is likely to reduce crop yields, with the greatest impacts falling on regions that are already food insecure. Developing and distributing climate-resilient seed varieties is therefore critical for protecting agricultural productivity and farmers' livelihoods. Cacho et al. (2020)[1] supports this idea and finds that the use of climate-resilient seeds brought substantial economic benefits to farmers in Malawi and Tanzania, estimated between USD 984 million and 2.1 billion.

This project investigates the policy-relevant question: **What is the causal effect of adopting new climate-robust wheat seeds on farmers' household earnings?** To answer this question, an agricultural team has developed new climate-robust seeds for wheat and identified 283 towns in a single province to study. Towns were randomly assigned to one of four groups: in group 0, no farmers were offered the new seeds while in groups 1, 2, and 3, 25%, 50%, and 75% of farmers, respectively, were offered the new seeds for farming.

A key empirical challenge in answering this question is the concern over endogeneity. Specifically, there is a possibility that farmers who choose to adopt the new seeds differ systematically from those who do not. For example, a skilled worker with more resources might be more likely to adopt new technologies, and perhaps have higher earnings already, regardless of the new seeds. This makes it difficult to isolate the causal effect of the seeds themselves. Our project addresses this challenge by employing a quasi-experimental research strategy, using randomized individual level assignment to treatment groups. Ideally, this random assignment will ensure that, on average, treated and control group farmers are comparable in both their observed and unobserved characteristics, allowing us to estimate the causal effect of seed adoption on farmers' earnings. This study's design provides a framework to understand the impact of new seed implementation in a realistic policy setting.

2 Data and Methodology

Our project uses a randomized controlled trial design to estimate the causal effect of adopting climate-robust wheat seeds on farmers' household earnings. The dataset constrains individual-level observations on 283 towns in a single province, with variables including the farmer's treatment assignment, whether the new seeds were used, household characteristics (size, age of household head, marital status), and log earnings (lnearnings).

The research design randomizes individuals so that farmers are randomly assigned to receive the treatment offer or not. Town group 0 serves as the control group, where no farmers were offered the new seeds, while town groups 1, 2, and 3, reflect the increasing intensities of treatment offers (25%, 50%, and 75% of farmers offered seeds).

We begin our experiment by assessing the validity of our RCT experiment design. First, we identify missing data, create a binary attrition indicator, and check attrition by our covariates. Then, we check attrition by each town group. Next, we check for balance across treatment and control groups to confirm that there are no systematic differences between those who use the new seeds vs those who do not. After checking for balance, we determine whether there were any peer effects to farmers who were not offered the climate-robust seeds. After these validity checks, we determine treatment effects, answering whether treatment increased the use of seeds as well as the impact of using the new seeds on farmers' earnings.

3 Results

The analysis reveals robust and statistically significant evidence of the effects of the climate-robust wheat seed intervention. These findings can be substantiated from the following perspectives.

3.1 Attrition

While individual-level covariates such as household size, age of the household head, and marital status are not strongly associated with missing outcome data (log earnings), there are statistically significant differences in attrition rates across treatment assignment and town group intensity. From the regression of attrition on covariates, only marital status shows a marginally significant relationship ($p = 0.0469$). This suggests that observable individual characteristics do not meaningfully predict whether a farmer's earnings data is missing. However, when examining attrition by treatment assignment, we find that treated individuals are significantly less likely to attrit than controls, by approximately 2.2 percentage points ($p < 0.001$). Furthermore, examining attrition by treatment intensity (town group), attrition decreases as the proportion of farmers offered the seeds increases. Specifically, compared to the control group (Group 0, 18% attrition), attrition is about 16% lower in Group 1, 13% lower in Group 2, and 3% lower in Group 3. These group-level differences are highly significant ($p < 0.001$ for all comparisons), suggesting that exposure to treatment may have encouraged participants to stay engaged in the study. Although attrition is not strongly predicted by individual characteristics, the systematic differences in attrition by treatment intensity raise concerns about potential bias—especially if unobserved traits correlated with both attrition and earnings differ by treatment group.

Table 1: Attrition by Covariates vs. Attrition by Town Group

Variable	Covariates Model	Town Group Model
Intercept	0.0928*** (0.0069)	0.1802*** (0.0022)
hhld_size	0.0013 (0.0009)	–
age_head_hhld	-0.00007 (0.00016)	–
married	0.0045* (0.0022)	–
town_group 1	–	-0.163*** (0.0031)
town_group 2	–	-0.132*** (0.0031)
town_group 3	–	-0.034*** (0.0031)
Residual SE	0.297	0.290
R^2	0.0009	0.051
Adj. R^2	0.0005	0.051
F-statistic	2.18 (p = 0.088)	1286 (p ¡ 0.001)

Notes: Standard errors in parentheses. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$.

3.2 Balance Check

To assess whether the observable characteristics are balanced between the treatment and control groups, we regressed the treatment assignment on baseline covariates including household size, age of the household head, marital status, and log earnings. However, the regression results indicate otherwise. All covariates, except for the age of the household head, are statistically significant at conventional levels. In particular, household size ($p < 0.001$), marital status ($p < 0.001$), and log earnings ($p < 0.001$) significantly predict whether a farmer was offered the treatment. This suggests that treatment was not completely random with respect to observed characteristics. Although the R-squared value of 0.0133 indicates that only about 1.3% of the variation in treatment assignment is explained by these observables, the statistical significance of the coefficients still raises concerns about imperfect randomization. Therefore, observable covariates are not fully balanced, which could bias the estimated treatment effects.

Table 2: Balance Check: Linear Regression of Treatment on Covariates

Variable	Estimate	Std. Error	t value	$Pr(>\|t\|)$
Intercept	-0.407	0.0286	-14.255	< 2e-16 ***
hhld_size	-0.0217	0.0016	-13.290	< 2e-16 ***
age_head_hhld	-0.0008	0.0003	-2.902	0.0037 **
married	-0.0136	0.0039	-3.519	0.0004 ***
lnearnings	0.0884	0.0030	29.574	< 2e-16 ***

Residual SE: 0.482 on 64,684 DF
Multiple R^2: 0.0134, Adjusted R^2: 0.0133
F-statistic: 219.2 on 4 and 64,684 DF, p-value: < 2.2e-16
Significance codes: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

3.3 Peer Effects

To examine whether there were peer effects among farmers who were not offered the climate-robust seeds, we restricted the sample to non-treated individuals(treatment=0)and estimated how their earnings varied by the intensity of seed offers in their towns. The regression results show that farmers in towns with higher treatment intensities, where 25%, 50%, or 75% of farmers were offered the new seeds, experienced significantly higher earnings compared to those in towns where no farmers were offered seeds (the reference group). Specifically, earnings increased by approximately 0.039, 0.105, and 0.153 log points for town groups 1, 2, and 3 respectively, with all coefficients being highly statistically significant ($p < 0.001$). These results indicate that even farmers who were not directly treated benefited indirectly through peer effects. The accompanying plot reinforces this finding, showing a clear upward trend in average earnings among non-treated farmers as the share of treated peers in their town increases. These spillover effects may reflect information sharing, imitation, or reduced uncertainty due to observing neighbors adopt the new technology. Together, this provides strong evidence that the benefits of seed adoption extended beyond directly treated individuals.

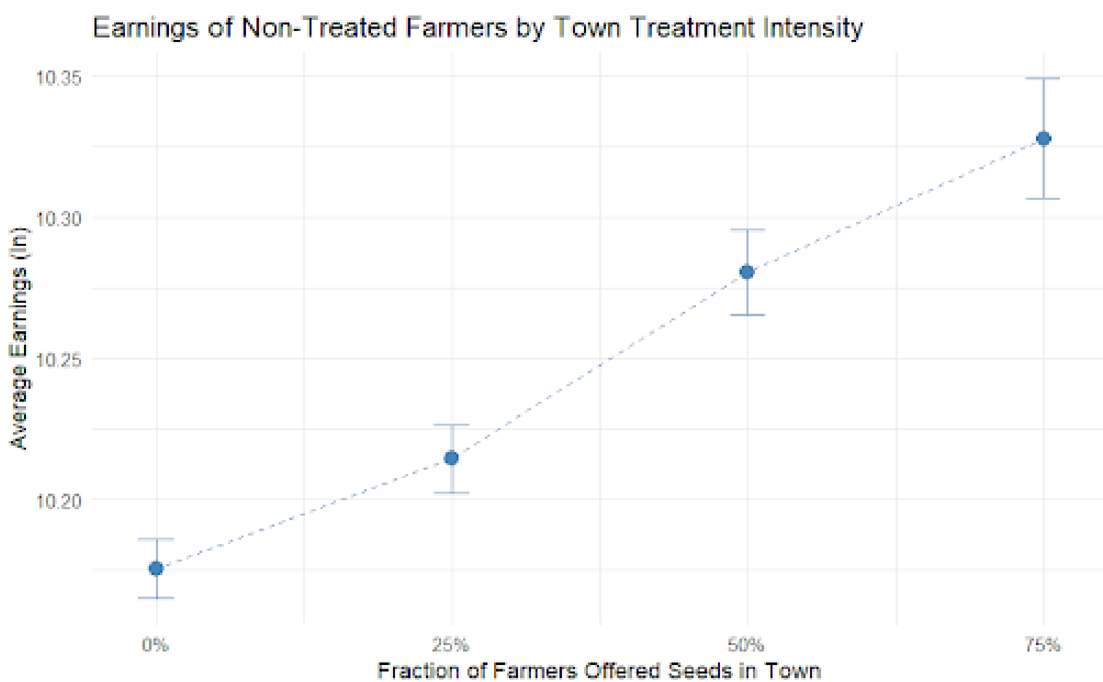

Figure 1: Peer Effects

3.4 Treatment Effects

Based on the regression results and the accompanying visualization, we can clearly conclude that the treatment significantly increased the likelihood of farmers using the new seeds. In the unclustered model, the treatment effect estimate is 0.5983, with a standard error of 0.0031, a t-value of 191.0, and a p-value well below 0.001, indicating strong statistical significance. To account for potential intra-cluster correlation at the town level, we also estimated the model with clustered standard errors by town. The treatment effect remains 0.5983, with a slightly larger standard error of 0.0112, and remains highly significant with a t-value above 53.4. In addition, the figure we draw visually reinforces results. The average seed use rate in the control group is approximately 40%, whereas the treatment group's usage rate climbs to nearly 60%. This dramatic difference highlights the effectiveness of the treatment intervention in promoting adoption of the new seeds.

Generally, the use of new seeds increases earnings. Based on the linear regression results (both unclustered and clustered standard errors), the coefficient on 'uses_new_seeds' is approximately 0.251 with a highly significant p-value ($p < 0.001$). This means that farmers who adopted the new climate-robust seeds experienced an estimated 25% increase in log household earnings compared to those who did not adopt the seeds. This finding is visually supported by the plotted confidence intervals: farmers using the new seeds have higher average log earnings, with non-overlapping confidence bands, indicating statistical significance. Additionally, the results are robust to clustering at the town level, confirming that the positive association between seed use and income holds even when accounting for potential intra-town correlation.

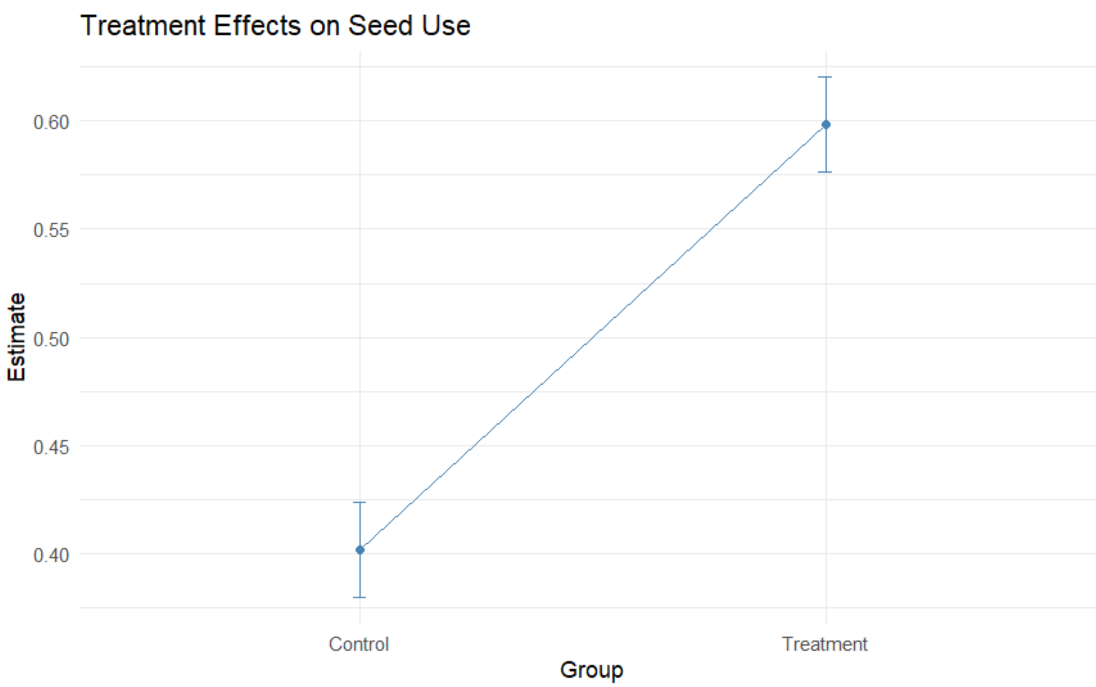

Figure 2: Treatment Effect on Seed Use

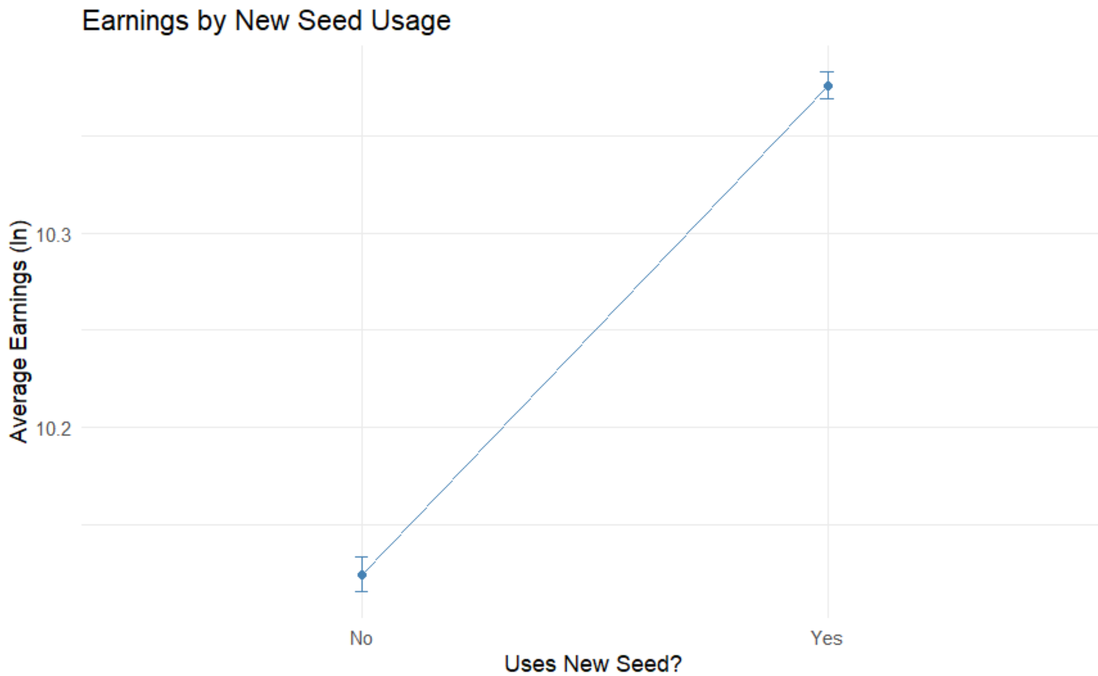

Figure 3: Treatment Effect on Earnings

4 Discussion

The randomized controlled trial provides evidence on the impact of introducing climate-robust wheat seeds on farmers' behavior and economic outcomes. The intervention significantly increased the likelihood of seed adoption, and in turn, the use of the seeds led to higher household earnings. These findings are consistent with prior literature, such as Cacho et al. (2020)[1], suggesting that climate-resilient agricultural technologies can produce substantial economic gains in vulnerable regions.

While we find statistically significant differences between treatment and control groups in some observable characteristics, such as household size, marital status, and baseline earnings, the explanatory power of these variables is low ($R^2 = 0.0133$), indicating that the magnitude of imbalance is relatively limited. Thus, although randomization may not be perfect, the groups are generally comparable.

Attrition analysis reveals more nuanced results. At the individual level, observable characteristics explain very little variation in attrition, and only marital status is marginally significant. However, when examining attrition across treatment status and town-level treatment intensity, we observe systematic and statistically significant differences. Farmers in treated groups and in towns with higher treatment intensity show notably lower attrition rates. This may reflect higher engagement or motivation among farmers who received the intervention. While this pattern does not necessarily invalidate the results, it does suggest that attrition may be partially driven by exposure to the treatment, raising the need for cautious interpretation of outcome comparisons.

Importantly, we also uncover strong peer effects. Among farmers who were not directly offered the new seeds, those living in towns where a larger share of neighbors received the treatment experienced significantly higher earnings. This suggests that informal learning, observation, and social influence may play a key role in facilitating technology diffusion. Ultimately, the results support the effectiveness of climate-robust seeds in improving farmer welfare, both through direct treatment and indirect peer channels.

References

[1] O.J. Cacho, J. Moss, P.K. Thornton, and et al., *The value of climate-resilient seeds for small-holder adaptation in sub-saharan africa.*, https://doi.org/10.1007/s10584-020-02817-z, 2020.

[2] Rishi P. Singh, Pagadala Vara V. Prasad, and K. Raja Reddy, *Chapter two - climate change: Implications for stakeholders in genetic resources and seed sector*, https://doi.org/10.1016/bs.agron.2014.09.002, 2014.