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Abstract

Despite the expansion of microcredit access, its outreach is still limited among farmers. One potential cause is a timing mismatch between cash flow and credit flow. Farmers have little income until their harvest is realized, while standard microcredit requires weekly installment payments. This mismatch causes underinvestment and borrowing for repayment, resulting in lower uptake rates. Furthermore, agricultural investment is sequential, while credit is disbursed as a lump sum. Present-biased (PB) farmers may fail to set aside sufficient money for later investment. To test these predictions, we conducted a randomized control trial modifying standard microcredit targeted at tenant farmers by setting repayment schedules to one-time repayment after harvest and making loan disbursement sequential. Discarding weekly repayment increased uptake and borrower's satisfaction without worsening repayment rates. Sequential disbursement increased later investments among PB borrowers and reduced loan sizes. We attribute the loan size reduction to the option value: Sequential disbursement allowed borrowers to adjust the total loan size after observing credit demand shocks, eliminating the need for precautionary borrowing. Calibrated models are used to evaluate counterfactual credit designs, showing that letting borrowers set the credit limit is beneficial for PB borrowers, while credit lines will be suboptimal for PB borrowers.

Keywords: Microcredit; Timing mismatch, Commitment; Option value; Precautionary borrowing

JEL Classification: G21, O16, Q14

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1 Introduction

Boosting agricultural production is a prerequisite for poverty reduction because agriculture is the primary source of income for poor households (Christiaensen et al., 2011). Financial inclusion has the potential to increase productive investment, but many farmers lack adequate access to credit owing to a lack of collateral. Although the expansion of microcredit programs has greatly improved financial access among the poor without collateral, they have limited reach among farmers.[1]

The low uptake of microcredit among farmers can be partly attributed to the mismatch of the timing between cash flow and credit flow. Farming does not generate income until harvest and requires sequential investment over the production cycle such as land preparation, sowing, irrigation, and fertilizers. Standard microcredit, on the contrary, requires frequent installments under which farmers need to repay part of the debt before harvest. This timing mismatch of cash inflow and credit outflow will be serious for farmers cultivating crops with long growing seasons.[2] Another mismatch is between cash outflow and credit inflow. Typically, loans are disbursed in a lump sum, and farmers need to set aside part of the disbursed fund for later investment, which may be difficult for present-biased (PB) farmers (Ashraf et al., 2006; Duflo et al., 2011). These timing mismatches may reduce the benefit from using microcredit, resulting in low uptake rates among farmers.

This study explored better microcredit contract designs by eliminating this timing mismatch. Using a simple multi-stage model, we first showed the cost of the timing mismatch: Requiring installment payments before harvest, as is the standard practice in microcredit, will not only cause underinvestment due to its high effective interest rate but also induce extra borrowing for repayment, resulting in lower uptake rates. Furthermore, PB borrowers prefer to lower the amount of initial disbursement to constrain their overconsumption and increase later investments. To empirically test these predictions, we randomly offered a credit contract to rice-growing farmers in rural Bangladesh, most of whom were sharecroppers without collateral land assets. Our treatment arms included four types of contracts that differ in timing of disbursement and repayment: (T1) traditional microcredit with a lump-sum disbursement and weekly installments; (T2) crop credit with a lump-sum disbursement and a lump-sum repayment after harvest; (T3) sequential credit with sequential disbursement and a lump-sum repayment after harvest; and (T4) sequential in-kind credit, which is a variant of (T3) with a part of the loan disbursed in kind to strengthen

[1] One exceptional study that found a high uptake rate among farmers is that of Fink et al. (2020), who also found significant impacts on on-farm labor and agricultural output.

[2] By cultivating multiple crops that differ in the timing of their harvest, farmers can generate frequent income flows. However, many smallholder farmers grow a single crop on their plot at a given period for production efficiency, and would therefore need non-farm income to repay the debt before harvest.

the borrower's commitment by reducing liquidity. We found that changing the repayment timing (T2–T4) substantially improved the uptake rates, especially among poor households. Sequential disbursement (T3 and T4) increased the investment among PB farmers, though it did not increase the uptake rate relative to T2 even among the PB farmers. These modified schemes (T2–T4) did not worsen the repayment rates and resulted in greater satisfaction and higher uptake rates in the subsequent season.

Interestingly, sequential credit (T3–T4) resulted in smaller loan size by 7%–12% compared to traditional microcredit (T1) and crop credit (T2). We attribute this reduction of the loan size to the option value of the sequential disbursement: Borrowers can decide the total loan size after observing credit demand shocks, which reduces precautionary borrowings. The effect of the option value on loan size, in general, is ambiguous depending on the nature of shocks. To confirm if the option value of the sequential disbursement tends to lower loan size, we incorporated productivity and expenditure shocks to the baseline model and conducted simulation analysis. Under the plausible parameter values, we found that the sequential disbursement will reduce the loan size through the reduction of precautionary borrowing and improve borrowers' welfare. We also used the calibrated model to evaluate two counterfactual credit products: sequential credit with self-set limit (SC-SSL) and credit lines (CL). The SC-SSL lets borrowers set the credit limit when applying for the credit, which provides additional commitment. CL allow the borrowers to borrow flexibly at any time within the limit. These two products are similar in terms of reducing the precautionary borrowing but differ in its commitment function. We found that the SC-SSL ensures greater expected utility than sequential credit for sophisticated PB borrowers and still works well even for partially naive PB borrowers. CL, on the contrary, achieve greater investment and profit, but result in lower expected utility than sequential credit, and in some cases, than crop credit. This last point suggests that investigating the impact on production is not sufficient to consider a desirable credit design.

Our study is related to emerging literature on the introduction of flexibility in microcredit, including less frequent installments (Field and Pande, 2008), longer grace periods (Battaglia et al., 2023; Field et al., 2013), flexible repayment schedules (Barboni and Agarwal, 2021; Czura, 2015; Shonchoy and Kurosaki, 2014), changing the timing of credit provision for farmers to sell the harvest when price increases (Burke et al., 2019), and providing credit lines to allow borrowers to withdraw or repay a flexible amount at any time (Aragón et al., 2020). It also contributes to the literature on the commitment device for PB individuals (Ashraf et al., 2006; Brune et al., 2021; Casaburi and Macchiavello, 2019), and the argument of commitment versus flexibility (Amador et al., 2006; John, 2020)

We extend this literature in several ways. First, we formalize the problem of the timing mismatch of cash flow and credit using the dynamic model of investment and consumption: the frequent installment causes underinvestment and borrowing for repayment, and the lump-sum disbursement causes overconsumption for PB borrowers.[3] Karlan and Mullainathan (2010) argued that the standard weekly repayment "greatly limits the size of the loans the poor can borrow ... by basing borrowers' repayment capacity on bad weeks, instead of average weeks," but we showed that it may conversely increase the loan size for farmers as they borrow for repaying installments to smooth consumption. Our model can also explain the positive impact of introducing a grace period on the investment amount found by Field et al. (2013).

Second, we introduce the commitment and flexibility by modifying the disbursement schedule. Existing studies of microcredit contract mainly focus on the repayment schedule (Afzal et al., 2019; Bauer et al., 2012; Battaglia et al., 2023; Fischer and Ghatak, 2016). However, the issue of commitment and flexibility in financial decision making is about managing available cash at an appropriate level at each period of time, and both the disbursement schedule and the repayment schedule can affect the level of available cash through credit inflows and outflows.[4] For borrowers who invest in stages, such as farmers, sequential disbursement is an effective way to provide both commitment and flexibility: commitment can be provided by reducing early disbursements, and flexibility can be provided by allowing the loan size to be adjusted in later stages. We found that sequential disbursement increased later stage investment among PB borrowers through its commitment function. Furthermore, its flexibility can induce the level of investment to be optimal. We contrast the benefits of commitment and flexibility for PB borrowers using simulation. The additional commitment by the SC-SSL improves the borrower's welfare,[5] but flexibility without commitment, as in the CL, may worsen their welfare.

Third, we demonstrated the importance of precautionary borrowing when considering the credit contract design. Understanding the precautionary borrowing motives provides a new lens to evaluate the value of credit access. Most credit programs provide additional loans after the repayment of the outstanding loans. Hence borrowers face credit constraints after receiving the initial disbursement, which induces them to borrow additional amounts for precaution. This precautionary borrowing can be reduced by ensuring access to additional funds after the disbursement, as in our sequential credit product. The mere existence of emergency loans, or additional credit sources, or allowing additional borrowing before the full repayment as in CL, can also reduce the precautionary borrowing.[6] While the literature on precautionary saving is extensive (Caballero, 1990; Carroll and

[3] Das et al. (2019) and Hossain et al. (2019) evaluated credit programs targeted at sharecroppers in Bangladesh as ours, but they employed the standard microcredit with monthly installments and a lump-sum upfront disbursement.

[4] Chowdhury et al. (2014) argued the advantage of sequential credit in the context of joint liability, but their focus was on preventing coordinated default, not on the commitment or flexibility.

[5] While costly commitment may reduce the welfare of partially naive PB borrowers (John, 2020), the commitment in the sequential disbursement (lower early disbursements) only imposes constraints and will not be harmful.

[6] Aragón et al. (2020) studied credit lines but assumed risk-neutral agents, which eliminates precautionary motives.

Samwick, 1998; Kimball, 1990), only a few studies shed light on precautionary borrowing (Alan et al., 2012; Druedahl and Jorgensen, 2018) and focus exclusively on financial crises in which households increase current borrowing due to uncertainty in future credit supply. In contrast, we focused on precautionary borrowing due to uncertainty in future credit demand, which is more common and has implications for the desirable design of credit contracts.

While our experimental context involved crop farmers, our arguments on the timing mismatch between cash flow and credit flow, the role of commitment and flexibility through disbursement schedules, and the importance of precautionary borrowing are applicable beyond agricultural settings. The desirable credit scheme should resolve the timing mismatch for potential borrowers, allowing additional funds for future shocks and sequential investment needs while providing commitment functions. There is no one-size-fits-all credit design, and our theoretical framework will help design desirable contracts for potential borrowers with irregular income and sequential investment needs.

The next section provides the baseline model that motivates our interventions. Section 3 illustrates the local context and experimental and survey settings, followed by empirical results. Section 5 extends the baseline model by introducing uncertainty to argue the option value and provides numerical simulations. Section 6 concludes.

2 Conceptual Framework

Agricultural production is characterized by sequential investments and infrequent income, typically realized only after harvest. In the case of rice production, farmers prepare and seed the land at the beginning of the planting season. Upfront investment is required for purchasing seed, land tillage, leveling, irrigation, and basal fertilizer (first fertilizer hereafter). Farmers then transplant the seedling, which incurs additional labor costs. One and a half months after seeding, farmers apply herbicides, topdressing fertilizer (second fertilizer hereafter), and pesticides. Weeding is labor-intensive and may require farmers to hire additional labor. Harvesting could occur more than three months after seeding, when farmers need additional labor for crop-cutting, threshing, and transporting. Until the harvest is sold, farmers have little income unless they work elsewhere(agricultural or non-agricultural). The typical schedule of agricultural investment is depicted in Table 1.

Typically, farmers who need credit should apply for the loan in advance. If the application is approved, they receive the full amount of the loan when they start production. In the standard

Suri et al. (2021) studied mobile short-term loans in Kenya, finding that the first loan was often quite low, which may be explained by the fact that additional borrowing is easier in the case of short-term loans.

Table 1: Typical schedule of agricultural investment and credit flow

	Stage 0	Stage 1	Stage 2	Stage 3
Production		(-) Seed (-) Land preparation (-) Basal fertilizer (-) Transplanting (-) Irrigation	(-) Topdressing fertilizer (-) Weeding (-) Herbicide (-) Pesticide	(+) Sell harvest (-) Crop-cutting (-) Threshing (-) Transporting
Credit	Application	(+) Disbursement (-) Regular installment	(-) Regular installment	(-) Regular installment

The positive sign (+) indicates the cash inflow and the negative sign (-) the cash outflow.

microcredit system, payment of regular installments begins a few weeks after disbursement, even though farmers have little income flow during this period. This creates a timing mismatch between cash flow and credit flow: Farmers have to pay when they need to invest, and receive credit only at the start of production while additional investment is needed later. The latter may lead to underinvestment at a later stage among farmers who have difficulty in saving (Ashraf et al., 2006; Dupas and Robinson, 2013).

To understand how the repayment and disbursement schedule affects farmers' decisions, consider a three-period model of a farmer with endowment A_0. Before the first period starts ($t = 0$), they apply for credit with a simple interest rate r. The timing of the decision-making and credit flows are described in Table 2. For simplicity, we ignore the labor decision and time discounting and assume that the land is fixed.

Table 2: Cash flow and timing of the decision-making

$t = 0$	$t = 1$	$t = 2$	$t = 3$
* Decide credit size $M \leq \overline{M}$ (and M_1)	Receive M_1 Repay $\pi_1 R$ * 1st investment K_1 * Consume c_1	Receive $M - M_1$ Repay $\pi_2 R$ * 2nd investment K_2 * Consume c_2	Harvest $Y = F(K_1, K_2)$ Repay $R_3 = (1 - \pi_1 - \pi_2)R$ Consume $c_3 = Y - R_3$

Asterisks (*) indicates the decision variables.

In each period, the farmer obtains utility from consumption c_t, evaluated by a concave utility function $u(c_t)$ that satisfies the Inada condition. They make the first investment K_1 at $t = 1$ and the second investment K_2 at $t = 2$ and then obtain the revenue from the harvest (net of harvesting costs) $Y = F(K_1, K_2)$ at $t = 3$.[7] Production function $F(K_1, K_2)$ is strictly increasing

[7]Since the harvesting costs can be paid by the harvesting revenue, we ignore them hereafter.

and concave in K_1 and K_2, and its second derivative matrix is a negative definite.[8] We denote the partial derivative of F with respect to K_j by F'_j.

Given this production technology and the interest rate r, they choose the loan size M at $t = 0$ subject to

$$M \leq \overline{M}, \tag{1}$$

where $\overline{M}$ is the upper limit of the loan size. We consider a microfinance institution (MFI) that disburses $M_1 \leq M$ at $t = 1$ and $M - M_1$ at $t = 2$, where M_1 is usually set by the MFI but can be determined by the borrower in a flexible microcredit design. The standard microcredit scheme corresponds to the case where $M_1 = M$. The total repayment amount is $R = (1 + r)M$, which is equally split over $t = 1, 2, 3$ under the standard weekly installment; equal installments of $\frac{1}{3}R$ at every period.[9] For generality, we denote the proportion of the installment amount at $t = 1, 2$ by π_1, π_2, respectively, where $\pi_1 + \pi_2 < 1$ and $\pi_1, \pi_2 \geq 0$. Then, the amount repaid at $t = 3$ is $R_3 = (1 - \pi_1 - \pi_2)R$, and the consumption at $t = 3$ is $c_3 = Y - R_3$.[10] Note that if one borrows M, they repay $(\pi_1 + \pi_2)(1 + r)M$ before obtaining income, and hence only $M - (\pi_1 + \pi_2)(1 + r)M$ is left by $t = 2$. We denote this fraction by

$$Q \equiv 1 - (\pi_1 + \pi_2)(1 + r). \tag{2}$$

The resources available at $t = 1$ and $t = 2$, A_1 and A_2, are expressed as

$$A_1 = A_0 + M_1 - \pi_1(1 + r)M, \tag{3}$$

$$A_2 = A_1 - c_1 - K_1 + (M - M_1) - \pi_2(1 + r)M. \tag{4}$$

Then the budget constraints at $t = 1$ and $t = 2$ can be denoted as

$$c_1 + K_1 \leq A_1, \tag{5}$$

$$c_2 + K_2 = A_2, \tag{6}$$

respectively. Changing the value of π_t and M_1 influences the budget constraints through their effects on A_1 and A_2. While we have ignored income flows other than harvest, Appendix A.1.1

[8]This ensures that the first-order conditions characterize the solution of the maximization problem. For this matrix to be negative definite, $F''_{11} < 0$, $F''_{22} < 0$, and $F''_{11}F''_{22} > (F''_{12})^2$. For the Cobb–Douglas production function $F(K_1, K_2) = \theta K_1^{\psi_1} K_2^{\psi_2}$, this condition is equivalent to $\psi_1 + \psi_2 < 1$ (decreasing returns to scale), which is plausible given the fixed land input.

[9]Most MFIs apply the simple interest rate over the loan maturity length. Here, we assume that the total repayment amounts are unaffected by the repayment schedule.

[10]Without uncertainty, borrowers will borrow as much as they need and will not save at $t = 2$. We will consider saving at $t = 2$ when we introduce the uncertainty in the later section.

shows that we can take other income flows into account simply by reinterpreting the endowment A_0 as the sum of the endowment and the other income flows.

We mainly consider following three products: (a) traditional microcredit ($\pi_1 = \pi_2 = \frac{1}{3}, M_1 = M$), (b) crop credit ($\pi_1 = \pi_2 = 0, M_1 = M$), and (c) sequential credit ($\pi_1 = \pi_2 = 0, M_1 < M$). We defer the full characterization of the model and solution to the Appendices, and present only important results.

2.1 A time-consistent borrower

A time-consistent farmer's problem is

$$\max_{c_1, c_2, K_1, K_2, M} \sum_{t=1}^{3} u(c_t)$$

subject to the budget constraints (5) and (6), and the borrowing limit (1). The first main result is that the borrower will choose the loan size M^* to satisfy

$$F'_j(K_1^*, K_2^*) \geq 1 + \frac{r}{Q}, \qquad j = 1, 2, \tag{7}$$

where the equality holds if the borrowing limit (1) is not binding. For the sake of brevity, consider the case wherein the equality holds. If $\pi_1 = \pi_2 = 0$, then $Q = 1$ by equation (2), and hence $F'_j(K_1^*, K_2^*) = 1 + r$, which implies that a farmer borrows credit until the marginal product of the investment equals its marginal cost. However, if $\pi_t > 0$, as in the traditional microcredit, then $Q < 1$ and $F'_j(K_1^*, K_2^*) = 1 + \frac{r}{Q} > 1 + r$, causing a reduction in investment. Note that borrowing M at $t = 0$ leaves only QM after repaying the installment. Hence, to finance an investment of size M', one must borrow $\frac{M'}{Q}$, requiring an interest payment of $\frac{rM'}{Q}$. This implies that the effective interest rate of this loan is $\frac{r}{Q}$, and the greater the ratio of the installment payment before gaining the income (a lower Q), the smaller the investment. For traditional microcredit ($\pi_1 = \pi_2 = 1/3$) with $r = 20\%$, $Q = 0.2$ and the effective interest rate $\frac{r}{Q}$ is as high as 100%. Note that if Q is negative, borrowing is suboptimal because it reduces the resources available before harvest.

This result remains unchanged if we allow for borrowing sources other than microcredit (Appendix A.1.2). Since borrowing from other sources for investment purposes was rare in our setting, we ignore the existence of other borrowing sources in the following discussion. This model can be applied to settings other than agriculture, wherein there is a gestation lag in investment. Field et al. (2013) found that the introduction of a grace period increased capital formation, which can be interpreted as the effect of the increase in Q owing to the grace period, as it effectively reduces the repayment amount before obtaining the return on investment.

The repayment schedule characterized by π_1 and π_2 affects the borrower's utility and behavior only through Q, and we can show that $c_1^* = c_2^* < c_3^*$, $\frac{\partial c_1^*}{\partial Q} = \frac{\partial c_2^*}{\partial Q} > 0$ and $\frac{\partial (c_1^*/c_3^*)}{\partial Q} = \frac{\partial (c_2^*/c_3^*)}{\partial Q} > 0$

— that is, requiring larger installment payments before harvest reduces consumption at periods 1 and 2 and increases the difference in consumption before and after harvest. Hence, the weekly installment requirement will lead to underinvestment and less consumption smoothing across time, which lowers the borrower's utility and uptake rates, as summarized in the following claim.

Claim 1 *The weekly installment requirement results in underinvestment and lower uptake rates.*

The impact of π_t on the loan size M^*, however, is undetermined without further assumptions on the utility and production functions even though the investment and consumption decline as π rises. This is because the requirement of installment before harvest induces borrowers to borrow for paying the installment to sustain consumption levels.

Figure 1 presents the effect of repayment schedules on borrowers' behavior . We assume the Cobb–Douglass production function $F(K_1, K_2) = \theta K_1^{\psi_1} K_2^{\psi_2}$, whose parameter values were calibrated to match the moment of our survey data as described in Appendix A.3.[11] The utility function is that of a constant relative risk aversion (CRRA) type:

$$u(c) = \begin{cases} \frac{c^{1-\gamma}-1}{1-\gamma} & \text{if } \gamma \geq 0, \gamma \neq 1 \\ \ln(c) & \text{if } \gamma = 1, \end{cases}$$

where the higher value of γ implies the higher demand for consumption smoothing. Note that the specification of the utility function does not affect the production decision but does affect the loan size and the levels of consumption in each period.

The upper panel of Figure 1 depicts the borrower's decision on the loan size M and the amount of the first investment K_1 against the endowment A_0 for different repayment schedules ($\pi_1 = \pi_2 = \pi = \{1/3, 1/6, 0\}$). We set $\gamma = 1$ in the left panel and $\gamma = 2$ in the right panel. While most empirical literature on the intertemporal substitution found $\gamma > 1$ (Ogaki et al., 1996; Yogo, 2004), the fact that the length of the period in our cases is only 1—2 months makes $\gamma = 1$ plausible, as people may show more tolerance toward consumption decline for only a few months rather than a whole year.

As indicated in equation (7), the investment size is determined by the marginal productivity and the value of π through Q and is not affected by the level of A_0. The loan size is decreasing in A_0.[12] In the range of A_0 described in the figure, a larger installment before harvest (a greater value

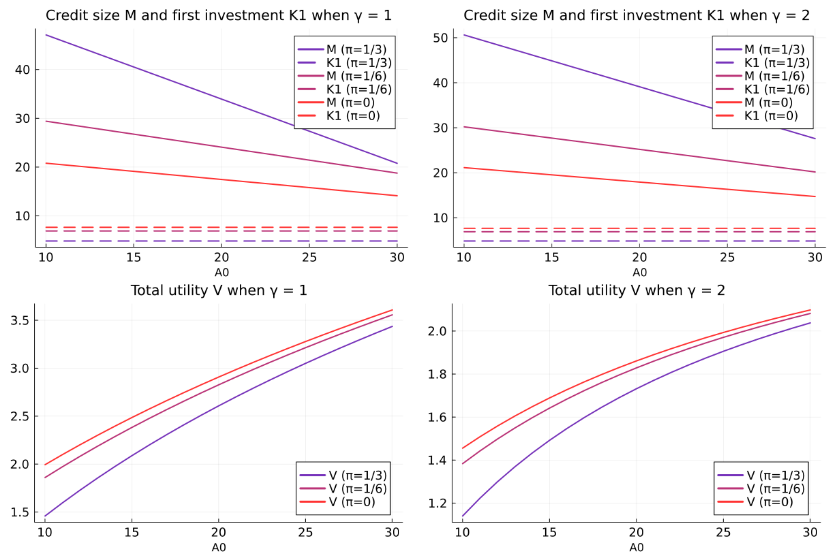
[11] The calibrated parameter values are $(\psi_1, \psi_2, \theta) = (0.254, 0.147, 16.196)$.

[12] With these functional specifications, the optimal loan size is linear in A_0, expressed as:

$$M^* = \frac{P^{1/\gamma}}{P^{1/\gamma}Q + 2(Q+r)} \left[\left(\frac{\alpha_1^{\alpha_2} \alpha_2^{\alpha_2} \theta}{P} \right)^{\frac{1}{1-\alpha_1-\alpha_2}} \left(2\alpha_1^{\alpha_1-\alpha_2} P^{1-\frac{1}{\gamma}} + \alpha_1 + \alpha_2 \right) - A_0 \right]$$

where $P \equiv 1 + \frac{r}{Q}$.

Figure 1: Loan size, first investment amount, and the total utility under the different value of π



$\pi = 1/3$ corresponds to traditional microcredit, and $\pi = 0$ crop credit (lump-sum payment after harvest). $\pi = 1/6$ is the intermediate case. γ is the parameter governing the intertemporal substitution.

of π) increases the loan size, especially for those with low A_0. The traditional microcredit ($\pi = 1/3$) results in the greatest loan size and the lowest investment size. The discrepancy between these two is substantial for those with low A_0, indicating that a considerable amount of credit is used for repayment among poor borrowers. With greater demand for consumption smoothing ($\gamma = 2$, right panel), the loan size becomes larger, especially under the traditional microcredit system, as farmers borrow more to sustain consumption levels before harvest.

The lower panel of Figure 1 shows that maximized total utility is lowest when $\pi = 1/3$ (traditional microcredit) and highest when $\pi = 0$. The difference is greater for those with low A_0, indicating that it is the farmer with low-asset or low-income flows from other sources who benefits most from the elimination of the regular repayment.

2.2 A present-biased borrower

For time-consistent borrowers, the disbursement schedule, captured by M_1/M (the share of the credit disbursed at $t = 1$), will not affect the borrower's decision unless M_1 is so small that the period-1 budget constraint (5) is binding. The borrower will not benefit from such a low level of M_1 since it only imposes the additional binding constraint. However, PB borrowers may prefer to set M_1 low to constrain the period-1 consumption. Now, consider a hyperbolic discounter who discounts the future utility by β and believes their β to be $\hat{\beta}$. For simplicity, set $\pi = 0$ and consider whether a PB borrower has an incentive to set a low M_1 at $t = 0$. The model is fully described in

Appendix A.1.3, and we briefly summarize the main results here, as the mechanism is quite similar to the standard argument of the demand for commitment (Laibson, 1997).

Claim 2 *A PB farmer who is aware of their present biasedness prefers the credit to be disbursed sequentially. Sequential credit will increase the second investment.*

Figure 2 illustrates the PB borrower's decision on the loan size and investment and the utility gain over the traditional microcredit under crop credit and sequential credit when $\gamma = 1$ and $\beta = \hat{\beta} = \{0.8, 0.6\}$.[13] For sequential credit, we present both the total loan size M and the first disbursement M_1.

The total loan size is similar between crop credit and sequential credit for low values of A_0. Under sequential credit, the first disbursement M_1 is chosen so that the budget constraint at $t = 1$, $c_1 + K_1 \leq A_0 + M_1$, is binding and limits the overconsumption at $t = 1$. This budget constraint lowers the first investment under sequential credit but increases the second investment, as farmers can secure enough resources to their period-2 self.

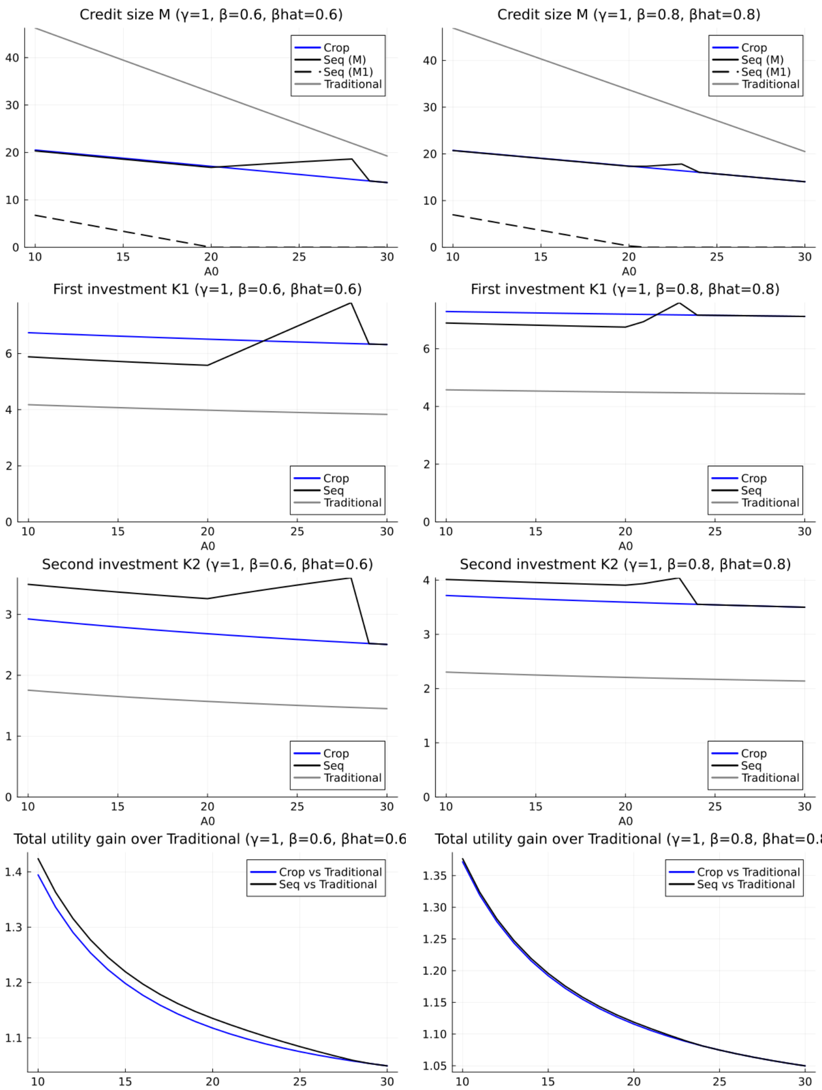
For larger values of A_0, however, the desirable level of M_1 becomes negative, which is infeasible, and hence, the farmer would set $M_1^* = 0$. While the budget constraint is still binding, the farmer's period-1 self has more resources to consume and invest, resulting in a greater K_1 in the figure. This in turn increases the marginal product of the second investment, inducing a greater second investment and resultant larger loan size. When A_0 is much larger, the farmer cannot make the budget constraint at $t = 1$ binding, even with $M_1 = 0$. In this case, they cannot constrain their period-1 self's choice, and there is no difference in outcomes between crop credit and sequential credit.

The maximized utility is greater under sequential credit than crop credit, though the magnitude of the difference depends on the present biasedness (β) and the degree of intertemporal substitution (γ). The difference in the utility is small when $\beta = 0.8$ or $\gamma = 2$. The value of the commitment is smaller when the present biasedness is milder ($\beta = 0.8$). The value of increased revenue due to the greater second investment is smaller when the consumption-smoothing motives are larger ($\gamma = 2$). The gain of sequential credit is somewhat large when $\beta = 0.6$ and $\gamma = 1$.

Note that even PB borrowers prefer crop credit if the upper bound of M_1 is set by the MFI and is too low for them. Especially, the existence of uncertainty, which is ignored in this baseline model, will increase the desired level of M_1, as it will provide the farmer with more flexibility (Amador et al., 2006). If borrowers are naive ($\hat{\beta} = 1$), sequential credit will not be preferred by them but may

[13] Appendix Figures 1 and 2 present the case when $\gamma = 2$ and the case when $\beta = 0.6, \hat{\beta} = 0.8$ (partially naive), respectively, with results quite similar to those in Figure 2. The utility gain under sequential credit is larger when $\gamma = 1$.

Figure 2: Loan size, investment amount, and the total utility of PB borrowers under crop credit, sequential credit, and traditional microcredit: $\gamma = 1$



β is the present bias parameter and $\hat{\beta}$ is the farmer's perception on their own β.

increase the second investment if the upper bound of M_1 is set adequately low.

3 Local Context, Product Design, and Randomization

3.1 Local context

Motivated by these theoretical predictions, we conducted a randomized controlled trial in the Dinajpur district of northwest Bangladesh, focusing on sharecropping farmers. The region suffers from a high poverty rate of 64.3%, significantly higher than the national average of 24.3% (Hill and Genoni, 2019). Most tenant farmers are landless and poor and do not have access to credit from formal banking sectors, including microfinance. Most of them are engaged in rice production.

Rice is a major agricultural product in Bangladesh and comprises half the agriculture sector's contribution to gross domestic product (GDP). Rice is cultivated throughout the year all over the country in three seasons: *Aush*, *Aman*, and *Boro*. *Aman* (rainy season) is the most important season (and the focus of our research), contributing 35% of the annual rice output. Land preparation for *Aman* begins in late June and lasts up to mid-July, while sowing spans mid-July to mid-August. Paddy harvesting begins in November and lasts until January.

Agricultural inputs are available at local markets. Farmers purchase fertilizers, pesticides, and herbicides from local traders. While some local traders sell hybrid seeds, most tenant farmers use traditional seeds.[14] For land preparation, agricultural modernization has replaced traditional animal-powered plowing with tractors or power tillers, and farmers pay in cash to local service providers to use the mechanical plowing service.

Most of the tenancy contracts require the tenants to pay 30% of the harvest to the landlord. Fixed-rent contracts are rare in this region, and only a fraction of the plots (less than 1%) were under fixed-rent contracts, both in our baseline survey and the endline survey. Cost sharing, which is often observed in sharecropping arrangements elsewhere, is uncommon in Bangladesh, partly because most of the landlords live in the cities and cannot monitor the input costs.[15]

Local MFIs do not provide credits designed for farmers, and mostly employ a "Grameen-Style" rigid contract design with weekly installment payments. Although the Bangladesh Rural Advancement Committee (BRAC) has introduced an experimental product for sharecroppers (BCUP), it requires monthly repayment that does not align with the cash flow of farmers. Borrowing from

[14] In our surveyed sample, only a few farmers purchased hybrid seeds in *Aman* season before and after our intervention. There were no significant differences in the usage of hybrid seeds across our treatment arms in the baseline and follow-up surveys.

[15] Without cost sharing, sharecroppers typically finance crop production by borrowing from informal money lenders and middlemen at high interest rates (Khandker et al., 2016; Hossain et al., 2019).

moneylenders is uncommon: at baseline, only 1% of the surveyed households borrowed from moneylenders in the past 12 months. Most of the borrowing sources at baseline were from shop owners (59.7%) followed by other non-governmental organizations (NGOs) including Grameen Bank. Of the total borrowing from shop owners, 92% reflected borrowing for food consumption purposes, in which case the borrowing amount is modest. Among all the borrowings at baseline, only 9.0% were for crop farming.

3.2 Survey

To implement the survey and experiment, we collaborated with *Gana Unnayan Kendra* (GUK), a grassroots organization that has worked in northern Bangladesh for 35 years in various development-related interventions. The GUK had provided microcredit under the traditional weekly installment contract. Their typical credit product was individual liability loans, though they required borrowers to form borrowing groups for facilitating peer evaluation and peer monitoring.

To start the survey, we first listed all the sub-districts of Dinajpur and conducted a village survey to understand the other MFIs' coverage and the prevalence of rice production under shared tenancy. We cross-verified the information on MFI penetration with the Microcredit Regulatory Authority's list of MFI agencies operating in Dinajpur. Finally, we identified three unions (Ghoraghat, Palsha, and Vaduria) in two sub-districts (Ghoraghat and Nawabganj) as our desired location for the experiment where the penetration of the other MFIs was low, rice production under share tenancy was widespread and accessibility from cities was limited. From these three unions, the GUK formed 50 groups of 20 potential borrowers each, at the beginning of May 2015. The groups were formed by the farmers themselves. During the group formation, farmers were informed that the access to credit offer and the type of credit contract would be randomized.

The baseline survey was conducted from June 2015 to obtain the basic demographic and socio-economic information, including land-size under tenancy agreement, of these 1,000 potential borrowers. Table 3 reports the summary statistics of our sample.

The average size of owned land is 12.3 decimals (approximately $500m^2$). While 57.2% of the sampled farmers were landless, nearly 30% owned land no less than 20 decimals, and most farmers tenanted land no less than 50 decimals (Appendix Figure 3).[16]. At baseline, the loan access was limited. About two-thirds of the sampled farmers had no borrowings in the past 12 months, and only 5% borrowed no less than 10,000 BDT (Appendix Figure 4).

We computed the first and second investment in a manner consistent with our conceptual framework described in Table 1. Specifically, the first investment consists of expenses for seeds, basal

[16]While some changed the areas of tenanted land between the baseline and the follow-up surveys, most farmers cultivated the same tenanted land

Table 3: Summary Statistics

	count	mean	sd	min	max
Owned land area (Baseline)	1000	12.275	15.691	0	50
Tenanted land area (Baseline)	1000	79.374	14.759	0	145
ln(asset) (Baseline)	1000	12.516	0.868	9.8	14.4
Any borrowing (baseline)	1000	0.351	0.478	0	1
Any saving (baseline)	1000	1.195	0.396	1	2
Total borrowing (Baseline)	1000	1297.597	5168.497	0	80000
Savings (Baseline)	1000	1145.738	2856.537	0	50000
Total other income (Baseline)	1000	100619.709	45755.029	0	385650
1st investment (Baseline)	1000	7642.315	2354.178	0	15033
2nd investment (Baseline)	1000	4320.190	1767.919	0	12405
Output (Baseline)	1000	32120.420	10215.358	0	84000
Any saving at NGO (baseline)	1000	0.772	0.420	0	1
wage income (annual)	1000	70942.920	52249.572	0	349600
Profit (Baseline)	1000	4043.523	5734.793	-14980	25738
Yield (Baseline)	997	5.247	0.885	2.47	8.65
Present-biased	988	0.589	0.492	0	1
Uptake	1000	0.561	0.497	0	1
Total loan amount (GUK)	1000	9029.960	8504.781	0	27300
Not repaid on due date (Arrear)	561	0.488	0.500	0	1
Default	561	0.119	0.325	0	1
% of amount not collected	561	0.078	0.237	0	.951
Cumulative savings	561	2320.989	495.026	300	3940

fertilizers, wages, and costs for hiring labor and machines for land preparation and transplanting, and irrigation fees. The second investment consists of expenses for topdressing fertilizers, herbicides, pesticides, and wages for hiring labor for weeding. Since our focus is on the impact of financial access on the investment, we excluded the imputed costs of family labors from the calculation of the investment amounts but considered them in computing the profit.[17] The amount of the first investment was almost twice as much as that of the second investment.

It turns out that many tenant farmers work as daily laborers due to the lack of farm income until harvest. The average annual household income from other sources than the tenant farming exceeded 100,000 Bangladesh Taka (BDT) (about 1,220 USD), of which 71,000 BDT was from wage income. This was much larger than the average profit from agricultural production, indicating that rice production is not a main source of income for most sampled farmers. While 22.5% of the surveyed households reported no wage income, a majority of them worked 240–360 days for wage income, with daily wage being 300 BDT on average. At median, individuals spent 20 days for earning wage income (Appendix Figure 5).[18] When self-employment is considered, almost all the households had income sources other than farming and spent substantial time in these activities (Appendix Figure 6). As a result, only 10% of the farmers earned *Aman* season profit exceeding a quarter of the total other income over the same period. This will mitigate the problem of the timing mismatch between the cash flow of the agricultural production and the credit flow from the MFI, and may lead to smaller impacts of removing the weekly installment and introducing sequential disbursement.

3.3 Product design

Before the main phase of the study (i.e., the *Aman*-cropping season in 2015), we implemented a small pilot study with the GUK to understand the cash flow in agricultural production in Dinajpur, while assessing the feasibility of the proposed experimental design. Based on bookkeeping exercises with tenant farmers, we computed the total cost of the entire cycle of rice production as well as the timing of each of the investment items for the typical farmer. We also discussed these estimates with the local agricultural extension officers and the GUK. Based on these conversations and estimates, the GUK agreed to provide a maximum loanable amount of 400 BDT (about 4.88 USD) per decimal of land to the sharecropping farmers, with a six-month interest rate of 12%.[19]

The credit products were individual liability loans disbursed through borrowing groups. To

[17] We also subtracted the labor costs for harvesting in computing the profit.

[18] Among those who earned wage income, 57.0% worked in their village and 38.4% worked in another village in the same union. Urban migration was rare due to the lack of job-related networks: only 1% of them migrated to another district (including Dhaka) for work.

[19] 1 decimal equals 40.5057 m^2.

join the borrowing group, individuals had to be tenancy farmers who did not borrow from existing microcredit programs. After joining the borrowing groups, they were entitled to borrow up to the maximum loanable amount. The next-round loan became available conditional on the repayment of the first round. The GUK accepted loan applications in May and commenced credit disbursement in early July. We provided the following four different products.

Traditional microcredit (T1): This is the standard microcredit product that the GUK had implemented elsewhere. The full loan amount was disbursed at the beginning of the crop season (July). Borrowers were liable to repay the loan in regular weekly installments of equal amounts, beginning from the first month after loan disbursement. The loan matured after harvest when the borrowers had to pay the last installment. This implies that out of a total of 24 weekly installments, 22–23 installments were required to be completed before harvest, rendering the value of Q in our model negative. This illustrates the drawback of the current microcredit program. While it intends to help farmers finance their investment, it instead reduces the resources available before harvest. This indicates that farmers who used this loan may have borrowed for purposes other than agricultural investment.

Crop credit (T2): This product removes the weekly installment from traditional microcredit (T1). The borrowers were required to repay the full amount at the end of the harvesting period, which corresponded to the due date of the last installment in T1. Thus, a farmer who borrowed 10,000 BDT at the beginning of the crop-cycle was required to repay 11,200 BDT in a single payment at the end of the cycle (in December). The product corresponds to the case of $\pi = 0$ and $M_1 = M$ in our model above.

Sequential credit (T3): This product modifies T2 by changing the disbursement schedule. To match the sequence of agricultural investment, the disbursement was divided into three phases. Based on the bookkeeping exercise in the pilot survey, we set the limit of the first disbursement at 60% of the maximum loan size so that the remaining 40% was still available for late-stage investment. Hence, a borrower could choose the amount of the first disbursement such that $M_1 \leq 0.6\overline{M}$. At the time of the second disbursement (one month after the first disbursement), borrowers could receive up to 20% of the loanable amount in addition to the unused loanable amount at the first disbursement. This means that borrowers could receive up to 80% of the loanable amount by this time. The third and final disbursement was made one month after the second disbursement.[20] At each disbursement, borrowers could decide the amount that they receive within the specified limit. While our model has assumed $M_2 = M - M_1$, the field team incorporated further flexibility by allowing $M_2 < M - M_1$, that is, borrowers can adjust the loan size ex post, which we will revisit

[20]Typically, the first disbursement began in early July, the second in mid-August, and the third in early October.

in a later section.[21]

Sequential in-kind credit (T4): This product intends to strengthen the commitment function of T3 by disbursing the credit in kind such as seed and fertilizer (valued within the loanable amount). In T3, borrowers may overconsume by using the disbursed credit. T4 aims at preventing overconsumption by disbursing the credit in investment goods. The GUK partnered with reputed local agricultural dealers to implement the in-kind credit distribution through pre-approved vouchers for fertilizers, seeds, pesticides, herbicides, and vitamins.[22] As in T3, the vouchers were distributed sequentially, with the value of the first disbursement (M_1) to be no more than 60% of the maximum loan size $\overline{M}$ and that of the second disbursement to be no more than $0.8\overline{M} - M_1$. The first and second disbursements were fully in kind, but the third installment was in cash to cover harvesting and crop processing-related activities.

For all the group members, the GUK conducted weekly meetings to monitor group activities and to facilitate loan collection for those who were repaying weekly.[23] During the weekly meeting, the GUK also encouraged borrowers to save and provided a savings deposit service, although there was no mandatory savings amount. Members in the control group (described in the next section) could use the savings deposit service of the GUK. This design, however, prevents us from inferring the outcome under crop credit and sequential credit without regular weekly meetings.

3.4 Randomization and balance tests

After collecting the baseline data, we randomly assigned 200 members (4 members per group) to each of the four credit products (T1–T4) for the *Aman*-cropping season in 2015. The remaining 200 members served as the control group.[24] Since the outcome variables of our interests are investment and production, we stratified the members based on the score of economic status that would correlate with the latent productivity. Specifically, we computed the score by factor analysis, wherein we included indicators for owning agricultural lands, owning livestock, owning productive

[21] Without uncertainty as in our baseline model, this modification does not affect the solution of the model.

[22] These are the inputs recommended by the Agriculture Department of Bangladesh for rice production.

[23] Armendáriz de Aghion and Morduch (2010) discuss the importance of the regular group meetings to sustain the repayment rate.

[24] See Appendix Figure 7. The capacity constraint of expanding branches in the field limited the total sample size. We had repeated discussions on whether to include the sequential in-kind treatment (T4) given the relatively small sample size. Given that removing T4 results in 250 farmers in each arm instead of 200 and smaller standard errors only by 12%, we finally decided to include T4 to examine the role of commitment and flexibility. With the power of 0.8 and a significance level of 0.05, the minimum detectable effect size (MDE) when assuming an i.i.d. data generating process is 0.28 standard deviation (the MDE would have been 0.25 if we had included 250 farmers in each arm). Hence, we did not expect to detect significant effects on noisy variables such as income and profits. We report the MDE to facilitate the interpretation of the statistical results when the outcomes were noisy.

assets, borrowing money in the last three years, having electricity connection, having a latrine toilet, housing conditions (if the house is made of mud), the area of agricultural land, and the years of education.[25] We stratified five households with similar scores and randomly divided them into five different experimental groups.

There exist potential spill-over effects within group members, especially through informal transactions with other borrowers in the same group. However, during the pilot, we did not detect such transactions. Moreover, we also asked the respondents to list any informal cash or in-kind transfers to other group members in the baseline and follow-up survey, finding no such transactions. We cannot deny the existence of other spill-over channels, such as spending more carefully to finance investment as a result of observing the behavior of members in other intervention arms; however, we believe that such spill-over effects are small. Furthermore, the spill-over effects, if any, will likely reduce the difference across treatments, making our estimates conservative ones.

The average uptake rate was 56.1% based on the whole sample as shown in Table 3. Excluding the farmers in the control group who were not offered the credit, the average uptake rate was 70%, which is relatively high, reflecting the fact that our sample consists of the farmers in the self-formed borrowing groups who exhibited an interest in taking out loans.[26]

The average loan size among the borrowers was 16,095 BDT (196.4 USD). The smallest loan size was 5,500 BDT in traditional microcredit and crop credit, and 3,360 BDT in sequential credit. The maximum loan size was 27,300 BDT. We excluded two observations from the analysis that reported that the area of the tenanted land in the follow-up survey was low to the point that their inferred maximum loanable amounts were less than 3,000 BDT,[27] since they likely did not report all the plots they cultivated, and thus, we would undervalue their total investment and output. For most borrowers, the actual loan size was strictly less than the inferred maximum loanable amount (Appendix Figure 8), implying that the constraint $M \leq \overline{M}$ was not binding in most cases.

The weather condition in the surveyed year caused the delay in the harvest, which affected the repayment performance. Many borrowers did not finish harvesting on the loan due date and the GUK extended the due date by three weeks (extended due date). However, 48.7% of the borrowers could not repay on this due date. Then, the GUK expended intensive efforts to ensure repayment

[25]To minimize the time for data collection for stratification, we asked local enumerators to first enter the information of these listed variables immediately after the household survey. The rest of the data were entered over several months to minimize data entry errors.

[26]Relatively high uptake rates among potential borrowers who had exhibited their interests in the loan were also observed in previous studies (Attanasio et al., 2015). Since some farmers might have shown an interest to keep the option of borrowing, it is not surprising to observe the imperfect uptake. Moreover, the uncertainty of receiving the loans might induce some of them to find other borrowing sources such as their family members and neighbors.

[27]We have no data on the loanable amount that the GUK actually imposed. We inferred the loanable amount based on the area of the tenanted land reported in the follow-up survey

and set the final due date one week after the extended due date. We defined the loans not fully repaid by the extended due date as the loans in arrears, and those not fully repaid by the final due date as defaulted loans. The default rate was 11.8%, which is relatively high compared to standard microcredit programs elsewhere. Note that some borrowers in traditional microcredit failed to pay the weekly installment and were allowed by the GUK to repay later and access future loans if they repaid all the loans by the final due date. Therefore, the weekly installment was not strictly implemented in the field, which would diminish the difference in the traditional microcredit (T1) and crop credit (T2).

Table 4 shows the results of the balance tests, where we regress some of the baseline characteristics on the treatment status. Note that the coefficient on the in-kind captures the differential effect for T4 compared to T3.[28] While we do not find significant differences across treatment groups in most baseline characteristics, there are significant differences in savings amounts between the control group and the other treatment groups. The control group had significantly lower levels of the savings. However, these standardized differences never exceed 0.2, and the characteristics are well balanced across the different treatment groups. In the analysis, we always include the baseline savings in the regression as the control.

4 Results

To investigate the impact of modifying the repayment and disbursement schedule, we estimate the following regression:

$$y_{ij}^F = \gamma_0 + \gamma_1 y_{ij}^B + \mathbf{T}_{ij}\boldsymbol{\tau} + \mathbf{X}_{ij}\boldsymbol{\gamma}_x + \gamma_F FS_{ij} + \zeta_j + \epsilon_{ij}$$

where y_{ij}^F is the outcome variable at the follow-up survey of the household i in the borrowing group j, y_{ij}^B is the lagged dependent variable measured at the baseline survey, $\mathbf{X}_{ij}$ the set of the control variables, FS_{ij} the factor score used for the randomization, ζ_j the group fixed effects, and ϵ_{ij} the error terms. We select the control variables included in the regression by post-double-selection (PDS) lasso proposed by Belloni et al. (2014). In the PDS, we include the baseline values of productive and non-productive assets (transformed into logarithms), livestock assets (transformed by the inverse-hyperbolic function), owned land area, tenanted land area, borrowing amount, saving amount, first and second investment, total output, the total income excluding the farm income, and their squared terms and interaction terms. Note that, as mentioned before, we always include the saving amount as the control. $\mathbf{T}_{ij}$ is a vector of indicators for each treatment, including traditional

[28] The variable named `Sequential` takes the value of 1 for the group offered sequential credit (T3) or sequential in-kind credit (T4), and 0 otherwise; and the variable named `in-kind` takes the value of 1 if offered T4, and 0 otherwise.

Table 4: Balance tests

	(1) Asset	(2) Tenancy area	(3) Borrowing	(4) 1st invest	(5) 2nd invest	(6) Output	(7) Other income	(8) Saving
Traditional	-0.025	-1.671	374.737	215.773	186.332	-247.121	-4415.046	567.995*
	(0.087)	(1.521)	(487.325)	(235.458)	(174.763)	(1016.439)	(4738.012)	(275.755)
Crop Credit	-0.030	-0.404	-104.288	333.130	83.633	-133.321	-2244.266	520.355**
	(0.088)	(1.540)	(415.657)	(242.937)	(176.209)	(1059.764)	(5036.563)	(191.771)
Sequential	0.023	0.030	167.598	338.879	169.472	563.970	-6486.131	637.935**
	(0.089)	(1.548)	(417.037)	(231.750)	(170.732)	(1026.573)	(4390.729)	(242.852)
In-kind	0.001	0.336	-210.446	-39.572	15.900	371.109	-41.780	-51.360
	(0.087)	(1.463)	(586.255)	(231.755)	(176.532)	(1015.672)	(4121.595)	(334.476)
Observations	998	998	998	998	998	998	998	998
Mean_Control	12.492	78.063	1594.405	7621.700	4383.276	31657.050	1.00e+05	1250.965
SD_Control	0.850	14.002	5614.285	2318.703	1824.851	9798.711	45688.444	3350.160
Trad_vs_Crop	0.960	0.374	0.340	0.625	0.578	0.912	0.657	0.861
Trad_vs_SeqCash	0.579	0.236	0.681	0.590	0.925	0.414	0.624	0.821
Trad_vs_SeqKind	0.566	0.155	0.513	0.723	0.996	0.240	0.638	0.959
Crop_vs_SeqCash	0.551	0.766	0.531	0.981	0.635	0.502	0.352	0.621
Crop_vs_SeqKind	0.539	0.597	0.916	0.889	0.576	0.309	0.373	0.825

The table reports the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$. The lower panel indicates the p value for the null hypothesis that the coefficients of the corresponding treatment indicators are the same.

microcredit with weekly installment (T1), crop credit (T2), and sequential credit (T3 and T4). We also add an indicator for the in-kind credit, whose coefficient captures the differential effect of T4 compared to T3. We use the HC3 robust standard errors (MacKinnon and White, 1985) given that the treatment was randomized at the individual level (Abadie et al., 2022).[29]

For the outcomes which are not relevant for the control group, such as uptake, we estimate:

$$y_{ij}^F = \gamma_0 + \mathbf{T}_{ij}^S \boldsymbol{\tau} + \mathbf{X}_{ij}\boldsymbol{\gamma}_x + \gamma_F FS_{ij} + \epsilon_{ij} \tag{8}$$

where $\mathbf{T}_i^S$ is a vector of indicators for each treatment other than traditional microcredit, which is set as the reference category. For these outcome variables, there are no baseline values available and hence the lagged dependent variable is not included in the regression equation.

4.1 Uptake

Table 5 reports the results on loan uptake using regression equation (8).[30] As predicted by the theory, removing the weekly installment payments increased uptake. Compared to traditional microcredit, crop credit and sequential credit achieved a higher uptake rate by 10.5 percentage points and 8.3 percentage points, respectively. Replacing cash disbursement in sequential credit by in-kind disbursement did not improve the uptake rate significantly, but its coefficient is relatively large. There were no significant differences in the uptake rates between crop credit and sequential credit (either cash or in-kind).

Although our sample comprises the farmers who expressed interest in borrowing, it is surprising that nearly 60% of the farmers who were offered traditional microcredit with negative Q took the loan. This suggests that many farmers do not borrow only to finance agricultural investments. Additionally, this may explain the lack of a strong positive impact of removing the weekly installment on investment, as discussed later.

[29] One might be tempted to estimate the local average treatment effects (LATE) by using the treatment variables as the instruments. However, the LATE estimates the average treatment effects (TE) over the people who switched to using the credit due to the treatment assignment, and these switchers will not be comparable across the treatment arms. Suppose farmers with greater TE are more likely to uptake the loan. As the regular repayment will discourage borrowers with low TE from taking up the loans, only those with high TE will uptake the loan. Then, even if the average TE are the same across the products, the LATE will be greatest for regular repayment credit, implying that the LATE is not a meaningful parameter in our case.

[30] The numbers in the lower panel are the p-values against the null hypothesis that the impacts are equal. Consider the regression equation

$$y_{ij}^F = \gamma_0 + \gamma_1 y_{ij}^B + \tau_C C_{ij} + \tau_S S_{ij} + \tau_K K_{ij} + \delta_0 PB_{ij} + \delta_C PB_{ij} \cdot C_{ij} + \delta_S PB_{ij} \cdot S_{ij} + \delta_K PB_{ij} \cdot K_{ij} + \mathbf{X}_{ij}\boldsymbol{\gamma}_x + \epsilon_{ij}$$

where C_{ij}, S_{ij}, K_{ij}, and PB_{ij} are indicators for crop credit, sequential credit, the in-kind disbursement, and PB farmers. The p-value reported in the row `PB_Crop_vs_SeqC`, for example, is against the null $H_0 : \tau_C + \delta_C = \tau_S + \delta_S$.

Table 5: Uptake and loan size

	(1) Uptake	(2) Uptake (low other income)	(3) Uptake (high other income)	(4) Uptake	(5) Loan size	(6) Loan size	(7) Loan size	(8) Loan size
Crop Credit	0.105*	0.135*	0.053	0.099	-10.878	-146.625	-313.192	-469.897
	(0.042)	(0.061)	(0.073)	(0.071)	(488.283)	(486.281)	(719.168)	(704.116)
Sequential	0.083*	0.037	0.031	0.080	-1256.512**	-1429.412**	-1906.040**	-2162.051**
	(0.041)	(0.069)	(0.071)	(0.068)	(455.571)	(440.824)	(642.715)	(624.022)
In-kind	0.068	0.152*	0.073	0.052	-574.932	-628.923	202.284	274.520
	(0.037)	(0.067)	(0.059)	(0.062)	(347.878)	(353.290)	(549.723)	(550.836)
PB=1				-0.007			-591.054	-388.489
				(0.066)			(789.403)	(764.149)
Crop Credit × PB=1				-0.012			655.020	646.191
				(0.089)			(1038.521)	(1011.621)
Sequential × PB=1				-0.008			1193.599	1306.182
				(0.088)			(948.752)	(910.236)
In-kind × PB=1				0.027			-1304.520	-1533.404*
				(0.081)			(764.092)	(761.126)
Observations	799	326	312	788	560	559	551	550
Mean_Control	0.595	0.570	0.616	0.595	16910.420		16910.420	
Crop_vs_SeqCash	0.570	0.112	0.748	0.767	0.001	0.001	0.009	0.006
Crop_vs_SeqKind	0.219	0.355	0.410	0.603	0.000	0.000	0.029	0.028
PB_Trad_vs_Crop				0.097			0.630	0.802
PB_Trad_vs_SeqC				0.183			0.285	0.180
PB_Trad_vs_SeqK				0.004			0.008	0.002
PB_Crop_vs_SeqC				0.758			0.038	0.040
PB_Crop_vs_SeqK				0.182			0.000	0.000

The table reports the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. We include the baseline outcome, group dummies, baseline savings, and variables selected by post-double-selection (PDS) lasso as control. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$. The lower panel indicates the p value for the null hypotheses that the coefficients of the corresponding treatment indicators are the same.

The theory also implies that the impact of regular repayment on uptake will be large among farmers with low endowment or low other income. In columns (2) and (3), we run the regression for the subsample with low total other income at the baseline (lower than the 40 percentile) and the subsample with high total other income (higher than the 60 percentile).[31], finding the results consistent with the theory. Although we found no significant impact of the sequential cash credit on the uptake in either of these subsamples, the overall results suggest that the weekly installment requirement limits the outreach of microcredit among farmers without sufficient steady income.

In column (4), we investigate if the modified lending schemes attracted more demand from the PB farmers by including the interaction terms with the indicator for being PB.[32] We found no significant difference in uptake decision between time-consistent farmers and PB farmers in any credit schemes. While sequential credit could provide the commitment functions for PB borrowers, it did not significantly improve the uptake rates over crop credit. This could be explained by the small difference in the total utility between crop credit and sequential credit as presented in the numerical exercises (when $\gamma = 2$ or $\beta = 0.8$) in Section 2.2.

4.2 Loan size

Column (5) of Table 5 reports the impact on the loan size. Since we only observe the loan size for those who availed credit, the analysis is based on the selected sample of the uptakers. To address the sample selection problem, we also report the results using the inverse probability weighting (IPW) (Robins et al., 1995; Wooldridge, 2010) in column (6).[33]

Removing the weekly repayment (crop credit) did not significantly lower the loan size. While correcting the sample selection by the IPW makes the results rather consistent with the prediction of our numerical exercises, we cannot find a significant decline in the loan size in crop credit compared to traditional microcredit. Only using the sample with low total other income does not substantially change the results. Note that the direction of $\frac{\partial M^*}{\partial Q}$ is in general undetermined and

[31] The results are similar when we divide the sample by the median.

[32] The PB indicator was constructed from hypothetical questions as in Ashraf et al. (2006). This measure might not be precise, causing attenuation bias. We cannot identify if a respondent is sophisticated or naive from these questions. Hence the results related to the present bias should be interpreted with caution.

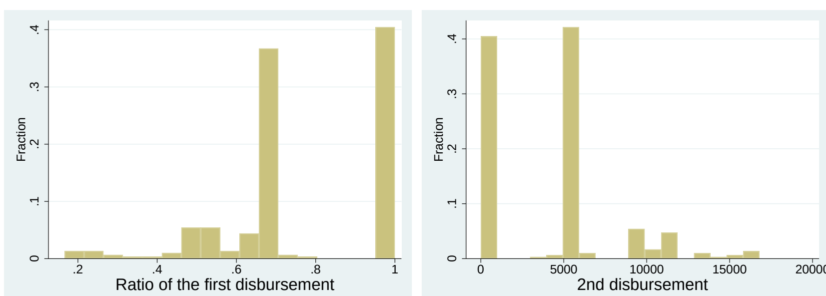
[33] We include, as the predictors for the sample selection, all the covariates of the regression and the uptake rate and average loan size of the other group members. We estimate the uptake decision for each treatment group by probit and run the regression for equation (8) using the inverse of the estimated uptake probability as the weight (we do not include the group fixed effect in estimating the uptake probability due to the perfect predictivity). This procedure intends to balance the characteristics of the uptakers across the treatment arms. The identifying assumption is that, conditional on these variables, the uptake decision is independent of the other factors than $\mathbf{X}_{ij}$ that determines the loan size. We do not report the control mean in the table as reporting the weighted mean of traditional microcredit is not very meaningful.

depends on the functional form of F and u.[34] Hence, the results do not contradict the prediction of the theory.

A striking finding is that sequential credit substantially reduced the loan size. Compared with crop credit, it reduced the loan size by 1,246-1,380 BDT or 7.4%–8.2% (columns (5) and (6)).[35] When combined with the in-kind disbursement, it reduced the loan size by 10.7%–11.8% compared to crop credit. The reduction in loan size under sequential cash credit was driven by time-consistent borrowers (columns (7) and (8)). For PB borrowers, the reduction in loan size was achieved when the credit was disbursed sequentially in kind (stronger commitment).

To explore the smaller loan size under sequential credit, we draw the distribution of $\frac{M_1}{M} = \frac{M_1}{M_1+M_2}$ in the left panel of Figure 3. As explained in Section 3.3, the borrower could choose the first disbursement M_1 subject to $M_1 \leq 0.6\overline{M}$, and the second disbursement M_2 subject to $M_2 \leq \overline{M} - M_1$. The value of $\frac{M_1}{M}$ is greater than 0.6 when $M_2 < \overline{M} - M_1$, and equal to 1 when $M_2 = 0$. The figure shows that most of the borrowers chose $M_2 < \overline{M} - M_1$ and furthermore, 40% of the borrowers chose $M_2 = 0$. In contrast, some borrowers recorded quite a low value of M_1/M, indicating small M_1 and large M_2. The right panel of Figure 3 depicts the distribution of M_2, showing that while many borrowers chose $M_2 = 0$, a fraction of borrowers recorded a fairly large M_2.

Figure 3: Distribution of $\frac{M_1}{M}$ and M_2



We argue that these results—a smaller loan size under sequential credit and the pattern of the second disbursement M_2 mentioned above—can be explained by the option value provided by sequential disbursement. We defer the model with the option value to the next section, and briefly explain its essence here. Between loan application and repayment, borrowers may experience a variety of shocks, such as productivity shocks and expenditure shocks. In standard credit or crop credit, where credit is disbursed upfront, borrowers must decide the loan size at the time

[34] See footnote 12. Also refer to footnote 51 of Appendix A.1.1 for the expression of $\frac{\partial M^*}{\partial Q}$.

[35] Appendix Figure 9 depicts the cumulative distribution and kernel density of the residualized loan size for each treatment group, showing that the sequential credit shifted the distribution to the left. Kolmogorov–Smirnov tests reject the equality of distributions of the loan size between sequential credit and crop credit, or between sequential credit and traditional microcredit, at the 1% level.

of application. This rigidity causes precautionary borrowing: borrowing a precautionary fund for potential shocks. Sequential disbursement allows borrowers to determine the total loan size after observing these shocks, eliminating the precautionary borrowing, and resulting in better investment decisions. Borrowers concerned about a potentially large shock at $t = 1$ will choose large M_1 for some buffer, and then choose small M_2 after observing no shocks.[36] In contrast, borrowers who believe the shock at $t = 1$ is small, if any, choose small M_1 to leave enough room for adjustment at $t = 2$.

PB borrowers still face the overconsumption problem at $t = 2$ under sequential disbursement: they could consume more by borrowing more at $t = 2$. Disbursing the credit in kind could alleviate this problem as the borrower would not be able to increase consumption by borrowing more unless they resell the in-kind disbursement. This commitment function would lower the loan size for PB borrowers, as found in columns (7)–(8) in Table 5.

One may be concerned that the second disbursement had a shorter maturity than the first disbursement, which made the effective interest rate for the second disbursement greater and may explain the smaller loan size under sequential credit. However, this cannot explain the behavior of borrowers choosing small M_1 and large M_2. Furthermore, as many borrowers chose $M_2 = 0$, explaining the smaller loan size solely by the higher effective interest rate requires an extremely large price elasticity that cannot be supported by existing literature (Dehejia et al., 2012; Karlan and Zinman, 2019).

One may also argue the restriction $M_1 \leq 0.6\overline{M}$ constrained the first investment, which reduced the marginal productivity of the second investment, which in turn resulted in the lower total loan size. However, this cannot explain why some farmers chose M_1 much lower than $0.6\overline{M}$. Furthermore, as shown below, sequential credit resulted in a greater first investment and did not reduce the second investment, which contradicts the prediction of this argument.

Note that there are no significant differences in the impacts on borrowing from other sources across treatment arms (Appendix Table 1), either from other MFIs or non-MFI borrowing sources. This implies that access to other financial services were limited in this region,[37] and the differential effects on the loan size were not caused by the change in the debt composition.

[36] This may resemble the demand for flexibility. However, the flexibility motive alone cannot explain the smaller loan size under sequential credit.

[37] Appendix A.1.2 shows that removing the regular installment (an increase in Q) will reduce the borrowing from other sources among borrowers. The increase in the uptake induced by the removal of the regular installment should also reduce the borrowing from other sources as the GUK loans will substitute the latter.

4.3 Investment, output, profit

We turn to the impact on investment. Our theory predicts that removing the weekly installment will increase both first and second investment, and our regression results are somewhat consistent with this prediction. Farmers in crop credit and sequential credit groups made more first-stage investments than those in the control or traditional microcredit groups (Table 6, column (1)), though the effect for the former was smaller and less significant.[38] Among time-consistent farmers, both crop credit and sequential credit significantly increased the first investment compared to traditional microcredit (column (2)). Among PB farmers, sequential credit significantly increased the first investment compared to the control group ($p = 0.01$).

Note that among time-consistent borrowers, none of the credit programs significantly increased investment relative to the control group. This is consistent with our earlier argument that many farmers may have used the loans for purposes other than agricultural investment. Although traditional microcredit would not increase the resources available before harvest, many farmers took this product. Since they had been engaged in crop production for many years without formal financial access, they were likely able to finance their investments without financial products. After the follow-up survey, we conducted an informal interview with farmers in the control group to ask how they had financed the investment; their typical response was that they had somehow managed to finance the investment, without specifying any particular means. The survey also asked about various financial transactions, but few mentioned transactions other than microcredit, such as borrowing from relatives or friends (2.3%) and from moneylenders (1.2%). Appendix Table 1 shows that neither of borrowing from other sources nor net money inflow — borrowing from other sources plus wage income minus savings — was significantly affected by our interventions. Because the poor tend to make extensive use of available financial services (Collins et al., 2009), some financial transactions may be missing from our survey data. Nonetheless, these quantitative results and informal interviews suggest that many farmers were not severely credit constrained in agricultural production.

Columns (3) and (4) present the results for the second investment. No significant differences in the average second investment across the treatment groups were observed (column (3)), but among PB farmers, sequential credit significantly increased the second investment compared to the control and crop credit groups ((column (4)), $p = 0.025$ and $p = 0.077$, respectively), consistent with the model prediction on the commitment function of sequential disbursement. In Appendix Table 2, we run the regression for the subsample with low total other income at the baseline (below the 40th percentile) and the subsample with high total other income (above the 60th percentile) and

[38]The p-value for the null hypothesis that group T2 (crop credit) and the control group have the same amount of the first investment is 0.078 and that for the null comparing T2 and T1 (traditional microcredit) is 0.206.

Table 6: Investment and output

	(1) Invest:1st	(2) Invest:1st	(3) Invest:2nd	(4) Invest:2nd	(5) Output	(6) Output	(7) Profit	(8) Profit
Traditional	43.282	-145.522	10.582	-128.083	295.690	-478.742	-142.346	-6.395
	(84.918)	(143.318)	(88.464)	(140.251)	(461.989)	(640.704)	(354.746)	(565.477)
Crop Credit	150.939	118.346	57.245	-30.576	654.705	362.868	35.854	114.052
	(85.769)	(153.456)	(87.760)	(150.808)	(478.357)	(630.700)	(372.224)	(545.089)
Sequential	277.642**	220.854	114.288	-110.749	786.160	243.211	-89.562	213.134
	(90.631)	(154.796)	(91.412)	(146.465)	(485.258)	(646.985)	(398.904)	(551.137)
In-kind	-69.597	5.954	-20.000	36.421	-463.466	-711.908	-168.227	-518.567
	(91.449)	(152.104)	(95.778)	(152.989)	(446.565)	(673.552)	(384.286)	(560.833)
PB=1		-71.431		-255.726		-517.170		257.303
		(134.766)		(140.541)		(705.106)		(532.372)
Traditional × PB=1		275.276		234.099		1335.017		-45.270
		(186.203)		(192.138)		(913.097)		(741.222)
Crop Credit × PB=1		41.829		114.921		588.073		44.954
		(191.185)		(196.532)		(893.023)		(734.348)
Sequential × PB=1		79.174		396.252*		928.747		-379.952
		(199.156)		(201.291)		(975.416)		(801.474)
In-kind × PB=1		-103.184		-91.214		429.817		567.934
		(193.273)		(198.565)		(911.598)		(750.604)
Observations	998	986	998	986	998	986	998	986
Mean_Control	7466.127	7466.127	4375.584	4375.584	33568.040	33568.040	5866.647	5866.647
Trad_vs_Crop	0.206	0.072	0.582	0.512	0.372	0.199	0.580	0.829
Trad_vs_SeqCash	0.009	0.015	0.243	0.906	0.240	0.281	0.884	0.699
Trad_vs_SeqKind	0.049	0.006	0.362	0.722	0.950	0.988	0.732	0.604
Crop_vs_SeqCash	0.175	0.534	0.521	0.606	0.761	0.856	0.729	0.859
Crop_vs_SeqKind	0.509	0.464	0.689	0.778	0.450	0.219	0.389	0.448
PB_Trad_vs_Crop		0.783		0.840		0.859		0.607
PB_Trad_vs_SeqC		0.143		0.131		0.588		0.813
PB_Trad_vs_SeqK		0.513		0.294		0.952		0.874
PB_Crop_vs_SeqCash		0.223		0.077		0.717		0.518
PB_Crop_vs_SeqKind		0.699		0.197		0.916		0.520

The table shows the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. We include the baseline outcome, group dummies, baseline savings, and variables selected by post-double-selection (PDS) lasso as control. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$.

find positive impacts of sequential credit on the first and second investments for borrowers with low total other income.[39] These indicate that PB farmers may have faced credit constraints, especially at a later stage. Since an increase in the second investment increases the marginal productivity of the first investment, the expectation that farmers will be able to make a sufficient level of second investment owing to the sequential disbursement could induce them to increase the first investment.

Columns (5) to (8) of Table 6 report the impacts on output and profit. As these outcome variables are noisy and our sample size is rather small, the MDE tends to be large, and we do not find any significant differences across the treatment arms. For example, the MDE for sequential credit versus control is 1116.9, which corresponds to a 19% increase in profit.[40] Given that the impact of microcredit on profits has been modest or insignificant in most previous studies (Augsburg et al., 2015; Banerjee et al., 2015) and its impact on investment was modest (columns (1)–(4)) in this study, it is not surprising that we did not find a significant impact on profit given our relatively small sample size.

4.4 Savings and repayment

Column (1) of Table 7 shows the impact on the amount of saving based on the household survey. Compared to the control group, households in the treatment groups achieved higher savings. Present bias did not significantly affect the pattern of the savings (Appendix Table 3). Given the result that the credit did not significantly increase output, we attribute the positive impact on savings to the GUK's encouragement of savings. In fact, the estimates are quite close to the regression with savings at NGOs as the outcome (columns (3)–(4) of Appendix Table 3), implying that the increased savings are mainly driven by the savings at NGOs, especially GUK.

Note that sequential credit had a smaller impact on the amount of saving compared to traditional microcredit and crop credit. This can be explained by precautionary borrowing with mental accounting and the GUK's encouragement of savings. With a lump-sum disbursement, borrowers would borrow or save more for precautionary purposes. With mental accounting and the GUK's encouragement, they would be less likely to withdraw the deposited money. To observe this effect, column (2) examines the amount deposited into the GUK savings account in the first three months (July–September) based on the borrowers' monthly administrative records. Even in sequential credit, the full amount of the loan was disbursed by the end of August.[41] Allowing one month for sequential credit borrowers to save additional money after receiving the second disbursement, we

[39]We do not include an indicator for PB in these subsample regressions because the sample size is small and the identification of the coefficients depends on a limited number of observations.

[40]If we were to implement three treatments instead of four (by removing the sequential in-kind as discussed in footnote 24), then the MDE would be 999.0, which is still large.

[41]The second disbursement was completed around mid-August, and no borrowers received the third disbursement.

Table 7: Savings and repayment performance

	(1) Saving	(2) Savings at MFI in Jul-Sept	(3) Net savings at MFI	(4) Arrear	(5) Arrear	(6) Default	(7) Default	(8) Uncollected: OLS	(9) Uncollected: Tobit
Traditional	1271.443**								
	(152.357)								
Crop Credit	1370.094**	40.199	54.823	-0.074	-0.092	-0.018	-0.028	0.005	0.019
	(130.947)	(69.155)	(65.526)	(0.061)	(0.060)	(0.042)	(0.045)	(0.029)	(0.205)
Sequential	1093.327**	-364.123**	-242.479**	-0.070	-0.090	-0.024	-0.031	0.001	-0.135
	(138.447)	(66.845)	(60.875)	(0.060)	(0.059)	(0.044)	(0.046)	(0.031)	(0.213)
In-kind	26.631	-170.041**	-14.064	-0.051	-0.071	-0.014	-0.036	0.000	0.062
	(119.543)	(56.110)	(44.047)	(0.056)	(0.054)	(0.038)	(0.038)	(0.026)	(0.208)
Observations	998	560	560	560	558	560	558	560	560
Mean_Control	266.884	1749.202	2432.437	0.588		0.160		0.094	0.094
Trad_vs_Crop	0.649								
Trad_vs_SeqCash	0.431								
Trad_vs_SeqKind	0.517								
Crop_vs_SeqCash	0.012	0.000	0.000	0.946	0.976	0.884	0.941	0.881	0.458
Crop_vs_SeqKind	0.037	0.000	0.000	0.389	0.196	0.584	0.292	0.882	0.643

The table shows the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. We include the baseline outcome, group dummies, baseline savings, and variables selected by post-double-selection (PDS) lasso as control. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$.

examined the amount of savings during July–September. The results supported our story. Sequential credit borrowers saved significantly less than traditional microcredit and crop credit borrowers by 10%. Including the interaction terms with the present bias indicator or correcting for sample selection by the IPW did not change the results (Appendix Table 3). Net savings at the MFIs at the follow-up survey (column (3)) were still lower for sequential credit, but the difference became smaller.

Columns (4)–(9) of Table 7 report the repayment performance. The outcome variable in columns (4) and (5) is an indicator for the loans in arrears, where we applied the IPW in column (5) to mitigate the sample selection bias. There are no significant differences across treatment arms. Columns (6) and (7) report the results for default (repayment not completed one week after the due date). The average default rate in traditional microcredit was 16.0%, and more flexible schemes such as crop credit and sequential credit did not worsen the default rate.

Columns (8) and (9) present the results on the ratio of uncollected loan amount. Since the MFI could confiscate the savings in the MFI savings account, the ratio of uncollected loan amount was calculated as

$$\text{ratio of uncollected loan amount} = 1 - \frac{\text{Amount repaid} + \text{Net savings at MFI}}{\text{Total amount to be repaid}}.$$

Since there are many observations wherein this value is zero, we also use the Tobit model. Both the ordinary least-squares (OLS) (column (8)) and Tobit (column (9)) show no significant differences across the treatment groups.

In any of the measures, modifying the repayment and disbursement schedule did not worsen the repayment performance.[42] Including the interaction terms with the present bias indicator does not change the results (Appendix Table 4). Hence, eliminating the timing mismatch can achieve greater financial inclusion without worsening financial sustainability, especially for farmers with lower steady income flows. While proponents of the weekly installment model emphasize its importance in keeping repayment rates high, our results do not support this view. At least in the agricultural setting, which is characterized by infrequent, lumpy income flows at harvest, allowing a one-time repayment after harvest does not harm repayment performance and increase uptake.

4.5 Uptake in the second round and satisfaction

Finally, we investigate the satisfaction with these new credit schemes. Columns (1) and (2) in Table 8 report the loan uptake in the second round when they were offered the same product as the first round. A higher uptake rate would reflect high borrower satisfaction. The uptake rate of traditional

[42] This result is consistent with that of Aragón et al. (2020), who found that the flexible credit program did not worsen the repayment rates.

microcredit was 44% at the second round, while crop credit and sequential credit achieved higher uptake rates by 10-12 percentage points. As in the first round, there were no systematic differences in the second-round uptake rate between time-consistent and PB borrowers.

Columns (3) to (6) report the results on the level of satisfaction reported by the borrowers. We use the OLS in columns (3) and (4), and the IPW in columns (5) and (6) to control for the sample selection. The borrowers of crop credit reported the greatest satisfaction, followed by those of sequential cash credit and then the sequential in-kind credit.

Table 8: Uptake in the second round

	(1)	(2)	(3)	(4)	(5)	(6)
	Uptake:2nd	Uptake:2nd	Satisfaction	Satisfaction	Satisfaction	Satisfaction
Crop Credit	0.121^{**}	0.111	1.891^{**}	1.766^{**}	1.838^{**}	1.788^{**}
	(0.046)	(0.080)	(0.111)	(0.199)	(0.101)	(0.175)
Sequential	0.096^{*}	0.122	1.092^{**}	0.926^{**}	1.086^{**}	0.947^{**}
	(0.046)	(0.079)	(0.108)	(0.201)	(0.097)	(0.175)
In-kind	0.038	0.050	-0.303^{**}	-0.261	-0.293^{**}	-0.199
	(0.046)	(0.072)	(0.083)	(0.138)	(0.079)	(0.128)
PB=1		0.010		-0.248		-0.178
		(0.075)		(0.212)		(0.185)
Crop Credit × PB=1		0.002		0.213		0.095
		(0.101)		(0.246)		(0.220)
Sequential × PB=1		-0.069		0.259		0.226
		(0.101)		(0.243)		(0.216)
In-kind × PB=1		0.004		-0.076		-0.152
		(0.096)		(0.181)		(0.167)
Observations	799	788	564	555	552	543
Mean_Control	0.440	0.440	2.831	2.831		
Crop_vs_SeqCash	0.590	0.886	0.000	0.000	0.000	0.000
Crop_vs_SeqKind	0.767	0.404	0.000	0.000	0.000	0.000
PB_Trad_vs_Crop		0.055		0.000		0.000
PB_Trad_vs_SeqC		0.375		0.000		0.000
PB_Trad_vs_SeqK		0.081		0.000		0.000
PB_Crop_vs_SeqC		0.303		0.000		0.000
PB_Crop_vs_SeqK		0.918		0.000		0.000

The table reports the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. We include the baseline outcome, group dummies, baseline savings, and variables selected by post-double-selection (PDS) lasso as control. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$.

Note that some borrowers were not satisfied with the implemented sequential disbursement. Among borrowers of sequential credit (T3 and T4), only 18% listed the sequential disbursement as their reason for satisfaction, and 5% reported that they were dissatisfied with it. While we do not know exact reasons for such dissatisfaction, this indicates the need to ascertain the cost to the borrower of the sequential disbursement, and to carefully design the timing and amount of each disbursement.

5 Option value and precautionary borrowings

5.1 Model

In the previous section, we mentioned the option value of sequential disbursement and the resulting reduction in loan size by eliminating precautionary borrowing. In this section, we model this option value by incorporating productivity shocks and expenditure or income shocks. We sketch the model only for time-consistent borrowers, leaving the full characterization of the solution, including the case of PB borrowers, to Appendix A.2. We then discuss its empirical relevance and present counterfactual policy evaluations to explore better contract design. Note that our model would not fit well to explain the decisions of borrowers who borrowed for non-agricultural production purposes; nevertheless, it provides guidance for considering better credit schemes for financing agricultural investment.

First, we modify the production function as

$$Y = \theta_1 \theta_2 F(K_1, K_2),$$

where $\theta_1 > 0$ and $\theta_2 > 0$ are the productivity shocks revealed at the beginning of period 1 and 2, respectively. We can interpret $\theta_t > 1$, $t = 1, 2$ as the positive shocks and $\theta_t < 1$ as the negative shocks. Second, we introduce expenditure/income shocks ξ_t, $t = 1, 2, 3$, which realized at the beginning of period t. These shocks reduce the resource available for consumption and investment at each period by ξ_t, so the budget constraints at each period become

$$\begin{aligned} c_1 + K_1 &\leq A_1 - \xi_1, \\ c_2 + K_2 &\leq A_2 - \xi_2, \end{aligned} \tag{9}$$

and the income at period 3 is $Y - \xi_3$. Negative values of ξ_t indicate positive income shocks. Hereafter, we refer to ξ_t as expenditure shocks.[43]

[43] The productivity shocks directly affect the investment choice while the expenditure shocks do not. For simplicity, we ignore the productivity shocks that are not observed by period 2 because they do not affect investment decisions.

The timing of the decision-making is summarized in Table 9. We consider crop credit and sequential credit, and then consider two counterfactual policies — SC-SSL and CL — which we explain later.

Table 9: Timing of the decision-making under uncertainties

	$t = 0$	$t = 1$ Observe θ_1, ξ_1	$t = 2$ Observe θ_2, ξ_2	$t = 3$ Observe ξ_3
Production and consumption		* 1st investment K_1 * Consume c_1	* 2nd investment K_2 * Consume c_2	Harvest $Y = \theta_1\theta_2 F(K_1, K_2)$ Consume c_3
Crop	* Decide M	Disburse M		Repay $(1+r)M$
Sequential	* Decide M_1	Disburse M_1	* Receive $M_2 \leq \bar{M} - M_1$	Repay $(1+r)(M_1 + M_2)$
SC-SSL	* Decide M, M_1	Disburse M_1	* Receive $M_2 \leq M - M_1$	Repay $(1+r)(M_1 + M_2)$
Credit lines		* Receive $M_1 \leq \overline{M}$	* Receive $M_2 \leq \bar{M} - M_1$	Repay $(1+r)(M_1 + M_2)$

The asterisk (*) indicates the decisions to be made.

First, consider the choice under crop credit by solving backward. At $t = 2$, a borrower chooses K_2 and c_2 after observing the productivity shock θ_2 and expenditure shock ξ_2. They will choose the second investment K_2^* such that

$$\begin{aligned} &\theta_1\theta_2 F_2'(K_1, K_2^*) = 1 && \text{if the constraint (9) is not binding,} \quad (10)\\ &u'(c_2^*) = \theta_1\theta_2 F_2'(K_1, K_2^*) E[u'(c_3^*)|\mathcal{I}_2] && \text{if the constraint (9) is binding,} \end{aligned}$$

where $\mathcal{I}_2$ is their information set at $t = 2$ including $(\theta_1, \theta_2, \xi_2)$. The constraint (9) will not be binding if they have set A_2 sufficiently high as a precaution against expenditure shocks and positive productivity shocks but eventually find that no such shocks occur. If the constraint (9) is not binding (i.e., they save at $t = 2$), reducing K_2 by 1 unit increases the savings carried over to $t = 3$ by 1, while reducing output at $t = 3$ by $\theta_1\theta_2 F_2'$. Therefore, they choose K_2 so that its marginal product equals 1, as expressed in equation (10). We can also show that they will choose the loan size M at $t = 0$ to satisfy

$$E[u'(c_2^*)] = (1 + r)E[u'(c_3^*)]. \tag{11}$$

Under sequential credit, a borrower can choose the amount of the second disbursement M_2 subject to the constraints

$$M_2 \leq \overline{M} - M_1. \tag{12}$$

$$M_2 \geq 0. \tag{13}$$

after observing $(\theta_1, \theta_2, \xi_1, \xi_2)$. The repayment amount at $t = 3$ is $(1+r)(M_1 + M_2)$. The first-order conditions at $t = 2$ are written as

$$u'(c_2^*) = (1+r)E[u'(c_3^*)|\mathcal{I}_2] + \mu - \nu,$$
$$[\theta_1\theta_2 F_2'(K_1, K_2^*) - (1+r)]E[u'(c_3^*)|\mathcal{I}_2] - \mu + \nu = 0,$$

where μ and ν are the Lagrange multipliers associated with the constraints (12) and (13), respectively. If these constraints are not binding, we obtain

$$\theta_1\theta_2 F_2'(K_1, K_2^*) = 1 + r.$$

By reducing K_2 by 1 unit, they can reduce their repayment at $t = 3$ by $(1+r)$ with reducing output by $\theta_1\theta_2 F_2'$. Now the marginal product of K_2 equals the capital cost $1 + r$, and the investment level becomes optimal.

Based on this decision rule, they choose (c_1, K_1) at $t = 1$ subject to the budget constraints

$$c_1 + K_1 \leq A_0 + M_1 - \xi_1. \tag{14}$$

Let the Lagrange multiplier associated with the constraint (14) be λ. Assuming the inner solution, the choice of M_1 at period 0 satisfies

$$E(\lambda) = E(\nu). \tag{15}$$

Suppose they choose a low M_1. If they found θ_1 or ξ_1 large, the budget constraint (14) is likely to be binding, resulting in too low c_1 and K_1. If, on the contrary, they choose M_1 high, then the budget constraint (14) will not be binding, but they cannot reduce the loan size due to the constraint (13) even when θ_t and ξ_t low. The condition (15) states that they set M_1 to balance these two possibilities.

Under sequential credit, the total loan size is determined at period 2. This means that sequential disbursement changes not only the timing of receiving funds but also the timing of deciding the total loan size, which eliminates the need for precautionary borrowing. If the constraints on M_2, (12)-(13), are not binding, M_2 (and hence, the total loan size) is chosen to satisfy

$$u'(c_2^*) = (1+r)E[u'(c_3^*)|\mathcal{I}_2],$$

where $c_3 = \theta_1\theta_2 F(K_1^*, K_2^*) - \xi_3 - R_3$, and R_3 is the repayment amount at $t = 3$. Now, compare this with the condition under crop credit, (11). Under crop credit, borrowers are concerned with the uncertainty regarding c_2 as expressed in $E[u'(c_2^*)]$ when deciding the loan size. To avoid the situation where c_2 is too small, crop credit borrowers borrow additional amounts as a precaution.

Note that uncertainty about c_3, the level of consumption at period 3, also induces precautionary borrowing. Even under sequential credit, c_3 is still uncertain at $t = 2$ owing to expenditure shocks ξ_3

when deciding M_2. Greater uncertainty in c_3 induces borrowers to borrow less to avoid a situation where income is low but repayment amount is large. Moreover, crop credit borrowers who decide the loan size M at $t = 0$ face more uncertainty about c_3 due to the productivity shocks θ_1, θ_2. The existence of severe productivity shocks will further induce crop credit borrowers to borrow less. Therefore, the impact of sequential disbursement on loan size by reducing precautionary borrowing will depend on the magnitude of potential productivity and expenditure shocks.

5.2 Numerical exercises and counterfactual simulations

As argued above, the level of precautionary borrowing depends on the magnitude of potential productivity and expenditure shocks. Since there exist no closed-form solutions to see this dependence, we use calibrated models to numerically investigate the level of precautionary borrowing motives under plausible degrees of productivity and expenditure shocks. To reduce the computational burden, we consider discrete and i.i.d productivity and expenditure shocks, θ_t, ξ_t, for $t = 1, 2$. We also omit expenditure shocks at $t = 3$, as it turns out that their inclusion hardly changes the results but substantially reduces the computational time.[44] In particular, we consider the following three cases:

Case 1 (Greater expenditure shocks):

$\theta_t \in \{0.9, 1.0, 1.1\}$, with $\Pr(\theta_t = 0.9) = \Pr(\theta_t = 1.1) = 0.1$, $\Pr(\theta_t = 1.0) = 0.8$.

$\xi_t \in \{0, 5.0\}$, with $\Pr(\xi_t = 0) = 0.8$, $\Pr(\xi_t = 5.0) = 0.2$.

Case 2 (Greater productivity shocks):

$\theta_t \in \{0.8, 1.0, 1.2\}$, with $\Pr(\theta_t = 0.8) = \Pr(\theta_t = 1.2) = 0.1$, $\Pr(\theta_t = 1.0) = 0.8$.

$\xi_t \in \{0, 2.0\}$, with $\Pr(\xi_t = 0) = 0.8$, $\Pr(\xi_t = 2.0) = 0.2$.

Case 3 (Severer productivity shocks):

$\theta_t \in \{0.6, 1.0, 1.4\}$, with $\Pr(\theta_t = 0.6) = \Pr(\theta_t = 1.4) = 0.1$, $\Pr(\theta_t = 1.0) = 0.8$.

$\xi_t \in \{0, 2.0\}$, with $\Pr(\xi_t = 0) = 0.8$, $\Pr(\xi_t = 2.0) = 0.2$.

Expenditure shocks are more important in case 1, while productivity shocks are more important in case 2. Case 3 considers larger productivity shocks. These calibrated models will be used later for counterfactual policy evaluations. To account for income other than agricultural production, we introduce a regular deterministic income y in each period, used as the horizontal axis. We set $\overline{M} = 32,000$ BDT, which corresponds to the maximum loanable amount for the average farmer. The details of the computation are given in Appendix A.3.

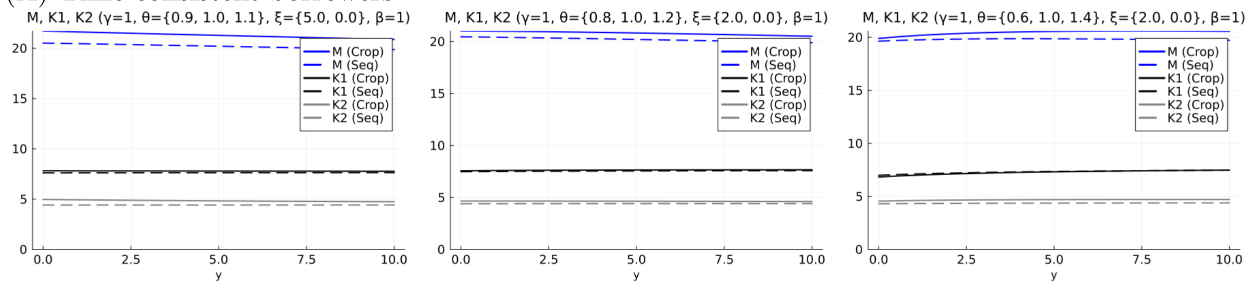
Figure 4 depicts the model prediction of the borrower's choice on the total loan size M^* and

[44] Appendix Figure 11 shows the loan size and investment amount for time-consistent borrowers when we consider the expenditure shock at $t = 3$ as $\xi_3 \in \{-5.0, 0, 5.0\}$ with $\Pr(\xi_3 = 0) = 0.8$ and $\Pr(\xi_3 = -5.0) = \Pr(\xi_3 = 5.0) = 0.1$. The pattern is almost identical to panel (A) of Figure 4, which ignores the expenditure shock at $t = 3$.

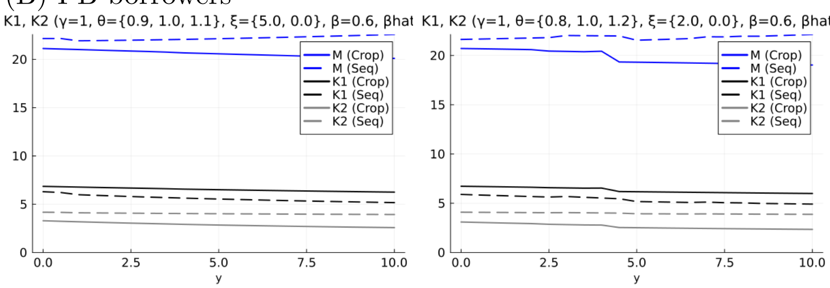
the investment amounts, K_1^* and K_2^* under crop credit (solid lines) and sequential credit (dashed lines) when $\gamma = 1$. To focus on the option value effect, we present the case wherein productivity is at the average level ($\theta_t = 1$) and there are no expenditure shocks ($\xi_t = 0$).[45].

Figure 4: Choice of (M, K_1, K_2) under crop credit and sequential credit when $\gamma = 1$

(A) Time-consistent borrowers



(B) PB borrowers



Panel (A) shows the results for time-consistent borrowers. The loan size M is lower under sequential credit than under crop credit in all the three cases, illustrating the importance of precautionary borrowing under crop credit even in the presence of severe productivity shocks.[46] As expected, the difference in loan size is largest in case 1 where expenditure shocks are more important.

Note that the second investment is lower under sequential credit, since crop credit leads to overinvestment as shown in equation (10). The difference in the first investment is much smaller. The ex-ante expected utility is slightly higher under sequential credit, and the gain in the expected utility is larger as productivity shocks become more severe (Appendix Figure 13).

Panel (B) shows the results for PB borrowers ($\beta = \hat{\beta} = 0.6$). We do not simulate case 3 since the maximization algorithm did not achieve convergence for some values of y. In contrast to the case of time-consistent borrowers, sequential credit results in higher loan sizes. At period 0, the PB borrower expects their future self to overconsume. Under crop credit, they choose a

[45]Appendix Figure 12 shows the average loan size under crop credit and sequential credit, indicating similar results of lower average loan size under sequential credit

[46]The analogous figures when $\gamma = 2$ are reported in the Appendix Figure 10. When $\gamma = 2$, the loan size in case 3 is quite similar between crop credit and sequential credit.

smaller loan size to avoid overconsumption. Under sequential credit, however, they can constrain consumption at period 1 by setting M_1 low and can finance the second investment by using the sequential disbursement $M_2 \leq \overline{M} - M_1$. This commitment function of sequential credit results in a larger investment at period 2. Furthermore, in anticipation of the larger K_2 and the resulting increase in the marginal product of the first investment, $F_1'(K_1, K_2)$, the borrower will also make a larger investment in period 1 than under crop credit. This may explain the larger first investment amount we found in Table 6. It may also explain the smaller difference in the loan size between crop credit and sequential cash credit among PB borrowers found in Table 5, although PB borrowers still borrowed less under sequential credit in our data.

5.3 Suggestive evidence on the role of productivity shocks and the size of the second disbursement

While the magnitude of precautionary borrowing depends on the size of potential productivity and expenditure shocks, unfortunately, our data do not contain information on productivity or expenditure shocks. However, since the second disbursement is determined by $M_2^* = K_2^* + c_2^* + \tilde{A}_2 - \xi_2$ and K_2^* depends on the productivity shocks (θ_1, θ_2), the variation in the second investment K_2 should be closely related to the variation in M_2 if the productivity shocks are important. We explore this testable implication in panel (A) of Table 10.

Columns (1)–(2) show the results when we use only the sample of time-consistent borrowers under sequential credit, and control for the demographic variables that are selected by PDS lasso. We do not control for group dummies or village dummies, given the possible presence of productivity shocks at the village level. We do not find a statistically significant correlation between K_2 and M_2. Including K_1, which is also affected by the productivity shocks, does not change the results. The pattern for the first disbursement, which is not affected by the productivity shocks at $t = 2$, is quite similar, as reported in columns (3) and (4). We also regress the total loan size $(M_1 + M_2)$ on K_2 and K_1 in column (5) but find no significant correlation.[47]. These results suggest that productivity shocks were not important determinants of loan size.

Note that the signs of the coefficients on K_1 and K_2 are negative instead of positive and large in columns (1)–(5). One might be concerned that there are some unobservable factors other than productivity and expenditure shocks that are correlated with K_1 and K_2. To address this issue, we use crop credit as a benchmark. If there are such unobservable factors that affect credit demand and are correlated with K_1 and K_2, they will also affect loan size under crop credit. Therefore, we regress loan size on K_1 and K_2 and their interaction terms with an indicator for sequential credit in column (6). The coefficients on these interaction terms should reflect the correlation between

[47] Adding the second-order terms of K_2 and K_1 does not change the results

Table 10: Determinants of second disbursement and first disbursement

(A) Investment amount and amount of each disbursement (time-consistent)

	(1)	(2)	(3)	(4)	(5)	(6)
	M2	M2	M1	M1	M:Seq	M:Crop& Seq
K_2	-0.497	-0.651		0.342	-0.352	-1.495
	(0.387)	(0.465)		(0.242)	(0.431)	(0.810)
K_1		-0.001	-0.178	-0.372	-0.861	1.122*
		(0.482)	(0.181)	(0.240)	(0.449)	(0.508)
Seq $\times K_2$						0.914
						(0.930)
Seq $\times K_1$						-0.731
						(0.561)
Observations	63	63	63	63	63	121

(B) Present bias and second disbursement

	(1)	(2)	(3)	(4)	(5)	(6)
	M2:Seq cash	M2:Seq kind	M1:Seq cash	M2ratio:Seq cash	M2=0:Seq cash	M2=0:Seq kind
PB=1	1390.971*	56.227	-493.724	0.072*	-0.768*	-0.186
	(602.319)	(736.931)	(451.828)	(0.031)	(0.353)	(0.339)
Observations	137	154	137	137	137	154

The table shows the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. We include the baseline outcome, group dummies, baseline savings, and variables selected by post-double-selection (PDS) lasso as control. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$.

productivity shocks and loan size after controlling for these unobservables. The coefficients are still insignificant, supporting the argument that productivity shocks were not important determinants of loan size.

The model implies that under sequential credit, a PB borrower will set M_1 low to limit the overconsumption of their period-1 self, while a time-consistent borrower will set M_1 to balance the probability of the budget constraints being bound at $t = 1$ and $t = 2$. Hence, a PB borrower will set M_1 lower and M_2 higher than a time-consistent borrower. Furthermore, since the PB borrower will be subject to the present bias in choosing M_2 at $t = 2$, their second disbursement will tend to be larger. This pattern is indeed found in the data, as reported in panel (B) of Table 10. Column (1) shows that M_2 of PB borrowers was larger than that of time-consistent borrowers by 1,559 BDT, which corresponds to 10% of the average loan size of sequential credit. However, there is no such pattern for sequential in-kind credit, which provides a commitment at $t = 2$ (column (2)). This suggests that the present bias at $t = 2$ is the main driver of the larger second disbursement. Furthermore, as expected, the first disbursement was smaller for PB borrowers, although not significantly so (column (3)). The ratio of M_2 to the final loan size is 8.6 percentage points larger for PB borrowers (column (4)). The proportion of borrowers who chose a zero second disbursement was lower for PB borrowers (column (5)), but not when the loan is disbursed in kind due to its commitment function (column (6)).

These results suggest a potential for another product. To mitigate the present bias problem at $t = 2$, the MFI can let the borrower choose the maximum loan size at $t = 0$. We call this product sequential credit with self-set limit (SC-SSL). This product differs from sequential credit only in the ability to choose M at $t = 0$. For a time-consistent borrower, it is optimal to set M large enough so that the period-2 constraint $M_2 \leq M - M_1$ is never binding ($E(\mu) = 0$). The full characterization of the model is provided in Appendix A.2.2 and A.2.3. The choice of M at $t = 0$ provides the commitment for the $t = 2$ decision since it can constrain the amount of consumption and investment at $t = 2$. We evaluate this hypothetical product using the calibrated model in the next section.

5.4 Counterfactual simulations

Now we evaluate the hypothetical product of SC-SSL, where the borrowers set the credit limit M at $t = 0$. We also evaluate another hypothetical product — credit lines (CL) — in which the borrower can choose M_1 at $t = 1$ and M_2 at $t = 2$, that is, they can borrow flexible amounts when they need and observe shocks. To make interest costs comparable across products in our model where there is no time discounting, we assume that each borrowing incurs the same interest rate r regardless of the timing of the borrowing or repayment. Note that time-consistent borrowers have no demand for commitment and set M to the maximum loanable amount, so their decision under these two hypothetical products is the same as under sequential credit, unless there are very severe negative productivity shocks at $t = 1$ such that the optimal credit demand given θ_1 is less than the first disbursement amount M_1^*, in which case CL generate greater expected utility than sequential credit.

Figure 5 shows the computational results for PB borrowers with $\beta = \hat{\beta} = 0.6$ and $\gamma = 1$, with panel (A) for case 1 (greater expenditure shocks) and panel (B) for case 2 (greater productivity shocks). The results when $\beta = \hat{\beta} = 0.8$ or when $\gamma = 2$ are shown in Appendix Figures. The top left figure in each panel shows the gain of the expected utility over crop credit for sequential credit (black solid lines), SC-SSL (blue dashed lines), and CL (red dashed lines).

SC-SSL achieves the largest expected utility gain. Compared to sequential credit, SC-SSL results in a smaller loan size (upper middle panel), a slightly larger first investment (lower left panel), and a smaller second investment (lower middle panel). In the top middle panel, the actual loan size $M_1 + M_2$ is shown as a blue dashed line and the self-set credit limit M is shown as a blue solid line, but both lines coincide. This means that the self-set limit is binding, which creates commitment and improves the welfare.

In contrast, CL may result in lower expected utility than crop credit when expenditure shocks are severe or the amount of other income flow is not small. The lower expected utility of CL is due to the larger loan size (upper middle panel), especially the larger first disbursement (upper right panel). CL are too flexible for PB borrowers. Under CL, PB borrowers are tempted to borrow larger amounts to finance excess consumption caused by the present bias. Note that CL do not necessarily underperform crop credit. When the present bias is modest ($\beta = 0.8$) or the motivation for consumption smoothing is larger ($\gamma = 2$), CL achieve greater expected utility, as shown in Appendix Figures 14-16. Nevertheless, CL are too flexible in many cases and allowing PB borrowers to set the credit limit through SC-SSL can improve their welfare.

One important lesson from the simulations is that examining only the impact on production-related outcomes such as investment, output, or profit can mislead the policy implication. Even though CL achieve the lowest expected utility among these schemes due to excessive borrowing caused by the present bias, they lead to the largest investment and output. If one calculates the profit by subtracting the input cost from the output,[48] CL also achieve the greatest profit (bottom right panel). To consider the welfare implications, one needs frequent consumption data and structural models that translate these variables into interpretable welfare measures such as expected utility.

[48]Since the money is fungible and the borrower can use the money for consumption instead of investment, it is reasonable and common to disregard the repayment amount when calculating the profit.

Figure 6 shows the simulation results for partially naive PB borrowers with $(\beta, \hat{\beta}) = (0.6, 0.8)$ and $\gamma = 1$.[49] Since partially naive borrowers may set the limit too low under SC-SSL by believing that their period-1 self will not overconsume as much, SC-SSL may lead to lower welfare. However, compared to sequential credit (black solid lines), SC-SSL (blue dashed lines) does not perform worse, and in fact, it outperforms sequential credit. The blue solid line in the top-middle figure shows the credit limit M that the borrower would set at $t = 0$, and it is not lower than the final credit demand under sequential credit (blue dashed line), which explains why the SC-SSL does not underperform sequential credit. Given that the SC-SSL (and sequential credit) gives greater expected utility than crop credit and CL, the SC-SSL will be the better credit design than existing microcredit schemes.

6 Conclusion

The timing mismatch between cash flows and credit flows caused by the standard microcredit for crop farmers would cause underinvestment and low uptake due to its greater effective interest rate. We evaluated two modified microcredit programs, crop credit and sequential credit, which match the timing of repayment and disbursement to the cash flow of typical rice farmers. Our empirical results show that these products increased the uptake rate without worsening the default rate. Furthermore, sequential credit increased the second investment for PB borrowers due to its commitment function, and reduced the loan size by eliminating the need for precautionary borrowing: under sequential credit, borrowers could determine the total loan size after observing productivity and expenditure shocks. In this sense, the sequential disbursement solves the mismatch of the timing of realization of the actual credit need and determination of the total loan size. Our counterfactual simulations based on the calibrated model indicate that increasing the commitment in sequential credit by having borrowers set the credit limit will be welfare-improving for PB borrowers, while CL that flexibly respond to borrower's credit demand will underperform sequential credit, and in some cases, even crop credit.

The concept of the precautionary borrowings shed a new light on the role of emergency loans, CL, and alternative borrowing sources. The mere access to these services can reduce the total loan size and alleviate the debt burden. However, as shown in our counterfactual analysis on the credit line, it may exacerbate the problem of overborrowing among PB borrowers. In this regard, a desirable financing system would be to put both flexibility and commitment into borrowing from one institution at the same time as limiting multiple borrowings. In the context of crop farmers, our sequential credit with self-set limit is one such product.

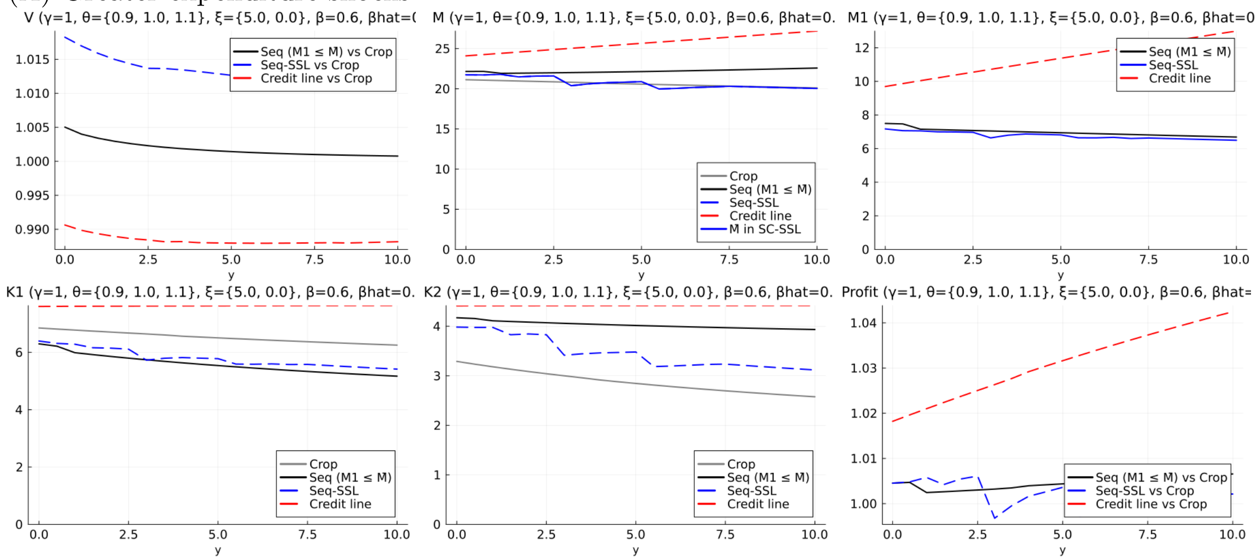
[49] Appendix Figure 17 reports the results when $\gamma = 2$.

Furthermore, we exemplify the importance of theoretical frameworks to derive welfare implication from the estimation results. In the calibrated model, CL result in greater investment and profit as found in the experimental evidence by Aragón et al. (2020), but they may provide lower expected utility than crop credit for PB borrowers under some parameter values. While CL reduce the precautionary borrowing and increase the investment and profit through its flexible disbursement, this flexibility counteracts for PB borrowers. Only investigating the impact on the production side will not suffice for identifying desirable policies, and we need theoretical frameworks that assess the program impact based on a set of variables related to consumption and production in a unified way. We leave this research line for future work.

This study also did not consider the issues relating to asymmetric information such as adverse selection and moral hazard, since modifying the timing of repayment and disbursement did not change the repayment performance. Rather, our point estimates suggest this timing modification may improve the repayment rate. This result is interesting as these modified schemes attracted borrowers with less steady income flows, who are usually regarded as riskier borrowers. Further investigation on the borrower's response to the change in the timing of repayment and disbursement in terms of selection and moral hazard will be another potential direction of future research.

Figure 5: Counterfactual policy simulations ($\beta = \hat{\beta} = 0.6$ and $\gamma = 1$)

(A) Greater expenditure shocks



(B) Greater productivity shocks

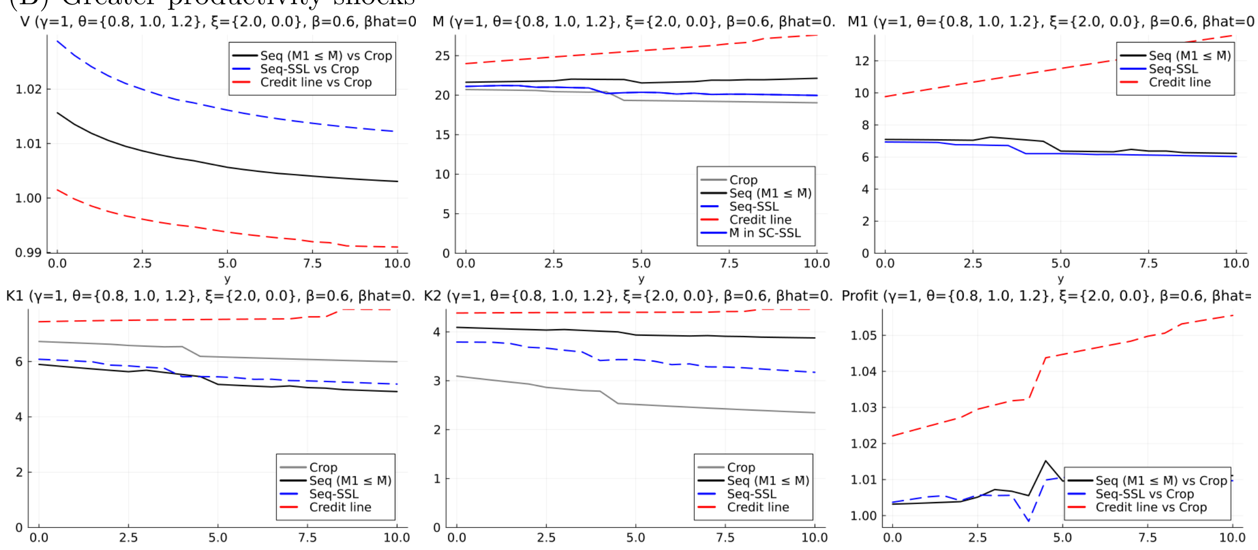
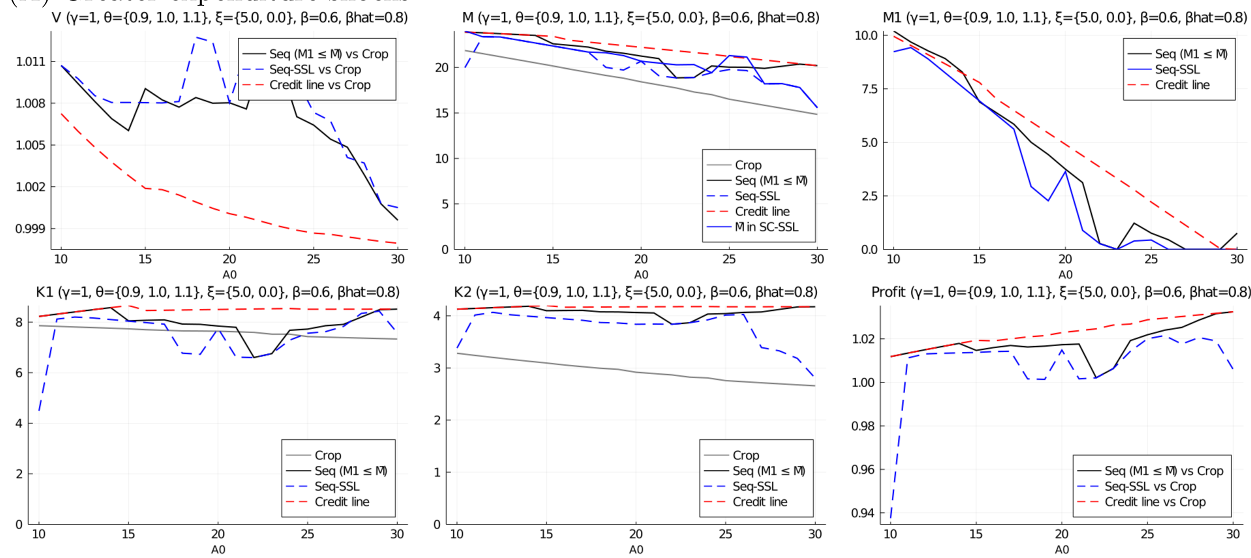
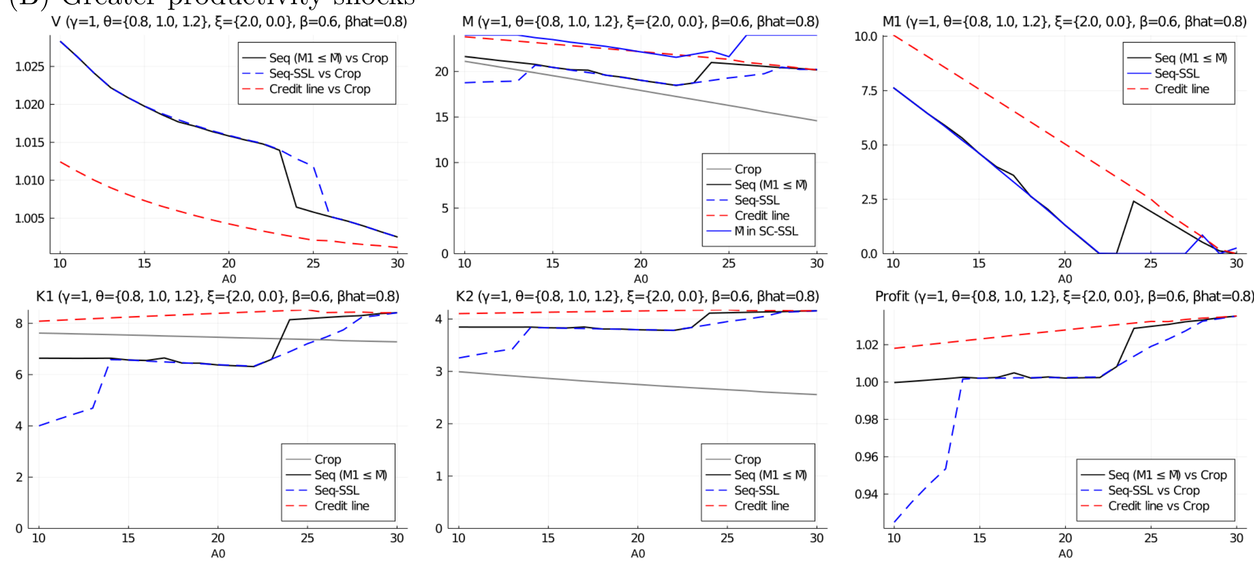


Figure 6: Counterfactual policy simulations ($\beta = 0.6, \hat{\beta} = 0.8$ and $\gamma = 1$)

(A) Greater expenditure shocks



(B) Greater productivity shocks



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A Appendix

A.1 Derivation of the optimal decision rule and comparative statics in the benchmark model

A.1.1 A time-consistent borrower

As outlined in section 2, the time-consistent farmer's problem is

$$\max_{c_1,c_2,K_1,K_2,M} \quad u(c_1)+u(c_2)+u(c_3)$$

$$\text{s.t.} \quad c_1+K_1 \le A_1 \tag{A.1}$$

$$c_2+K_2 = A_2 \tag{A.2}$$

$$c_3 = F(K_1,K_2)-(1-\pi_1-\pi_2)(1+r)M \tag{A.3}$$

$$M \le \overline{M},$$

where A_1 and A_2 are the resources available for consumption and investment at periods 1 and 2 defined in equations (3) and (4) in the main text, respectively. For generality, we consider other income flows at periods 1 and 2, y_1, y_2. These income flows can be easily introduced by modifying the transition of the asset level A_t as follows:

$$A_1 = A_0+y_1+M_1-\pi_1(1+r)M, \tag{A.4}$$

$$A_2 = A_1+y_2-c_1-K_1+M-M_1-\pi_2(1+r)M. \tag{A.5}$$

Note that the disbursement schedule, captured by M_1, will not affect the borrower's decision unless M_1 is sufficiently small that the period-1 budget constraint (A.1) is binding. The borrower will not benefit from such a low level of M_1 since it only imposes an additional binding constraint. Hence, if the borrower could choose M_1, they would set M_1 large enough that the budget constraint (A.1) would not be binding.

We solve the problem by backward induction. Since the consumption at $t=3$ is automatically determined once the level of investment (K_1,K_2) and the loan size M are chosen, there is no decision to be made at $t=3$. Hence, we start with the problem at $t=2$, where the borrower chooses (c_2,K_2). Using the equations (A.2) and (A.3), we can write the value function at $t=2$ as

$$V_2(A_2,K_1,M) = \max_{K_2}\ u\left(A_2-K_2\right)+u\left(F(K_1,K_2)-(1-\pi_1-\pi_2)(1+r)M\right) \tag{A.6}$$

The vector (A_2,K_1,M) constitutes the state variables for the decision problem at $t=2$. The first-order condition (FOC) is

$$u'(c_2^*) = F_2'(K_1,K_2^*)u'(c_3^*), \tag{A.7}$$

where we use asterisks to denote the solution. Note that the solutions are the functions of the state variables (A_2, K_1, M), which we express as $c_2^* = c_2^*(A_2, K_1, M)$ and $K_2^* = K_2^*(A_2, K_1, M)$. Partial derivatives of the value function are:

$$\frac{\partial V_2}{\partial A_2} = u'(c_2^*) \tag{A.8}$$
$$\frac{\partial V_2}{\partial K_1} = F_1'(K_1, K_2^*)u'(c_3^*) \tag{A.9}$$
$$\frac{\partial V_2}{\partial M} = -(1 - \pi_1 - \pi_2)(1 + r)u'(c_3^*). \tag{A.10}$$

Now, consider the problem at $t = 1$. Using the value function (A.6) and the transition equation (A.5), we write the problem as

$$\begin{aligned} &\max_{c_1, K_1} u(c_1) + V_2(A_2, K_1, M) \\ \text{s.t. } &c_1 + K_1 \leq A_1 \\ &A_2 = A_1 + y_1 - c_1 - K_1 + M - M_1 - \pi_2(1 + r)M. \end{aligned} \tag{A.11}$$

Note that the constraint (A.11) will not be binding if $M - M_1$ is sufficiently small.[50] Then, we can write the value function as

$$V_1(A_1, M) = \max_{c_1, K_1} \; u(c_1) + V_2 \left(A_1 - c_1 - K_1 + M - M_1 - \pi_2(1 + r)M, K_1, M\right).$$

The FOCs are

$$u'(c_1^*) - \frac{\partial V_2}{\partial A_2} = 0,$$
$$-\frac{\partial V_2}{\partial A_2} + \frac{\partial V_2}{\partial K_1} = 0.$$

Using equations (A.8) and (A.9), these conditions reduce to

$$u'(c_1^*) = u'(c_2^*), \tag{A.12}$$
$$u'(c_2^*) = F_1'(K_1^*, K_2^*)u'(c_3^*). \tag{A.13}$$

Since u' is strictly decreasing, equation (A.12) implies

$$c_1^* = c_2^*. \tag{A.14}$$

Combined with equations (A.7) and (A.12), equation (A.13) implies

$$F_1'(K_1^*, K_2^*) = F_2'(K_1^*, K_2^*). \tag{A.15}$$

[50] Suppose the constraint (A.11) is binding. Then $A_2 = M - M_1 + \pi_2(1 + r)M$ and hence $c_2 = A_2 - K_2 = M - M_1 - K_2 - \pi_2(1 + r)M$. If $M - M_1$ is sufficiently small, then $c_2 < 0$, which contradicts the borrower's optimization.

The partial derivatives of the value function are:

$$\frac{\partial V_1}{\partial A_1} = \frac{\partial V_2}{\partial A_2} = u'(c_2^*) \tag{A.16}$$

$$\frac{\partial V_1}{\partial M} = [1-\pi_2(1+r)]\frac{\partial V_2}{\partial A_2} + \frac{\partial V_2}{\partial M} = [1-\pi_2(1+r)]u'(c_2^*) - (1-\pi_1-\pi_2)(1+r)u'(c_3^*). \tag{A.17}$$

Finally, consider the problem at $t = 0$ in which the borrower solves

$$\begin{aligned} &\max_{M} \ V_1(A_1, M) \\ \text{s.t. } & M \leq \overline{M} \\ & A_1 = A_0 + M_1 - \pi_1(1+r)M. \end{aligned} \tag{A.18}$$

If the constraint (A.18) is not binding, the FOC is

$$-\pi_1(1+r)\frac{\partial V_1}{\partial A_1} + \frac{\partial V_1}{\partial M} = 0,$$

which can be rewritten by using equations (A.16), (A.17), and (A.7) as

$$QF_2'(K_1^*, K_2^*)u'(c_3^*) - (Q+r)\,u'(c_3^*) = 0, \tag{A.19}$$

where $Q \equiv 1 - (\pi_1 + \pi_2)(1+r)$. Hence the borrower chooses the loan size M so that

$$F_1'(K_1^*, K_2^*) = F_2'(K_1^*, K_2^*) = 1 + \frac{r}{Q}. \tag{A.20}$$

If $\pi = 0$, then $Q = 1$ and $F_1'(K_1^*, K_2^*) = 1 + r$ holds: the farmer employs credit until its marginal product equals its cost. However, if $\pi > 0$ as in the standard microcredit, then $1 + \frac{r}{Q} > 1 + r$, resulting in underinvestment. Furthermore, if $Q \leq 0$, then the left-hand side of equation (A.19) is always negative for any $r > 0$, and it is suboptimal for farmers to take loans. This is because the borrower must repay $(1-Q)M$ before harvest, and $Q \leq 0$ implies that they must repay the amount they borrowed (M) or more before harvest. If the constraint (A.18) is binding, then $M = \overline{M}$ and $F_1'(K_1^*, K_2^*) = F_2'(K_1^*, K_2^*) > 1 + \frac{r}{Q}$.

Unless the constraint (A.18) is binding, the investment decision only depends on $\frac{r}{Q}$. Hence, the initial wealth A_0 and other income flows y_1, y_2 will not affect K_t. From equations (A.2), (A.4), (A.5) and (A.14), we can obtain

$$c_1^* = c_2^* = \frac{1}{2}(\tilde{A}_0 - K_1^* - K_2^* + QM^*).$$

where $\tilde{A}_0 = A_0 + y_1 + y_2$.

The effect of the repayment schedule π_1 and π_2 only works through the change in Q. We can apply the comparative statics to the FOCs (A.7), (A.14), (A.15) and (A.20), and derive

$$\frac{\partial K_1^*}{\partial Q} > 0,$$
$$\frac{\partial K_2^*}{\partial Q} > 0,$$
$$\frac{\partial c_1^*}{\partial Q} = \frac{\partial c_2^*}{\partial Q} > 0,$$

implying that increasing the ratio of the installment before harvest (a decrease in Q) will reduce the investment and consumption at $t = 1, 2$. Its impact on the loan size M is undetermined without further assumptions on the utility and production functions even though the investment and consumption declines.[51] Specifically, the effect of Q on M can be written as

$$\frac{\partial M^*}{\partial Q} = \frac{1}{Q}\left[\frac{\partial K_1^*}{\partial Q} + \frac{\partial K_2^*}{\partial Q} + 2\frac{\partial c_2^*}{\partial Q} - M^*\right].$$

The last term M^* captures the effect of borrowing for repayment. Reducing Q by ΔQ lowers the resources available before harvest by ΔM, which induces borrowers to borrow for installment repayment to smooth consumption and finance the investment. Furthermore, by denoting the optimized total utility by $V \equiv u(c_1^*) + u(c_2^*) + u(c_3^*)$, we can also derive

$$\frac{\partial V}{\partial Q} = \frac{rM^*}{Q}u'(c_3^*) > 0.$$

A greater ratio of installment before harvest reduces the total utility, and thereby reduces the uptake rate.

A.1.2 Additional funding sources

Now we incorporate additional funding sources into the baseline model by allowing a farmer to borrow b_t at period t. Denote the debt outstanding at period t by B_t and consider the transaction

[51] To be concrete, the exact expressions of the comparative statics when $M^* < \overline{M}$ are

$$\frac{\partial K_j^*}{\partial Q} = \frac{r}{Q^2}\frac{F_{12}'' - F_{jj}''}{F_{11}''F_{22}'' - (F_{12}'')^2} > 0 \qquad \text{for } j = 1, 2,$$
$$\frac{\partial c_1^*}{\partial Q} = \frac{\partial c_2^*}{\partial Q} = -\frac{rD_0}{D_1} > 0,$$

where $D_0 \equiv u'(c_3^*) - (Q + r)M^*u''(c_3^*) > 0$ and $D_1 \equiv Q^2u''(c_2^*) + 2(Q + r)^2u''(c_3^*) < 0$. Note that $F_{12}'' - F_{11}'' > 0$, $F_{12}'' - F_{22}'' > 0$ and $F_{11}''F_{22}'' > (F_{12}'')^2$ are directly derived from the property of the production function. We can also derive

$$\frac{\partial M^*}{\partial Q} = \frac{1}{Q}\left[\frac{r}{Q^2}\frac{2F_{12}'' - F_{11}'' - F_{22}''}{F_{11}''F_{22}'' - (F_{12}'')^2} - \frac{2rD_0}{D_1} - M^*\right],$$

whose sign is undetermined without further assumptions. We can also show that when $M^* = \overline{M}$, $\frac{\partial K_j^*}{\partial Q} > 0$ for $j = 1, 2$ and $\frac{\partial c_1^*}{\partial Q} = \frac{\partial c_2^*}{\partial Q} > 0$.

function for B_t given by

$$B_{t+1} = \rho_t(B_t + b_t)$$

where $\rho_t(d) > d$ is the debt outstanding including the interest payment. If a farmer can borrow at a fixed interest rate i, then $\rho_t(d) = (1+i)d$ and $\rho_t'(d) = 1+i$. As the poor often rely on multiple borrowing sources with different interest rates (Collins et al., 2009), we assume $\rho_t(\cdot)$ to be weakly convex and differentiable, satisfying $r_t'(\cdot) > 1$ and $\rho_t''(\cdot) \geq 0$. Given the fact that people often borrow money from relatives and friends without interest payment, it is likely that $\rho_t(d) > (1+r)d$ for small d. Since the investment generates the return at $t = 3$, it is optimal for them to repay the debt at $t = 3$. For generality, we allow the borrower to choose M_1 and to have other income flow y_t. Then the problem of the farmer is modified as

$$\begin{aligned}
&\max_{c_1,c_2,K_1,K_2,M,M_1,b_1,b_2} u(c_1) + u(c_2) + u(c_3) \\
\text{s.t. } & c_1 + K_1 \leq A_1 + b_1 \\
& c_2 + K_2 = A_2 + b_2 \\
& c_3 = F(K_1, K_2) + y_3 - (1 - \pi_1 - \pi_2)(1+r)M - B_3 \\
& A_1 = A_0 + y_1 + M_1 - \pi_1(1+r)M \\
& A_2 = A_1 + y_2 - c_1 - K_1 + M - M_1 - \pi_2(1+r)M \\
& M_1 \leq M \leq \overline{M} \\
& b_1 \geq 0 \\
& b_2 \geq 0 \\
& B_2 = \rho_1(b_1) \\
& B_3 = \rho_2(B_2 + b_2).
\end{aligned}$$

The value function at $t = 2$ is defined as

$$V_2(A_2, K_1, M, B_2) = \max_{K_2, b_2} u\left(A_2 + b_2 - K_2\right) + u\left(F(K_1, K_2) - (1 - \pi_1 - \pi_2)(1+r)M - \rho_2(B_2 + b_2)\right).$$

The FOCs are given by equation (A.7) and

$$u'(c_2^*) = \rho_2'(B_2 + b_2^*)u'(c_3^*),$$

where c_2^*, K_2^* and b_2^* are the functions of (A_2, K_1, M, B_2). These two FOCs imply

$$\begin{aligned}
& b_2^* = 0 && \text{if } \rho_2'(B_2) > F_2'(K_1, K_2^*) \\
& F_2'(K_1, K_2^*) = \rho_2'(B_2 + b_2^*) && \text{otherwise.}
\end{aligned} \tag{A.21}$$

Partial derivatives of the value function are given by equations (A.8), (A.9), (A.10), and

$$\frac{\partial V_2}{\partial B_2} = -\rho_2'(B_2 + b_2^*)u'(c_3^*). \tag{A.22}$$

Now consider the problem at $t = 1$. Note that if $c_1^* + K_1^* \leq A_1$, the farmer will choose $b_1^* = 0$. To see this, consider the value function at $t = 1$:

$$\begin{aligned} V_1(A_1, M, M_1) = \max_{c_1, K_1, b_1} \; & u(c_1) + V_2\left(A_1 + y_2 - c_1 - K_1 + M - M_1 - \pi_2(1+r)M, K_1, M, \rho_1(b_1)\right) \\ \text{s.t. } & c_1 + K_1 \leq A_1 + b_1. \end{aligned}$$

The FOCs are

$$\begin{aligned} u'(c_1^*) - \frac{\partial V_2}{\partial A_2} &= 0, \\ -\frac{\partial V_2}{\partial A_2} + \frac{\partial V_2}{\partial K_1} &= 0, \\ \rho_1'(b_1)\frac{\partial V_2}{\partial B_2} &= 0. \end{aligned}$$

But because $\frac{\partial V_2}{\partial B_2} < 0$ as shown in (A.22), it is optimal to set $b_1^* = 0$ in this case. The first two FOCs reduce to the same conditions as in the baseline model above:

$$\begin{aligned} c_1^* &= c_2^*. \\ u'(c_2^*) &= F_1'(K_1^*, K_2^*)u'(c_3^*), \end{aligned}$$

which implies

$$F_1'(K_1^*, K_2^*) = F_2'(K_1^*, K_2^*).$$

The partial derivatives of the value function are the same as the baseline model:

$$\frac{\partial V_1}{\partial A_1} = \frac{\partial V_2}{\partial A_2} = u'(c_2^*)$$

$$\frac{\partial V_1}{\partial M} = [1 - \pi_2(1+r)]\frac{\partial V_2}{\partial A_2} + \frac{\partial V_2}{\partial M} = [1 - \pi_2(1+r)]u'(c_2^*) - (1 - \pi_1 - \pi_2)(1+r)u'(c_3^*). \tag{A.23}$$

$$\frac{\partial V_1}{\partial M_1} = -\frac{\partial V_2}{\partial A_2} = -u'(c_2^*). \tag{A.24}$$

Next we consider the case where $c_1^* + K_1^* > A_1$. Then $c_1 = A_1 + b_1 - K_1$ and the value function becomes

$$V_1(A_1, M, M_1) = \max_{K_1, b_1} \; u(A_1 + b_1 - K_1) + V_2\left(y_2 + M - M_1 - \pi_2(1+r)M, K_1, M, \rho_1(b_1)\right),$$

which gives the FOCs as

$$\begin{aligned} u'(c_1^*) &= \frac{\partial V_2}{\partial K_1}, \\ u'(c_1^*) + \rho_1'(b_1)\frac{\partial V_2}{\partial B_2} &= 0. \end{aligned}$$

With equations (A.9) and (A.22), these two FOCs imply

$$F_1'(K_1^*, K_2^*) = \rho_1'(b_1)\rho_2'(B_2 + b_2^*).$$

Combined with the assumption of $\rho_1'(b_1) > 1$ and equation (A.21), this indicates

$$F_1'(K_1^*, K_2^*) > F_2'(K_1^*, K_2^*).$$

The partial derivatives of the value function are given by

$$\frac{\partial V_1}{\partial A_1} = u'(c_1^*)$$

and equations (A.23) and (A.24).

Finally, we consider the problem at $t = 0$, in which the borrower solves

$$\begin{aligned} &\max_{M, M_1} V_1(A_1, M, M_1) \\ \text{s.t. } & M_1 \leq M \leq \overline{M} \\ & A_1 = A_0 + y_1 + M_1 - \pi_1(1+r)M. \end{aligned} \tag{A.25}$$

If the constraint (A.25) is not binding, the FOCs are

$$\begin{aligned} &-\pi_1(1+r)\frac{\partial V_1}{\partial A_1} + \frac{\partial V_1}{\partial M} = 0 \\ &\frac{\partial V_1}{\partial A_1} + \frac{\partial V_1}{\partial M_1} = 0. \end{aligned}$$

Note that $\frac{\partial V_1}{\partial A_1} = u'(c_2^*)$ if $c_1^* + K_1^* \leq A_1$ and $\frac{\partial V_1}{\partial A_1} = u'(c_1^*)$ if $c_1^* + K_1^* > A_1$. Since $\frac{\partial V_1}{\partial M_1} = -u'(c_2^*)$, the second FOC implies that the borrower will choose M_1 large enough so that $c_1^* + K_1^* \leq A_1$ holds. Any M_1 that results in $c_1^* + K_1^* \leq A_1$ will give the same utility level. Then the first FOC implies the same condition as in the baseline model above:

$$QF_2'(K_1^*, K_2^*)u'(c_3^*) = (Q + r)\, u'(c_3^*).$$

Since the borrower chooses M_1 to satisfy $c_1^* + K_1^* \leq A_1$, we finally obtain $b_1^* = 0$ and

$$F_1'(K_1^*, K_2^*) = F_2'(K_1^*, K_2^*) = \rho_2'(b_2^*) = 1 + \frac{r}{Q}.$$

Note that if $\rho_2'(0) > 1 + \frac{r}{Q}$, then they will not rely on these additional borrowing sources. The above expression implies that the lower Q (a greater ratio of installment before harvest) will induce more borrowing if $\rho_2'' > 0$. If $\rho_2'' > 0$, they only use the microcredit if $\rho_2' > 1 + \frac{r}{Q}$ and will not use the microcredit otherwise.

A.1.3 A present-biased borrower

Consider a quasi-hyperbolic discounter who discounts the future by β. At $t = 0$, they decide the total loan size M and the amount of the credit disbursed at $t = 1$, M_1. They believe that their future self will discount the future by $\hat{\beta} \in [\beta, 1]$. If $\hat{\beta} = \beta$, they correctly predict their present biasedness (sophisticated). If $\hat{\beta} = 1$, they are unaware of their present bias (naive).

For simplicity, consider the case of $\pi = 0$. The resources available for consumption and investment at $t = 1, 2$ are

$$\begin{aligned} A_1 &= A_0 + M_1, \\ A_2 &= A_1 - c_1 - K_1 + M - M_1. \end{aligned}$$

Period-2 problem

Write the discounted value function that their period-2 self maximizes as W_2:

$$W_2(A_2, K_1, M; \beta) = \max_{K_2} \ u(A_2 - K_2) + \beta u \left(F(K_1, K_2) - (1 + r)M \right),$$

where we explicitly write that W depends on the present bias β along with the state variables (A_2, K_1, M). The FOC is

$$u'(c_2^*) = \beta F_2'(K_1, K_2^*) u'(c_3^*), \tag{A.26}$$

where $c_3^* = F(K_1, K_2^*) - (1 + r)M$. This gives the decision rules for c_2 and K_2 as a function of the state variables (A_2, K_1, M) and the present biasedness β, denoted by $c_2^* = c_2(A_2, K_1, M; \beta)$ and $K_2^* = K_2(A_2, K_1, M; \beta)$. For brevity, we denote these rules as $c_2^{*(\beta)} \equiv c_2(A_2, K_1, M; \beta)$, $K_2^{*(\beta)} \equiv K_2(A_2, K_1, M; \beta)$, and $c_3^{*(\beta)} \equiv F(K_1, K_2^{*(\beta)}) - (1 + r)M$.

The partial derivatives of the discounted continuation value are

$$\begin{aligned} \frac{\partial W_2(A_2, K_1, M; \beta)}{\partial A_2} &= u'(c_2^{*(\beta)}) \\ \frac{\partial W_2(A_2, K_1, M; \beta)}{\partial K_1} &= \beta F_1'(K_1, K_2^{*(\beta)}) u'(c_3^{*(\beta)}) \\ \frac{\partial W_2(A_2, K_1, M; \beta)}{\partial M} &= -(1 + r)\beta u'(c_3^{*(\beta)}). \end{aligned}$$

Period-1 problem

At $t = 1$, they believe that their period-2 self will follow the decision rule $c_2^{*(\hat{\beta})}$ and $K_2^{*(\hat{\beta})}$. We define the state variables as (A_0, M, M_1) instead of (A_1, M), which makes the analysis simpler. The discounted value function that their period-1 self maximizes is

$$\begin{aligned} W_1(A_0, M, M_1; \beta, \hat{\beta}) = \max_{c_1, K_1} \; & u(c_1) + \beta \hat{V}_2(A_2, K_1, M; \hat{\beta}) \\ \text{s.t. } & c_1 + K_1 \leq A_0 + M_1 \\ & A_2 = A_0 + M - c_1 - K_1 \end{aligned} \tag{A.27}$$

where

$$\hat{V}_2(A_2, K_1, M; \hat{\beta}) = u(c_2^{*(\hat{\beta})}) + u\left(F(K_1, K_2^{*(\hat{\beta})}) - (1+r)M\right)$$

is the continuation value under the decision rule with their belief $\hat{\beta}$.

First, we derive the partial derivatives of $\hat{V}_2(A_2^*, K_1^*, M; \hat{\beta})$ by exploiting the link between $\hat{V}_2(A_2, K_1, M; \hat{\beta})$ and $W_2(A_2, K_1, M; \hat{\beta})$ following Harris and Laibson (2001). Given the decision rule $c_2^{*(\hat{\beta})}$ and $K_2^{*(\hat{\beta})}$, the discounted continuation value $W_2(A_2, K_1, M; \hat{\beta})$ is written as:

$$W_2(A_2, K_1, M; \hat{\beta}) = u(c_2^{*(\hat{\beta})}) + \hat{\beta} u\left(F(K_1, K_2^{*(\hat{\beta})}) - (1+r)M\right).$$

Hence $\hat{V}_2(A_2, K_1, M; \hat{\beta})$ and $W_2(A_2, K_1, M; \hat{\beta})$ are linked in the following way:

$$W_2(A_2, K_1, M; \hat{\beta}) - \hat{\beta} \hat{V}_2(A_2, K_1, M; \hat{\beta}) = (1 - \hat{\beta}) u(c_2^{*(\hat{\beta})}),$$

or

$$\hat{V}_2(A_2, K_1, M; \hat{\beta}) = \frac{1}{\hat{\beta}} \left[W_2(A_2, K_1, M; \hat{\beta}) - (1 - \hat{\beta}) u(c_2^{*(\hat{\beta})})\right].$$

Then, we can derive[52]:

$$\begin{aligned}
\frac{\partial \hat{V}_2(A_2,K_1,M;\hat{\beta})}{\partial A_2} &= \frac{1}{\hat{\beta}}\left[\frac{\partial W_2(A_2,K_1,M;\hat{\beta})}{\partial A_2} - (1-\hat{\beta})u'(c_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right], \\
&= F_2'(K_1,K_2^{*(\hat{\beta})})u'(c_3^{*(\hat{\beta})})\left[1-(1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right] \qquad \text{(A.28)} \\
\frac{\partial \hat{V}_2(A_2,K_1,M;\hat{\beta})}{\partial K_1} &= \frac{1}{\hat{\beta}}\left[\frac{\partial W_2(A_2,K_1,M;\hat{\beta})}{\partial K_1} - (1-\hat{\beta})u'(c_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial K_1}\right] \\
&= u'(c_3^{*(\hat{\beta})})\left[F_1'(K_1,K_2^{*(\hat{\beta})}) + (1-\hat{\beta})F_2'(K_1,K_2^{*(\hat{\beta})})\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}\right], \\
\frac{\partial \hat{V}_2(A_2,K_1,M;\hat{\beta})}{\partial M} &= \frac{1}{\hat{\beta}}\left[\frac{\partial W_2(A_2,K_1,M;\hat{\beta})}{\partial M} - (1-\hat{\beta})u'(c_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial M}\right] \\
&= -u'(c_3^{*(\hat{\beta})})\left[1+r+(1-\hat{\beta})F_2'(K_1,K_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial M}\right].
\end{aligned}$$

Decision rules at $t=1$ We denote the decision rules of the borrower's period-1 self by $c_1^{*(\beta,\hat{\beta})} \equiv c_1(A_0,M,M_1;\beta,\hat{\beta})$ and $K_1^{*(\beta,\hat{\beta})} \equiv K_1(A_0,M,M_1;\beta,\hat{\beta})$ to make explicit their dependence on the true β and their belief $\hat{\beta}$. We separately consider the decision rules when the constraint (A.27) is not binding versus when it is.

[52]By differentiating equation (A.26), we can derive the partial derivatives $\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}$ and $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}$ as follows:

$$\begin{aligned}
\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} &= \frac{\hat{\beta}[F_{22}''u'(c_3^{*(\hat{\beta})}) + (F_2')^2u''(c_3^{*(\hat{\beta})})]}{D_2} > 0 \\
\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1} &= -\frac{\hat{\beta}[F_{12}''u'(c_3^{*(\hat{\beta})}) + F_1'F_2'u''(c_3^{*(\hat{\beta})})]}{D_2}
\end{aligned}$$

where $D_2 \equiv u''(c_2^{*(\hat{\beta})}) + \hat{\beta}[F_{22}''u'(c_3^{*(\hat{\beta})}) + (F_2')^2u''(c_3^{*(\hat{\beta})})] < 0$. It is straightforward to show $0 < \frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} < 1$. Since $K_2 = A_2 - c_2$, $\frac{\partial K_2^{*(\hat{\beta})}}{\partial A_2} = 1 - \frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} \in (0,1)$. The sign of $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}$ depends on F_{12}'' (complementarity between K_1 and K_2) and the concavity of u. Unless the complementarity is sufficiently strong or a farmer is nearly risk neutral, $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}$ is negative. An increase in K_1 has two effects: (1) leaving less resources at period 2 and hence reducing K_2, and (2) increasing the marginal product of K_2 and increasing K_2. The total effect depends on these two effects. If we assume a Cobb-Douglass production function and CRRA utility function $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$, then $F_1'F_2'u''(c_3) + F_{12}''u'(c_3) = F_{12}''c_3^{-(1+\gamma)}[(1-\gamma)Y - (1+r)M]$. Most empirical literature on the intertemporal substitution has found that $\gamma \geq 1$ (Ogaki et al., 1996; Yogo, 2004), in which case $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1} < 0$.

Case (a): the constraint (A.27) **is not binding.** The FOCs are

$$u'(c_1^{*(\beta,\hat{\beta})}) - \beta\frac{\partial \hat{V}_2(A_2^*, K_1^{*(\beta,\hat{\beta})}, M; \hat{\beta})}{\partial A_2} = 0 \tag{A.29}$$

$$-\beta\frac{\partial \hat{V}_2(A_2^*, K_1^{*(\beta,\hat{\beta})}, M; \hat{\beta})}{\partial A_2} + \beta\frac{\partial \hat{V}_2(A_2^*, K_1^{*(\beta,\hat{\beta})}, M; \hat{\beta})}{\partial K_1} = 0, \tag{A.30}$$

where $A_2^* = A_0 + M - c_1^{*(\beta,\hat{\beta})} - K_1^{*(\beta,\hat{\beta})}$ is the value of A_2 on the optimal path. Using expression (A.28), the FOC (A.29) is rewritten as

$$u'(c_1^{*(\beta,\hat{\beta})}) = \beta F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})})u'(c_3^{*(\hat{\beta})})\left[1 - (1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right], \tag{A.31}$$

where $\frac{c_2^{*(\hat{\beta})}}{\partial A_2} > 0$ (footnote 52). Comparison with the FOC at $t = 2$, (A.26), implies $c_1^{*(\beta,\hat{\beta})} \geq c_2^{*(\hat{\beta})}$ where the strict inequality holds if $\hat{\beta} < 1$. The term $(1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}$ reflects the fact that the borrower who understands their present bias ($\hat{\beta} < 1$) makes their consumption decision considering that the current increase in the consumption and thus the reduction in A_2 will constrain their period-2 consumption, alleviating the present bias problem at $t = 2$. Hence, being aware of one ' s own present bias will further exacerbate the overconsumption at $t = 1$, as they expect that their future self will consume more if they choose lower consumption to leave more assets for their future self.

We can also rewrite the FOC (A.30) as

$$F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) - F_1'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) = (1-\hat{\beta})\hat{\beta}F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})})\left[\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} + \frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}\right] \tag{A.32}$$

The marginal product of the investment will be equalize if they are unaware of their present bias ($\hat{\beta} = 1$). If $\beta < 1$, then $F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) > F_1'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})})$.[53]

Note that given A_0 and M, the value of M_1 will not affect the state variable at $t = 2$, (A_2, K_1, M), when the constraint (A.27) is not binding. Hence, the FOCs (A.29) and (A.30) imply that:

$$\frac{\partial c_1^{*(\beta,\hat{\beta})}}{\partial M_1} = 0, \quad \frac{\partial K_1^{*(\beta,\hat{\beta})}}{\partial M_1} = 0,$$

which also implies that:

$$\frac{\partial W_1(A_0, M, M_1; \beta, \hat{\beta})}{\partial M_1} = 0.$$

[53] Using the expression for the partial derivatives derived in footnote 52, equation (A.32) becomes

$$F_2' - F_1' = (1-\hat{\beta})\hat{\beta}F_2'\frac{(F_{22}'' - F_{12}'')u'(c_3^{*(\hat{\beta})}) + F_2'(F_2' - F_1')u''(c_3^{*(\hat{\beta})})}{D_2},$$

which can be rewritten as

$$F_2' - F_1' = (1-\hat{\beta})\hat{\beta}F_2'u'(c_3^{*(\hat{\beta})})\frac{F_{22}'' - F_{12}''}{u''(c_2^{*(\hat{\beta})}) + \hat{\beta}[F_{22}''u'(c_3^{*(\hat{\beta})}) + \hat{\beta}(F_2')^2u''(c_3^{*(\hat{\beta})})]}.$$

As both of the numerator and denominator are negative, $F_2' - F_1' > 0$ as long as $0 < \hat{\beta} < 1$.

Case (b): the constraint (A.27) **is binding.** With the constraint (A.27) binding, the borrower maximizes $u(A_1 - K_1) + \beta \hat{V}_2(M - M_1, K_1, M; \hat{\beta})$, which gives the FOC

$$-u'(c_1^{*(\beta,\hat{\beta})}) + \beta \frac{\partial \hat{V}_2(M - M_1, K_1^{*(\beta,\hat{\beta})}, M; \hat{\beta})}{\partial K_1} = 0$$

which balances the current cost of reducing c_1 and the future benefit of increasing K_1. By substituting expression (A.30), this condition becomes

$$u'(c_1^{*(\beta,\hat{\beta})}) = \beta u'(c_3^{*(\hat{\beta})}) \left[F_1'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) + (1-\hat{\beta}) F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) \frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1} \right].$$

If $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1} < 0$, which is the plausible case as stated in footnote 52, being aware of one's own present bias will further exacerbate the overconsumption at $t = 1$, as they expect that their future self will compensate for the reduction of the output loss, due to the smaller first investment, by increasing the second investment.

Period-0 problem

Now consider the problem at $t = 0$ and examine if they prefer to make this constraint binding. Considering the decision rules of their future selves, they maximize their utility

$$u(c_1^{*(\hat{\beta},\hat{\beta})}) + \hat{V}_2(A_2, K_1^{*(\hat{\beta},\hat{\beta})}, M; \hat{\beta})$$

by setting M and M_1 appropriately.

Let $c_1^{+(\hat{\beta},\hat{\beta})}$ and $K_1^{+(\hat{\beta},\hat{\beta})}$ be the level of c_1 and K_1 that would be chosen when the constraint (A.27) is not binding and the present bias parameter is $\hat{\beta}$. Define $M_1^{+(\hat{\beta},\hat{\beta})}$ as the level of the first disbursement that just covers the expenditure at $t = 1$, net of the endowment A_0, that is, $c_1^{+(\hat{\beta},\hat{\beta})} + K_1^{+(\hat{\beta},\hat{\beta})} = A_0 + M_1^{+(\hat{\beta},\hat{\beta})}$. With this $M_1^{+(\hat{\beta},\hat{\beta})}$, $A_2 = M - M_1^{+(\hat{\beta},\hat{\beta})}$. Hence, utility when $M_1 = M_1^{+(\hat{\beta},\hat{\beta})}$ is expressed as

$$u(A_0 + M_1^{+(\hat{\beta},\hat{\beta})} - K_1^{+(\hat{\beta},\hat{\beta})}) + \hat{V}_2(M - M_1^{+(\hat{\beta},\hat{\beta})}, K_1^{+(\hat{\beta},\hat{\beta})}, M; \hat{\beta})$$

Now, consider the change in the utility if they reduce M_1 from $M_1^{+(\hat{\beta},\hat{\beta})}$ by ΔM_1, which tightens the budget constraint at $t = 1$ by ΔM_1. The utility change caused by this reduction is

$$-\Delta M_1 \left[u'(c_1^{+(\hat{\beta},\hat{\beta})}) \left(1 - \frac{\partial K_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1} \right) - \frac{\partial \hat{V}_2(\cdot;\hat{\beta})}{\partial A_2} + \frac{\partial \hat{V}_2(\cdot;\hat{\beta})}{\partial K_1} \frac{\partial K_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1} \right]$$

Note that we are evaluating this expression at $(c_1, K_1, M_1) = (c_1^{+(\hat{\beta},\hat{\beta})}, K_1^{+(\hat{\beta},\hat{\beta})}, M_1^{+(\hat{\beta},\hat{\beta})})$, and we can substitute the equations (A.29) and (A.30). By substituting these and arranging terms, we can rewrite the above expression as

$$-\Delta M_1 \left(1 - \frac{1}{\hat{\beta}}\right) u'(c_1^{+(\hat{\beta},\hat{\beta})}) \left(1 - \frac{\partial K_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1}\right),$$

which is positive if $0 < \hat{\beta} < 1$. Hence, borrowers who are aware of their present bias problem will prefer to set M_1 low for the period-1 budget constraint to be binding.

By setting M_1 small for the period-1 budget constraint to be binding, they can increase A_2. Since $\frac{\partial K_2^{*(\hat{\beta})}}{\partial A_2} > 0$ as shown in footnote 52, it is straightforward to show that sequential credit that allows borrowers to choose the amount of the first disbursement will increase the second investment.[54]

A.2 Uncertainty and option values

We introduce productivity and expenditure shocks. Particularly, we consider the production function

$$Y = \theta_1 \theta_2 F(K_1, K_2),$$

where $\theta_t > 0$ are the productivity shocks revealed at the beginning of period $t = 1, 2$. Expenditure/income shocks $\xi_t \geq 0$ revealed at the beginning of period $t = 1, 2, 3$, and negative values of ξ_t indicate positive income shocks. The budget constraints at each period are

$$\begin{aligned} c_1 + K_1 &\leq A_1 - \xi_1 \\ c_2 + K_2 &\leq A_2 - \xi_2. \end{aligned}$$

We assume that the expectation and derivatives are exchangeable. Given the fact that some borrowers made considerable savings, we allow that borrowers can carry over the savings to period 3. For brevity, we consider the case with $\pi_t = 0$.

A.2.1 Crop credit

First, we consider the decisions of a time-consistent borrower under crop credit, where they choose the loan size $M \leq \bar{M}$ at period 0. The resources available for consumption and investment at

[54] The FOC with respect to M_1 implies that the borrower will choose M_1 to satisfy

$$\left[1 - (1 - \hat{\beta}) \frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1}\right] u'(c_1^{*(\hat{\beta},\hat{\beta})}) = \left[1 - (1 - \hat{\beta}) \frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right] u'(c_2^{*(\hat{\beta})}).$$

Under crop credit, the period-1 budget constraint will not be binding, and the consumption profile satisfies

$$u'(c_1^{*(\hat{\beta},\hat{\beta})}) = \left[1 - (1 - \hat{\beta}) \frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right] u'(c_2^{*(\hat{\beta})}),$$

which follows from the equations (A.26) and (A.31). Clearly, the consumption path will be smoother under sequential credit than under crop credit.

periods 1 and 2 are

$$\begin{aligned} A_1 &= A_0 + M, \\ A_2 &= A_1 - \xi_1 - c_1 - K_1. \end{aligned} \tag{A.33}$$

Consider the maximization problem at period 2, when the borrower knows the realized values of θ_1, θ_2, and ξ_2. The value function under crop credit is

$$\begin{aligned} V_2^C(A_2, K_1, M, \theta_1, \theta_2, \xi_2) = \max_{c_2, K_2} \; & u(c_2) + E\left[u(c_3)|\mathcal{I}_2\right] \\ \text{s.t. } & c_2 + K_2 \leq A_2 - \xi_2 \qquad \text{(A.34)} \\ & c_3 = \theta_1\theta_2 F(K_1, K_2) - (1+r)M + A_2 - \xi_2 - c_2 - K_2 - \xi_3, \end{aligned}$$

where $\mathcal{I}_2$ is the information set at $t = 2$ including $(A_2, K_1, M, \theta_1, \theta_2, \xi_2)$. Denoting the Lagrange multiplier associated with the constraint (A.34) by η, the FOCs are written as

$$u'(c_2^*) - E[u'(c_3^*)|\mathcal{I}_2] - \eta = 0, \tag{A.35}$$

$$\left[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1\right] E[u'(c_3^*)|\mathcal{I}_2] - \eta = 0.$$

If the constraint (A.34) is not binding, then the second investment satisfies $\theta_1\theta_2 F_2'(K_1, K_2^*) = 1$. The partial derivatives of the value function are[55]:

$$\frac{\partial V_2^C}{\partial A_2} = u'(c_2^*) \tag{A.36}$$

$$\frac{\partial V_2^C}{\partial K_1} = \theta_1\theta_2 F_1'(K_1, K_2^*) E[u'(c_3^*)|\mathcal{I}_2] \tag{A.37}$$

$$\frac{\partial V_2^C}{\partial M} = -(1+r) E[u'(c_3^*)|\mathcal{I}_2].$$

Next, consider the problem at period 1, when the borrower only knows the value of θ_1 and ξ_1. The value function in period 1 is

$$\begin{aligned} V_1^C(A_1, M, \theta_1, \xi_1) = \max_{c_1, K_1} \; & u(c_1) + E\left[V_2^C(A_2, K_1, M, \theta_1, \theta_2, \xi_2)|\mathcal{I}_1\right] \\ \text{s.t. } & c_1 + K_1 \leq A_1 - \xi_1, \end{aligned}$$

[55]These partial derivatives do not depend on whether the constraint (A.34) is binding or not. For example, when the constraint (A.34) is binding, then

$$V_2^C(A_2, K_1, M, \theta_1, \theta_2, \xi_2) = \max_{K_2} \; u\left(A_2 - \xi_2 - K_2\right) + E\left[u\left(\theta_1\theta_2 F(K_1, K_2) - (1+r)M\right)|\mathcal{I}_2\right],$$

and we obtain $\frac{\partial V_2^C}{\partial A_2} = u'(c_2^*)$. When the constraint (A.34) is not binding, then $\frac{\partial V_2^C}{\partial A_2} = E[u'(c_3^*)|\mathcal{I}_2]$. However, in this case $\eta = 0$ and the FOC (A.35) implies $u'(c_2^*) = E[u'(c_3^*)|\mathcal{I}_2]$, resulting in $\frac{\partial V_2^C}{\partial A_2} = u'(c_2^*)$.

where $\mathcal{I}_1$ is the information set at $t = 1$ including $(A_1, M, \theta_1, \xi_1)$. The FOCs and equations (A.33), (A.36), and (A.37) imply that:

$$u'(c_1^*) = E[u'(c_2^*)|\mathcal{I}_1].$$
$$E[u'(c_2^*)|\mathcal{I}_1] = \theta_1 E[\theta_2 F_1'(K_1^*, K_2^*) u'(c_3^*)|\mathcal{I}_1].$$

The partial derivatives of the value function are

$$\frac{\partial V_1^C}{\partial A_1} = E\left[\left.\frac{\partial V_2}{\partial A_2}\right| \mathcal{I}_1\right] = E[u'(c_2^*)|\mathcal{I}_1] \tag{A.38}$$
$$\frac{\partial V_1^C}{\partial M} = E\left[\left.\frac{\partial V_2}{\partial M}\right| \mathcal{I}_1\right] = -(1+r)E[u'(c_3^*)|\mathcal{I}_1]. \tag{A.39}$$

Finally consider the period-0 problem. The problem to solve is

$$\begin{aligned} &\max_M \; E[V_1(A_1, M, \theta_1, \xi_1)] \\ &\text{s.t. } \; M \le \overline{M}. \\ &\qquad A_1 = A_0 + M. \end{aligned} \tag{A.40}$$

If the constraint (A.40) is not binding, the FOC is

$$E\left[\frac{\partial V_1}{\partial A_1}\right] + E\left[\frac{\partial V_1}{\partial M}\right] = 0,$$

which can be rewritten by using equations (A.38) and (A.39) as

$$E[u'(c_2^*)] = (1+r)E[u'(c_3^*)].$$

A.2.2 Sequential credit

Next, consider the decision under sequential credit. A borrower determines the loan size $M \le \overline{M}$ and the amount of the first disbursement $M_1 \le M$ at period 0. At period 2, they can determine the amount of the second disbursement $M_2 \le M - M_1$ after observing the shocks $(\theta_1, \theta_2, \xi_1, \xi_2)$. The repayment amount at period 3 is then $(1+r)(M_1 + M_2)$. Since M_2, the second disbursement amount, is now the decision variable at period 2, denoting

$$\begin{aligned} A_1 &= A_0 + M_1 \\ \tilde{A}_2 &= A_1 - \xi_1 - c_1 - K_1. \end{aligned}$$

First, consider the period-2 problem. The value function is:

$$
\begin{aligned}
V_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2) = \max_{c_2, K_2, M_2} \quad & u(c_2) + E[u(c_3)|\mathcal{I}_2] \\
\text{s.t. } & c_2 + K_2 \le \tilde{A}_2 - \xi_2 + M_2 && \text{(A.41)} \\
& M_2 \le M - M_1 && \text{(A.42)} \\
& M_2 \ge 0 && \text{(A.43)} \\
& c_3 = \theta_1\theta_2 F(K_1, K_2) - (1+r)(M_1 + M_2) + \tilde{A}_2 - \xi_2 + M_2 - c_2 - K_2 - \xi_3.
\end{aligned}
$$

Note that the state variables include M_1, as it affects the upper limit of M_2. The FOCs are:

$$u'(c_2^*) - E[u'(c_3^*)|\mathcal{I}_2] - \eta = 0, \tag{A.44}$$

$$[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1]E[u'(c_3^*)|\mathcal{I}_2] - \eta = 0, \tag{A.45}$$

$$-rE[u'(c_3^*)|\mathcal{I}_2] + \eta - \mu + \nu = 0, \tag{A.46}$$

where η, μ, and ν are the Lagrange multipliers associated with the constraints (A.41), (A.42), and (A.43), respectively. Note that, at the very least, either μ or ν should be zero. Furthermore, equation (A.46) implies that $\eta = rE[u'(c_3^*)|\mathcal{I}_2] + \mu - \nu$, implying that $\eta > 0$ if $\nu = 0$. Hence there are four possible cases: (i) $\mu = \nu = 0, \eta > 0$, (ii) $\mu > 0, \nu = 0, \eta > 0$, (iii) $\mu = 0, \nu > 0, \eta = 0$, and (iv) $\mu = 0, \nu > 0, \eta > 0$. By substituting (A.46) into equations (A.44) and (A.45), we obtain

$$u'(c_2^*) = (1+r)E[u'(c_3^*)|\mathcal{I}_2] + \mu - \nu, \tag{A.47}$$

$$[\theta_1\theta_2 F_2'(K_1, K_2^*) - (1+r)]E[u'(c_3^*)|\mathcal{I}_2] = \mu - \nu.$$

The partial derivatives of the value function are

$$\frac{\partial V_2^S}{\partial \tilde{A}_2} = u'(c_2^*) \tag{A.48}$$

$$\frac{\partial V_2^S}{\partial K_1} = \theta_1\theta_2 F_1'(K_1, K_2^*)E[u'(c_3^*)|\mathcal{I}_2] \tag{A.49}$$

$$\frac{\partial V_2^S}{\partial M} = \begin{cases} 0 & \text{if } \mu = 0 \\ u'(c_2^*) - (1+r)E[u'(c_3^*)|\mathcal{I}_2] & \text{if } \mu > 0 \end{cases} \tag{A.50}$$

$$\frac{\partial V_2^S}{\partial M_1} = \begin{cases} -(1+r)E[u'(c_3^*)|\mathcal{I}_2] & \text{if } \mu = 0 \\ -u'(c_2^*) & \text{if } \mu > 0 \end{cases} \tag{A.51}$$

In deriving $\frac{\partial V_2^S}{\partial M}$ and $\frac{\partial V_2^S}{\partial M_1}$, we used the fact that if $\mu > 0$, then $\nu = 0$ and hence $\eta = 0$.

Now consider the period-1 problem. The value function is

$$
\begin{aligned}
V_1^S(A_1, M, M_1, \theta_1, \xi_1) = \max_{c_1, K_1} \ & u(c_1) + E\left[V_2^S(A_1 - \xi_1 - c_1 - K_1, K_1, M, M_1, \theta_1, \theta_2, \xi_2)\middle|\, \mathcal{I}_1\right] \\
\text{s.t. } & c_1 + K_1 \le A_1 - \xi_1 && \text{(A.52)}
\end{aligned}
$$

The FOCs are

$$u'(c_1^*) - E\left[\frac{\partial V_2^S}{\partial \tilde{A}_2}\middle| \mathcal{I}_1\right] - \lambda = 0$$
$$E\left[-\frac{\partial V_2^S}{\partial \tilde{A}_2} + \frac{\partial V_2^S}{\partial K_1}\middle| \mathcal{I}_1\right] - \lambda = 0,$$

where λ is the Lagrange multiplier associated with the constraint (A.52). Using equations (A.48) and (A.49), these conditions reduce to

$$u'(c_1^*) = E\left[u'(c_2^*)|\mathcal{I}_1\right] + \lambda.$$
$$\theta_1 E\left[\theta_2 F_1'(K_1^*, K_2^*)u'(c_3^*)|\mathcal{I}_1\right] = E\left[u'(c_2^*)|\mathcal{I}_1\right] + \lambda.$$

The partial derivatives of the value function are:[56]

$$\frac{\partial V_1^S}{\partial A_1} = \begin{cases} E\left[u'(c_2^*)|\mathcal{I}_1\right] & \text{if } \lambda = 0 \\ u'(c_1^*) & \text{if } \lambda > 0, \end{cases}$$
$$\frac{\partial V_1^S}{\partial M} = E[\mu|\mathcal{I}_1]$$
$$\frac{\partial V_1^S}{\partial M_1} = -E\left[u'(c_2^*)|\mathcal{I}_1\right] - E[\nu|\mathcal{I}_1].$$

Finally, consider the period-0 problem. They maximize $E[V_1^S(A_1 = A_0 + M_1, M, M_1, \theta_1, \xi_1)]$. The FOC with respect to M_1 is written as:

$$E[\lambda] - E[\nu] = 0,$$

which shows the balance between the resource constraint (higher M_1 enables more investment at $t = 1$ in case of high productivity) and the constraint on reducing the repayment (higher M_1 leaves less room for reducing the loan size at $t = 2$ in case of low productivity).

In sequential credit with self-set limit, they can also choose M. When $M^* < \overline{M}$, the FOC implies $E\left[\frac{\partial V_1^S}{\partial M}\right] = 0$, which reduces to:

$$E[\mu] = 0.$$

[56]Here we provide the derivation of $\frac{\partial V_1^S}{\partial M}$. An analogous procedure gives $\frac{\partial V_1^S}{\partial M_1}$. From the definition of the value function $V_1^S(A_1, M, M_1, \theta_1, \xi_1)$ and equation (A.50),

$$\begin{aligned}\frac{\partial V_1^S}{\partial M} =& E\left[\frac{\partial V_2^S}{\partial M}\middle| \mathcal{I}_1\right] = \Pr(\mu = 0|\mathcal{I}_1) \cdot 0 + \Pr(\mu > 0|\mathcal{I}_1) E\left[u'(c_2^*) - (1+r)u'(c_3^*)|\mathcal{I}_1, \mu > 0\right] \\ =& \Pr(\mu > 0|\mathcal{I}_1) E\left[\mu - \nu|\mathcal{I}_1, \mu > 0\right]\end{aligned}$$

where the last equation follows from equations (A.44) and (A.46). Using the fact that $\nu = 0$ if $\mu > 0$ and that $E\left[\mu|\mathcal{I}_1\right] = \Pr(\mu > 0|\mathcal{I}_1) E\left[\mu|\mathcal{I}_1, \mu > 0\right]$ if $\mu \geq 0$, we obtain

$$\frac{\partial V_1^S}{\partial M} = E\left[\mu|\mathcal{I}_1\right].$$

This suggests that the borrower will choose a sufficiently high M that the period-2 constraint $M_2 \leq M - M_1$ is never binding.

A.2.3 Present-biased borrowers under sequential credit

Now, consider the decision of the present-biased (PB) borrower under sequential credit. The discounted value function for their period-2 self is:

$$
\begin{aligned}
W_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \beta) = \max_{c_2, K_2, M_2} \quad & u(c_2) + \beta E[u(c_3)|\mathcal{I}_2] \\
\text{s.t.} \quad & c_2 + K_2 \leq \tilde{A}_2 - \xi_2 + M_2 \\
& M_2 \leq M - M_1 \qquad \text{(A.53)} \\
& M_2 \geq 0 \qquad \text{(A.54)} \\
& c_3 = \theta_1\theta_2 F(K_1, K_2) - (1+r)(M_1 + M_2) + \tilde{A}_2 - \xi_2 + M_2 - c_2 - K_2 - \xi_3.
\end{aligned}
$$

Analogous to the case of the time-consistent borrowers, the FOCs can be written as:

$$
\begin{aligned}
& u'(c_2^*) - \beta E[u'(c_3^*)|\mathcal{I}_2] - \eta = 0, \\
& \left[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1\right] \beta E[u'(c_3^*)|\mathcal{I}_2] - \eta = 0, \\
& -\beta r E[u'(c_3^*)|\mathcal{I}_2] + \eta - \mu + \nu = 0,
\end{aligned}
$$

which gives us the decision rules $c_2^* = c_2(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \beta)$, $K_2^* = K_2(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \beta)$, and $M_2^* = M_2(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \beta)$. Hereafter, we write them as $c_2^{*(\beta)}$, $K_2^{*(\beta)}$, and $M_2^{*(\beta)}$ for brevity. If the constraints (A.53) and (A.54) are not binding, then the second investment will be made optimally. The partial derivatives of the value function are

$$
\begin{aligned}
\frac{\partial W_2^S(\cdot;\beta)}{\partial \tilde{A}_2} &= u'(c_2^{*(\beta)}) \\
\frac{\partial W_2^S(\cdot;\beta)}{\partial K_1} &= \theta_1\theta_2 F_1'(K_1, K_2^{*(\beta)}) \beta E[u'(c_3^{*(\beta)})|\mathcal{I}_2] \\
\frac{\partial W_2^S(\cdot;\beta)}{\partial M} &= \begin{cases} 0 & \text{if } \mu = 0 \\ u'(c_2^{*(\beta)}) - (1+r)\beta E[u'(c_3^{*(\beta)})|\mathcal{I}_2] & \text{if } \mu > 0 \end{cases} \\
\frac{\partial W_2^S(\cdot;\beta)}{\partial \alpha} &= \begin{cases} -(1+r)\beta E[u'(c_3^{*(\beta)})|\mathcal{I}_2] & \text{if } \mu = 0 \\ -u'(c_2^{*(\beta)}) & \text{if } \mu > 0 \end{cases}
\end{aligned}
$$

Now, consider the period-1 problem. With their present bias parameter β and perception on it

$\hat{\beta}$, the value function at the period-1 decision maker is written as

$$W_1^S(A_1, M, M_1, \theta_1, \xi_1; \beta, \hat{\beta}) = \max_{c_1, K_1} u(c_1) + \beta E\left[\hat{V}_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \hat{\beta})\Big| \mathcal{I}_1\right]$$
$$\text{s.t. } c_1 + K_1 \leq A_1 - \xi_1 \tag{A.55}$$
$$\tilde{A}_2 = A_1 - \xi_1 - c_1 - K_1$$

where $\hat{V}_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \hat{\beta})$ is the continuation value under the decision rule with belief $\hat{\beta}$ defined as

$$\hat{V}_2^S(\cdot; \hat{\beta}) = u\left(c_2^{*(\hat{\beta})}\right) + E\left[u\left(c_3^{*(\hat{\beta})}\right)|\mathcal{I}_2\right],$$

in which $c_3^{*(\hat{\beta})} = \theta_1\theta_2 F(K_1, K_2^{*(\hat{\beta})}) - (1+r)(M_1 + M_2^{*(\hat{\beta})}) + \tilde{A}_2 - \xi_2 + M_2^{*(\hat{\beta})} - c_2^{*(\hat{\beta})} - K_2^{*(\hat{\beta})} - \xi_3$.

The FOCs are:

$$u'(c_1^*) - \beta E\left[\frac{\partial \hat{V}_2^S(\cdot; \hat{\beta})}{\partial \tilde{A}_2}\bigg| \mathcal{I}_1\right] - \lambda = 0, \tag{A.56}$$

$$\beta E\left[-\frac{\partial \hat{V}_2^S(\cdot; \hat{\beta})}{\partial \tilde{A}_2} + \frac{\partial \hat{V}_2^S(\cdot; \hat{\beta})}{\partial K_1}\bigg| \mathcal{I}_1\right] - \lambda = 0, \tag{A.57}$$

where λ is the Lagrange multiplier associated with the constraint (A.55). These conditions give

$$u'(c_1^*) = \beta E\left[\frac{\partial \hat{V}_2^S(\cdot; \hat{\beta})}{\partial K_1}\bigg| \mathcal{I}_1\right].$$

These characterize the decision rules $c_1^* = c_1(A_1, M, M_1, \theta_1, \xi_1; \beta, \hat{\beta})$ and $K_1^* = K_1(A_1, M, M_1, \theta_1, \xi_1; \beta, \hat{\beta})$, which we denote by $c_1^{*(\beta,\hat{\beta})}$ and $K_1^{*(\beta,\hat{\beta})}$.

As in the case of no uncertainty, we utilize the relationship between V_2^S and W_2^S:

$$\hat{V}_2^S(\cdot; \hat{\beta}) = \frac{1}{\hat{\beta}}\left[W_2^S(\cdot; \hat{\beta}) - (1-\hat{\beta})u(c_2^{*(\hat{\beta})})\right].$$

Thereafore, we can derive the partial derivatives of $\hat{V}_2^S(\cdot; \hat{\beta})$ as follows:

$$\begin{aligned}
\frac{\partial \hat{V}_2(\cdot; \hat{\beta})}{\partial \tilde{A}_2} &= \frac{1}{\hat{\beta}}\left[\frac{\partial W_2^S(\cdot; \hat{\beta})}{\partial \tilde{A}_2} - (1-\hat{\beta})u'(c_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2}\right] = \frac{1}{\hat{\beta}}\left[1 - (1-\hat{\beta})\frac{\partial c_2^*(\cdot; \hat{\beta})}{\partial \tilde{A}_2}\right]u'(c_2^{*(\hat{\beta})}) \\
\frac{\partial \hat{V}_2(\cdot; \hat{\beta})}{\partial K_1} &= \frac{1}{\hat{\beta}}\left[\frac{\partial W_2^S(\cdot; \hat{\beta})}{\partial K_1} - (1-\hat{\beta})u'(c_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial K_1}\right] \\
&= \theta_1\theta_2 F_1'(K_1, K_2^{*(\hat{\beta})})E\left[u'(c_3^{*(\hat{\beta})})|\mathcal{I}_2\right] - \frac{1-\hat{\beta}}{\hat{\beta}}u'(c_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial K_1}. \\
\frac{\partial \hat{V}_2(\cdot; \hat{\beta})}{\partial M} &= \frac{1}{\hat{\beta}}\left[\frac{\partial W_2^S(\cdot; \hat{\beta})}{\partial M} - (1-\hat{\beta})u'(c_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial M}\right] \\
\frac{\partial \hat{V}_2(\cdot; \hat{\beta})}{\partial M_1} &= \frac{1}{\hat{\beta}}\left[\frac{\partial W_2^S(\cdot; \hat{\beta})}{\partial M_1} - (1-\hat{\beta})u'(c_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial M_1}\right]
\end{aligned}$$

Then, the FOCs (A.56) and (A.57) can be written as:

$$u'(c_1^{*(\beta,\hat{\beta})}) = \frac{\beta}{\hat{\beta}} E\left[\left\{1-(1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2}\right\} u'(c_2^{*(\hat{\beta})})\middle| \mathcal{I}_1\right] + \lambda,$$

$$\beta E\left[\theta_1\theta_2 F_1'(K_1^*, K_2^{*(\hat{\beta})}) u'(c_3^{*(\hat{\beta})})\middle| \mathcal{I}_1\right] = \frac{\beta}{\hat{\beta}} E\left[\left\{1-(1-\hat{\beta})\left(\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2} - \frac{\partial c_2^{*(\hat{\beta})}}{\partial K_1}\right)\right\} u'(c_2^{*(\hat{\beta})})\middle| \mathcal{I}_1\right] + \lambda.$$

We can also derive the partial derivatives of $W_1^S(\cdot;\beta,\hat{\beta})$ as follows:

$$\begin{aligned}
\frac{\partial W_1^S(\cdot;\beta,\hat{\beta})}{\partial \tilde{A}_2} &= u'(c_1^{*(\beta,\hat{\beta})}) \\
\frac{\partial W_1^S(\cdot;\beta,\hat{\beta})}{\partial M} &= \frac{\beta}{\hat{\beta}} E\left[\mu - (1-\hat{\beta}) u'(c_2^{*(\hat{\beta})}) \frac{\partial c_2^{*(\hat{\beta})}}{\partial M}\middle| \mathcal{I}_1\right] \\
\frac{\partial W_1^S(\cdot;\beta,\hat{\beta})}{\partial M_1} &= -\frac{\beta}{\hat{\beta}} E\left[u'(c_2^{*(\hat{\beta})}) + \nu + (1-\hat{\beta}) u'(c_2^{*(\hat{\beta})}) \frac{\partial c_2^{*(\hat{\beta})}}{\partial M_1}\middle| \mathcal{I}_1\right]
\end{aligned}$$

Finally consider the period-0 problem. For generality, we consider the case of sequential credit with self-set limit in which the borrower can also choose M. The problem to solve is

$$\begin{aligned}
\max_{M\le \overline{M}, M_1 \le M} \quad & E[u(c_1^{*(\beta,\hat{\beta})}) + \hat{V}_2^S(\tilde{A}_2, K_1^{*(\beta,\hat{\beta})}, M, M_1, \theta_1, \theta_2, \xi_2; \hat{\beta})] \\
\text{s.t.} \quad & A_1 = A_0 + M_1 \\
& \tilde{A}_2 = A_1 - \xi_1 - c_1^{*(\beta,\hat{\beta})} - K_1^{*(\beta,\hat{\beta})}.
\end{aligned}$$

This can be written by using $W_1(\cdot;\hat{\beta},\hat{\beta})$ as follows:

$$\begin{aligned}
\max_{M\le \overline{M}, M_1 \le M} \quad & \frac{1}{\hat{\beta}} E\left[W_1^S(A_1, M, M_1, \theta_1, \xi_1; \hat{\beta}, \hat{\beta}) - (1-\hat{\beta}) u(c_1^{*(\hat{\beta},\hat{\beta})})\right] \\
\text{s.t.} \quad & A_1 = A_0 + M_1
\end{aligned}$$

Solving the FOCs when $M^* < \overline{M}$, we can obtain

$$E[\mu] = (1-\hat{\beta}) E\left[u'(c_1^{*(\hat{\beta},\hat{\beta})}) \frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M} + u'(c_2^{*(\hat{\beta})}) \frac{\partial c_2^{*(\hat{\beta})}}{\partial M}\right]$$

and

$$E[\lambda] - E[\nu] = (1-\hat{\beta}) E\left[u'(c_1^{*(\hat{\beta},\hat{\beta})}) \left(\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial A_1} + \frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1}\right) + u'(c_2^{*(\hat{\beta})}) \left(\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2} + \frac{\partial c_2^{*(\hat{\beta})}}{\partial M_1}\right)\right].$$

The right-hand sides of these equations are positive. Remember that for the time-consistent borrowers, the right-hand sides are zero. This implies that the PB borrower will choose M and M_1 so that the probability of the resource constraints at $t = 1, 2$ being binding becomes higher, resulting in lower levels of M and M_1.

A.2.4 Credit lines

This subsection describes the borrower's decision under credit lines (CL), in which a borrower can choose M_1 and M_2 at $t = 1$ and $t = 2$, respectively, with the constraint $M_1 + M_2 \leq \bar{M}$. We consider the case that this constraint is not binding, and hence, $\mu = 0$, that is, the upper limit of the loan size is sufficiently large compared to its demand as in most cases of our field study.

First, consider the time-consistent borrower. The period 2 problem is the same as under sequential credit, except that the constraint (A.42)) is replaced by $M_2 \leq \overline{M} - M_1$. Hence we can use the same value function as that under sequential credit by replacing M by $\overline{M}$, that is, $V_2^S(\tilde{A}_2, K_1, \overline{M}, M_1, \theta_1, \theta_2, \xi_2)$.

Now consider the period-1 problem, in which they solve

$$\max_{c_1, K_1, M_1} \; u(c_1) + E\left[V_2^S(A_1 - \xi_1 - c_1 - K_1, K_1, \overline{M}, M_1, \theta_1, \theta_2, \xi_2) \middle| \mathcal{I}_1 \right]$$

$$\text{s.t. } c_1 + K_1 \leq A_0 + M_1 - \xi_1 \tag{A.58}$$

The FOCs are

$$\begin{aligned}
u'(c_1^*) - E\left[\frac{\partial V_2^S}{\partial \tilde{A}_2} \middle| \mathcal{I}_1 \right] - \lambda^{cl} &= 0 \\
E\left[-\frac{\partial V_2^S}{\partial \tilde{A}_2} + \frac{\partial V_2^S}{\partial K_1} \middle| \mathcal{I}_1 \right] - \lambda^{cl} &= 0, \\
E\left[\frac{\partial V_2^S}{\partial \tilde{A}_2} + \frac{\partial V_2^S}{\partial M_1} \middle| \mathcal{I}_1 \right] + \lambda^{cl} &= 0,
\end{aligned}$$

where λ^{cl} is the Lagrange multiplier associated with the constraint (A.58). Note that $\frac{\partial V_2^S}{\partial \tilde{A}_2} + \frac{\partial V_2^S}{\partial M_1} = 0$ by equations (A.47), (A.48), and (A.51) if $\nu = 0$. Hence, the borrower will set M_1 so that $\lambda^{cl} = 0$ or to a level at which the budget constraints are no longer binding at the optimal levels of (c_1^*, K_1^*), that is, $M_1^* = c_1^* + K_1^* + \xi - A_0$. Based on equations (A.48) and (A.49), the optimal consumption and investment (c_1^*, K_1^*) satisfy the FOCs

$$\begin{aligned}
u'(c_1^*) &= E\left[u'(c_2^*) | \mathcal{I}_1 \right], \\
\theta_1 E\left[\theta_2 F_1'(K_1^*, K_2^*) u'(c_3^*) | \mathcal{I}_1 \right] &= E\left[u'(c_2^*) | \mathcal{I}_1 \right].
\end{aligned}$$

Now, consider the decision of the PB borrower under CL. Again, the borrower's problem at $t = 2$ is the same as sequential credit, which gives us the value function $\hat{V}_2^S(\tilde{A}_2, K_1, \overline{M}, M_1, \theta_1, \theta_2, \xi_2; \hat{\beta})$. At $t = 1$, they solve

$$\max_{c_1, K_1, M_1} \; u(c_1) + \beta E\left[\hat{V}_2^S(\tilde{A}_2, K_1, \overline{M}, M_1, \theta_1, \theta_2, \xi_2; \hat{\beta}) \middle| \mathcal{I}_1 \right]$$

$$\begin{aligned}
\text{s.t. } & c_1 + K_1 \leq A_0 + M_1 - \xi_1 \\
& \tilde{A}_2 = A_0 + M_1 - \xi_1 - c_1 - K_1.
\end{aligned}$$

The FOCs are:

$$
\begin{aligned}
u'(c_1^*) - \beta E\left[\frac{\partial \hat{V}_2^S(\cdot;\hat{\beta})}{\partial \tilde{A}_2}\middle| \mathcal{I}_1\right] - \lambda^{cl} = 0, \\
\beta E\left[-\frac{\partial \hat{V}_2^S(\cdot;\hat{\beta})}{\partial \tilde{A}_2} + \frac{\partial \hat{V}_2^S(\cdot;\hat{\beta})}{\partial K_1}\middle| \mathcal{I}_1\right] - \lambda^{cl} = 0, \\
\beta E\left[\frac{\partial \hat{V}_2^S(\cdot;\hat{\beta})}{\partial \tilde{A}_2} + \frac{\partial \hat{V}_2^S(\cdot;\hat{\beta})}{\partial M_1}\middle| \mathcal{I}_1\right] - \lambda^{cl} = 0.
\end{aligned}
$$

As in the time-consistent borrower's case, the borrower will set M_1 so that $\lambda^{cl} = 0$, or $M_1^* = c_1 + K_1 + \xi - A_0$. Using the analogous argument to the case of sequential credit, other two FOCs can be rewritten as

$$
\begin{aligned}
u'(c_1^{*(\beta,\hat{\beta})}) &= \frac{\beta}{\hat{\beta}} E\left[\left\{1 - (1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2}\right\} u'(c_2^{*(\hat{\beta})})\middle| \mathcal{I}_1\right], \\
E\left[\theta_1\theta_2 F_1'(K_1^*, K_2^{*(\hat{\beta})}) u'(c_3^{*(\hat{\beta})})\middle| \mathcal{I}_1\right] &= \frac{1}{\hat{\beta}} E\left[\left\{1 - (1-\hat{\beta})\left(\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2} - \frac{\partial c_2^{*(\hat{\beta})}}{\partial K_1}\right)\right\} u'(c_2^{*(\hat{\beta})})\middle| \mathcal{I}_1\right].
\end{aligned}
$$

A.3 Numerical examples

With the three-period model, we can derive the solution of the model directly by solving the nonlinear system equations and nonlinear optimization, which help us avoid computing the value for every state and avoid the curse of dimensionality.

A.3.1 Benchmark model

First consider the benchmark model without uncertainty. As stated in equations (A.7), (A.14), (A.15), and (A.20), the FOCs are given by

$$
\begin{aligned}
c_1^* &= c_2^* \qquad \text{(A.59)} \\
F_1'(K_1^*, K_2^*) &= F_2'(K_1^*, K_2^*) \qquad \text{(A.60)} \\
u'(c_2^*) &= F_2'(K_1^*, K_2^*) u'(c_3^*) \\
F_1'(K_1^*, K_2^*) &= 1 + \frac{r}{Q}. \qquad \text{(A.61)}
\end{aligned}
$$

Solving these nonlinear system equations is computationally expensive. To reduce the computational burden, we can exploit the structure of the problem as follows.

First, with the Cobb–Douglass production function $F(K_1, K_2) = \theta K_1^{\psi_1} K_2^{\psi_2}$, the equation (A.60) implies that K_2^* can be written as a function of K_1:

$$
K_2^*(K_1) = \frac{\psi_2}{\psi_1} K_1. \qquad \text{(A.62)}
$$

Then from equation (A.59) combined with equations (6) and (4), we can derive the optimal consumption level at $t = 1, 2$ as a function of K_1 and M:

$$c_1^*(K_1, M) = c_2^*(K_1, M) = \frac{1}{2}\left[A_0 + QM - K_1 - K_2^*(K_1)\right].$$

The optimal consumption level at $t = 3$ can also be written as a function of K_1 and M:

$$c_3^*(K_1, M) = F(K_1, K_2^*(K_1)) - (Q + r)M.$$

Then, we can obtain the optimal level of K_1 and M by solving:

$$\begin{aligned} u'\left(c_2^*(K_1, M)\right) &= F_2'\left(K_1, K_2^*(K_1)\right) u'\left(c_3^*(K_1, M)\right) \\ F_1'\left(K_1, K_2^*(K_1)\right) &= 1 + \frac{r}{Q} \end{aligned}$$

This is the nonlinear system equation with two unknowns, which can be solved fairly quickly.

To calibrate the parameter values, we use the equations (A.62) and (A.61) and the Cobb–Douglass production function:

$$\begin{aligned} \frac{\psi_1}{\psi_2} &= \frac{K_1^*}{K_2^*}, \\ \psi_2 \theta K_1^{*\psi_1} K_2^{*\psi_2 - 1} &= 1 + \frac{r}{Q}, \\ Y &= \theta K_1^{*\psi_1} K_2^{*\psi_2}. \end{aligned}$$

We set $r = 0.12$ to mimic our intervention described in the next section. Crop credit corresponds to the case of $Q = 1$. The sample averages of K_1, K_2, and Y for crop credit borrowers were 8,547 BDT, 4,179 BDT, and 33,767 BDT, respectively, which yield the calibrated parameter values as $(\psi_1, \psi_2, \theta) = (0.254, 0.147, 16.196)$.[57]

A.3.2 Crop credit under uncertainty

The model with uncertainty can be solved backward. For generality, we consider the case of the PB borrower. The time-consistent borrower is the special case where $\beta = \hat{\beta} = 1$. To reduce the computational burdens, here we assume away the expenditure/income shocks at $t = 3$, which enables us to derive the solution at $t = 2$ as closed forms and substantially reduce the computational time.

[57]This calibration only uses the information on the average input and output amount. Another approach to obtain these parameters is estimating the production function, using the variation across households rather than only using the average. However, the observed inputs (K_1, K_2) will be related to the unobserved productivity θ, and without valid exogenous instruments, we cannot obtain the consistent estimates on the production function parameters.

The solution of the period-2 problem in crop credit is characterized by

$$\begin{aligned} u'(c_2^*) &= \beta u'(c_3^*) + \eta \\ \left[\theta_1 \theta_2 F_2'(K_1, K_2^*) - 1\right] \beta u'(c_3^*) &= \eta \end{aligned} \tag{A.63}$$

where η is the Lagrange multiplier associated with the constraint $c_2 + K_2 \leq A_2 - \xi_2$.

Suppose the constraint is not binding ($\eta = 0$). With the Cobb–Douglass production function, equation (A.63) implies that the optimal second investment K_2^* satisfies

$$K_2^* = \left(\psi_2 \theta_1 \theta_2 \theta K_1^{\psi_1}\right)^{\frac{1}{1-\psi_2}}.$$

Substituting this K_2^*, we can derive the optimal consumption levels as:

$$\begin{aligned} c_2^* &= \frac{1}{1+\beta^{1/\gamma}} \left[\theta_1 \theta_2 F(K_1, K_2^*) - (1+r)M + A_2 - \xi_2 - K_2^*\right]. \\ c_3^* &= \theta_1 \theta_2 F(K_1, K_2^*) - (1+r)M + A_2 - \xi_2 - K_2^* - c_2^*. \end{aligned}$$

If it so happens that $c_2^* + K_2^* > A_2 - \xi_2$, then the constraint $c_2 + K_2 \leq A_2 - \xi_2$ is binding at the optimum, and we recompute the optimal level of the second investment by solving the nonlinear equation

$$u'(A_2 - K_2^* - \xi_2) = \theta_1 \theta_2 F_2'(K_1, K_2^*) \beta u' \left(\theta_1 \theta_2 F_2(K_1, K_2^*) - (1+r)M\right)$$

Then, the optimal consumption levels are derived as $c_2^* = A_2 - K_2^* - \xi_2$ and $c_3^* = \theta_1 \theta_2 F_2(K_1, K_2^*) - (1+r)M$. If we allow for the expenditure/income shocks at $t = 3$, c_2^* is obtained by finding the value satisfying $u'(c_2^*) = \beta E[u'(c_3^*)|\mathcal{I}_2]$.

These characterize the decision rules for K_2, c_2, and c_3 as a functions on the state variables $(A_2, K_1, M, \theta_1, \theta_2, \xi_2)$ and the present bias parameter β. Once we obtain (c_2^*, c_3^*), we can derive the (undiscounted) value of being at state $(A_2, K_1, M, \theta_1, \theta_2, \xi_2)$ under the present bias parameter β as

$$V_2(A_2, K_1, M, \theta_1, \theta_2, \xi_2; \beta) = u\left(c_2^*(A_2, K_1, M, \theta_1, \theta_2, \xi_2; \beta)\right) + u\left(c_3^*(A_2, K_1, M, \theta_1, \theta_2, \xi_2; \beta)\right).$$

The borrower who perceives their present bias parameter to be $\hat{\beta}$ evaluates the value of being the state $(A_2, K_1, M, \theta_1, \theta_2, \xi_2)$ as $V_2(A_2, K_1, M, \theta_1, \theta_2, \xi_2; \hat{\beta})$. At period 1, they will solve

$$\max_{c_1, K_1} u(c_1) + \beta E\left[V_2(A_2, K_1, M, \theta_1, \theta_2, \xi_2; \hat{\beta})|\mathcal{I}_1\right]$$

subject to $c_1 + K_1 \leq A_1 - \xi_1$, where $A_2 = A_1 - \xi_1 - c_1 - K_1$ and the expectation is taken over (θ_2, ξ_2). This can be solved by nonlinear optimization routines, which gives us the decision rules c_1 and K_1 as functions of $(A_1, M, \theta_1, \xi_1)$. We denote them by $c_1(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta})$, and $K_1(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta})$

as they will also depend on the actual present bias parameter β and their belief in it, $\hat{\beta}$. We denote the value of being the state $(A_1, M, \theta_1, \xi_1)$ for this borrower as:

$$\begin{aligned} V_1(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta}) =& u\left(c_1(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta})\right) \\ &+ E\left[V_2\left(A_2(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta}), K_1(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta}), M, \theta_1, \theta_2, \xi_2; \hat{\beta}\right) | \mathcal{I}_1\right] \end{aligned}$$

where $A_2(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta}) = A_1 - \xi_1 - c_1(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta}) - K_1(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta})$.

Remember that $A_1 = A_0 + M$. Therefore, the borrower will choose the optimal loan size M^* by solving

$$\max_M E\left[V_1(A_0 + M, M, \theta_1, \xi_1; \beta, \hat{\beta})\right]$$

where the expectation is taken over (θ_1, ξ_1). Once M^* is obtained, the optimal level of c_1, c_2, c_3, K_1, K_2 for possible values of $(\theta_1, \theta_2, \xi_1, \xi_2)$ can be computed accordingly. By searching M^* first, we only need to compute the value function in the states that are visited through the optimization search routine.

A.3.3 Sequential credit under uncertainty

The solution of the period-2 problem in sequential credit is characterized by

$$u'(c_2^*) = \beta u'(c_3^*) + \eta \tag{A.64}$$

$$\left[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1\right] \beta u'(c_3^*) = \eta \tag{A.65}$$

$$- r\beta u'(c_3^*) + \eta - \mu + \nu = 0, \tag{A.66}$$

where η, μ, and ν are the Lagrange multipliers associated with the constraints $c_2 + K_2 \le \tilde{A}_2 - \xi_2 + M_2$, $M_2 \le M - M_1$, and $M_2 \ge 0$, respectively. As argued in Appendix A.2.2, there are four cases: (i) $\mu = \nu = 0, \eta > 0$, (ii) $\mu > 0, \nu = 0, \eta > 0$, (iii) $\mu = 0, \nu > 0, \eta = 0$, and (iv) $\mu = 0, \nu > 0, \eta > 0$. In case (i), the solution satisfies $c_2^* + K_2^* = \tilde{A}_2 - \xi_2 + M_2^*$ and $0 < M_2^* < M - M_1$. Case (ii) corresponds to the case where $c_2^* + K_2^* = \tilde{A}_2 + M_2^*$ and $M_2^* = M - M_1$. Case (iii) is the case where $c_2^* + K_2^* < \tilde{A}_2 - \xi_2$ and $M_2^* = 0$. In case (iv), $c_2^* + K_2^* = \tilde{A}_2 - \xi_2$ and $M_2^* = 0$.

By using (A.66), the conditions (A.64) and (A.65) reduce to

$$\begin{aligned} &u'(c_2^*) = (1+r)\beta u'(c_3^*) + \mu - \nu, \\ &\left[\theta_1\theta_2 F_2'(K_1, K_2^*) - (1+r)\right] \beta u'(c_3^*) = \mu - \nu, \end{aligned} \tag{A.67}$$

First consider case (i). With the Cobb–Douglass production function, equation (A.67) implies

$$K_2^* = \left(\frac{\psi_2\theta_1\theta_2\theta K_1^{\psi_1}}{1+r}\right)^{\frac{1}{1-\psi_2}}.$$

With the CRRA utility function, the optimal period-2 consumption level is

$$c_2^* = \frac{1}{1+r+[\beta(1+r)]^{1/\gamma}} \left[\theta_1\theta_2 F(K_1, K_2^*) - (1+r)(M_1 + K_2^* - \tilde{A}_2 + \xi_2)\right].$$

Then the optimal level of M_2 and c_3 are determined accordingly:

$$\begin{aligned} M_2^* &= c_2^* + K_2^* - \tilde{A}_2 + \xi_2 \\ c_3^* &= \theta_1\theta_2 F(K_1, K_2^*) - (1+r)(M_1 + M_2^*). \end{aligned}$$

If M_2^* as derived above exceeds $M - M_1$, then it corresponds to case (ii). The level of M_2 is set as $M_2^* = M - M_1$, and the period-2 consumption satisfies $c_2^* = \tilde{A}_2 + M_2^* - K_2^*$, where K_2^* is determined by

$$u'(\tilde{A}_2 - \xi_2 + M_2^* - K_2^*) = \theta_1\theta_2 F_2'(K_1, K_2^*)\beta u'\left(\theta_1\theta_2 F_2(K_1, K_2^*) - (1+r)M\right).$$

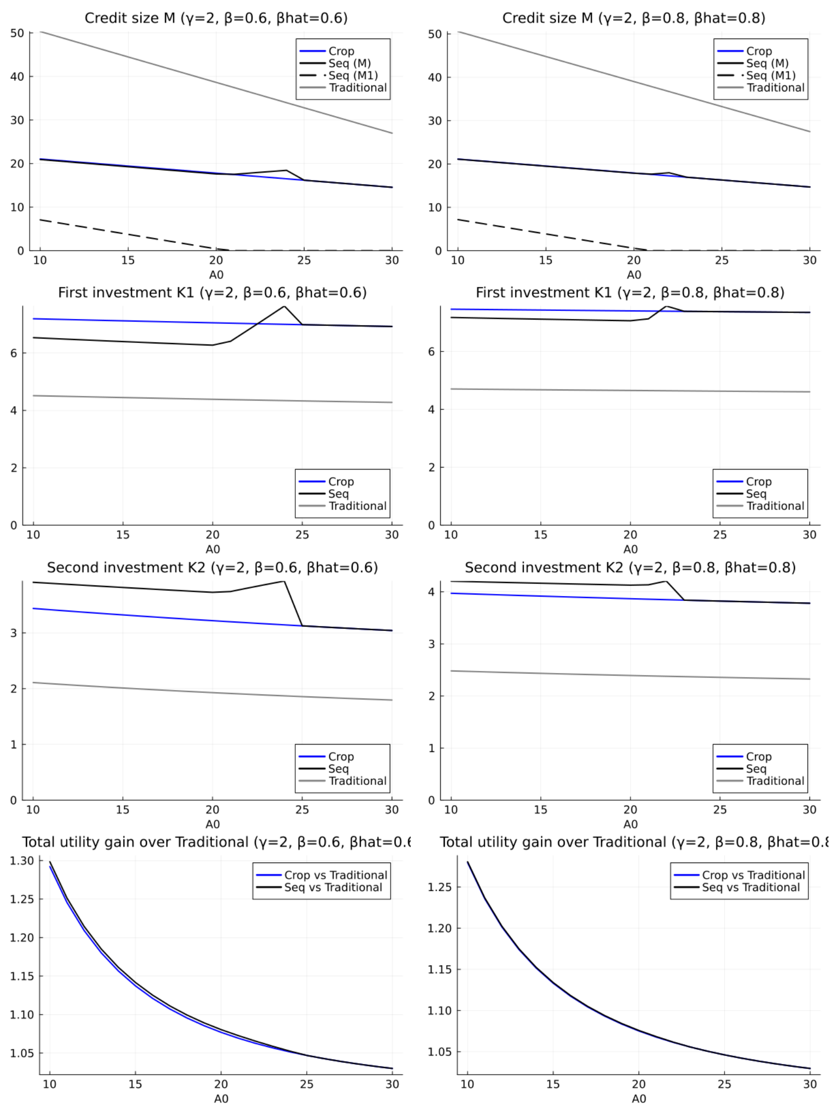
Once K_2^* is determined, we can compute $c_3^* = \theta_1\theta_2 F_2(K_1, K_2^*) - (1+r)M$.

If, however, M_2^* derived above is negative, then the optimal M_2 is 0, as in cases (iii) or (iv). Case (iii) is similar to crop credit when $\eta = 0$, and case (iv) is analogous to crop credit with $\eta > 0$.

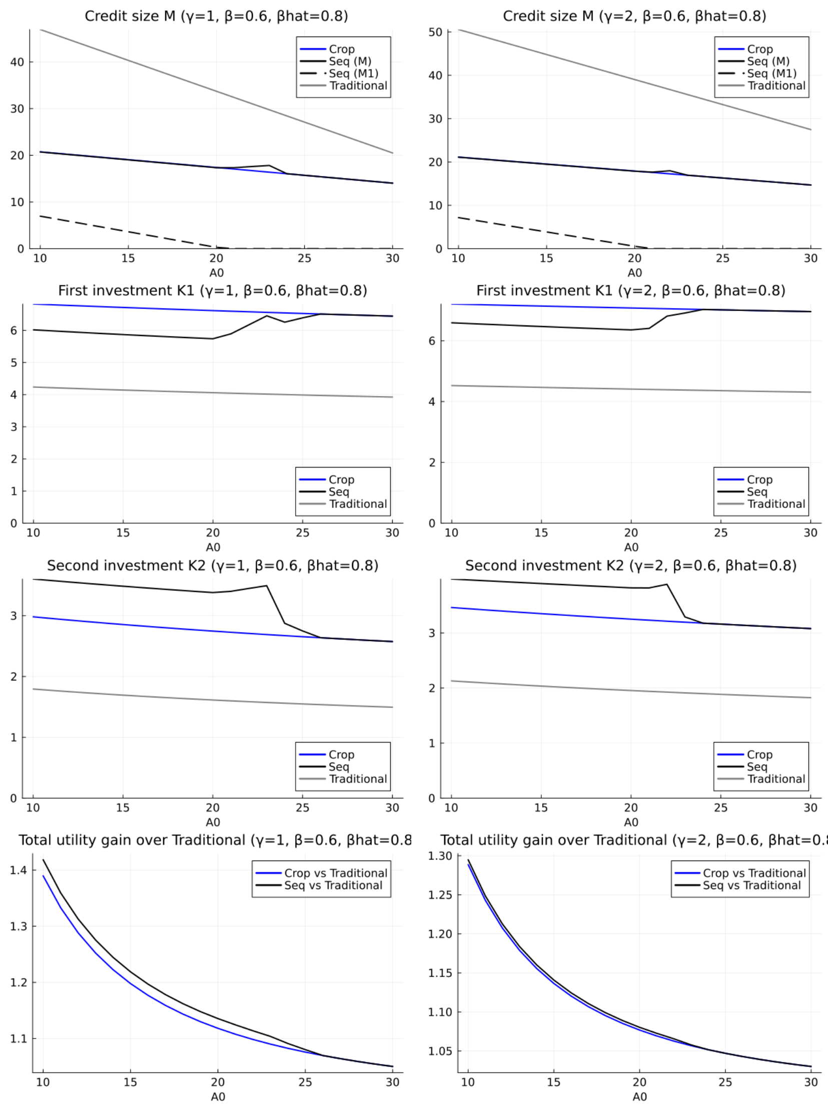
Once we obtain the decision rules for K_2, M_2, c_2, and c_3 as functions on the state variables $(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2)$, the computation procedures are similar to the case of crop credit described above, except that the borrower chooses the amount of the first disbursement M_1 at $t = 0$. Let $\underline{M}_1$ denote the lowest value of M_1 such that the budget constraint at $t = 1$ is not binding at any value of θ_1 and ξ_1, that is, $c_1^{*(\bar{\theta}_1, \bar{\xi}_1, \hat{\beta}, \hat{\beta})} + K_1^{*(\bar{\theta}_1, \bar{\xi}_1, \hat{\beta}, \hat{\beta})} = A_0 + \underline{M}_1 - \xi_1$ where $c_1^{*(\bar{\theta}_1, \bar{\xi}_1, \hat{\beta}, \hat{\beta})}$ and $K_1^{*(\bar{\theta}_1, \bar{\xi}_1, \hat{\beta}, \hat{\beta})}$ are the values of c_1 and K_1 that would be selected under the greatest values of θ_1 and ξ_1 with the perception of the belief $\hat{\beta}$. Since any M_1 larger than $\underline{M}_1$ will have no effect on the decisions and hence, the utility function will be flat for $M_1 > \underline{M}_1$. This will cause a failure in the optimization routine. To deal with this problem, we first derive $c_1^{*(\bar{\theta}_1, \bar{\xi}_1, \hat{\beta}, \hat{\beta})}$ and $K_1^{*(\bar{\theta}_1, \bar{\xi}_1, \hat{\beta}, \hat{\beta})}$ to obtain $\underline{M}_1$, and conduct the optimization routine over the domain of $(0, \underline{M}_1)$. Sequential credit with self-set limit simply extends this problem by allowing a borrower to choose M at $t = 0$.

A.4 Appendix Figures and Tables

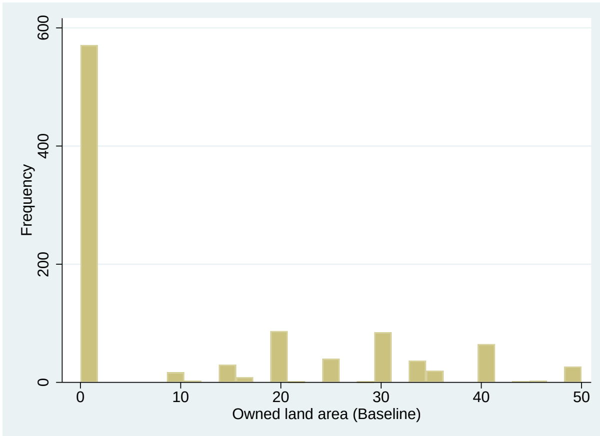
Appendix Figure 1: Choice of (M, K_1, K_2) and the total utility of PB borrowers under crop credit, sequential credit, and traditional microcredit: $\gamma = 2$

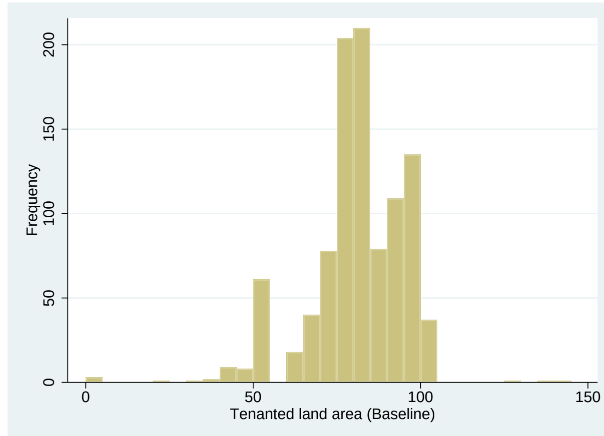


Appendix Figure 2: Choice of (M, K_1, K_2) and the total utility of PB borrowers under crop credit, sequential credit, and traditional microcredit: Partially naive farmers ($\beta = 0.6, \hat{\beta} = 0.8$)

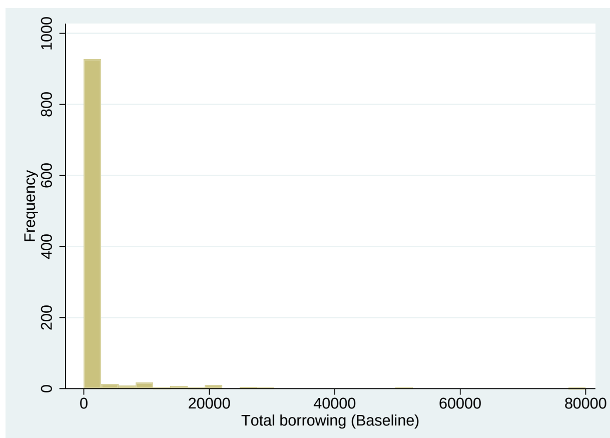


Appendix Figure 3: Areas of owned land and tenancy land

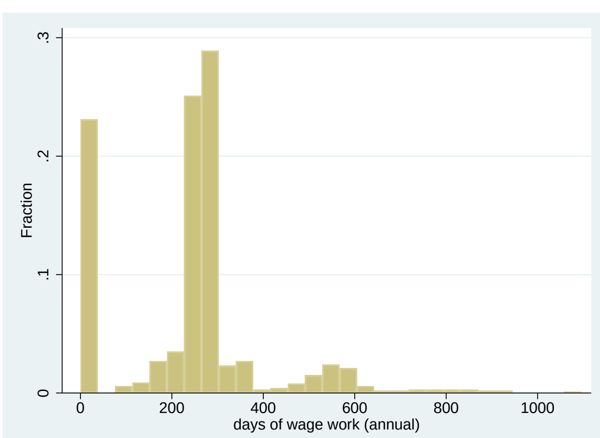


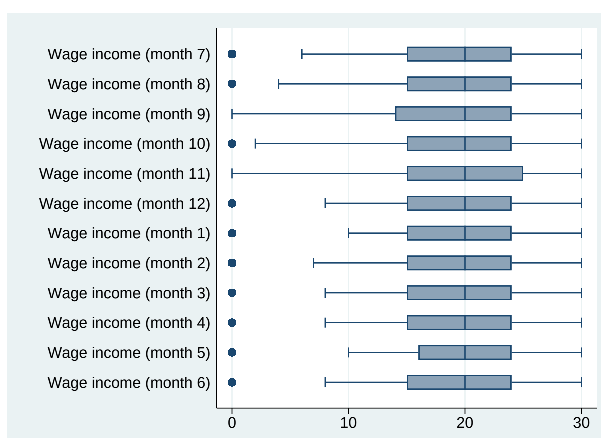


Appendix Figure 4: Borrowing amount in the past 12 months at baseline



Appendix Figure 5: Days of working as daily labor in the last 12 months (Baseline)

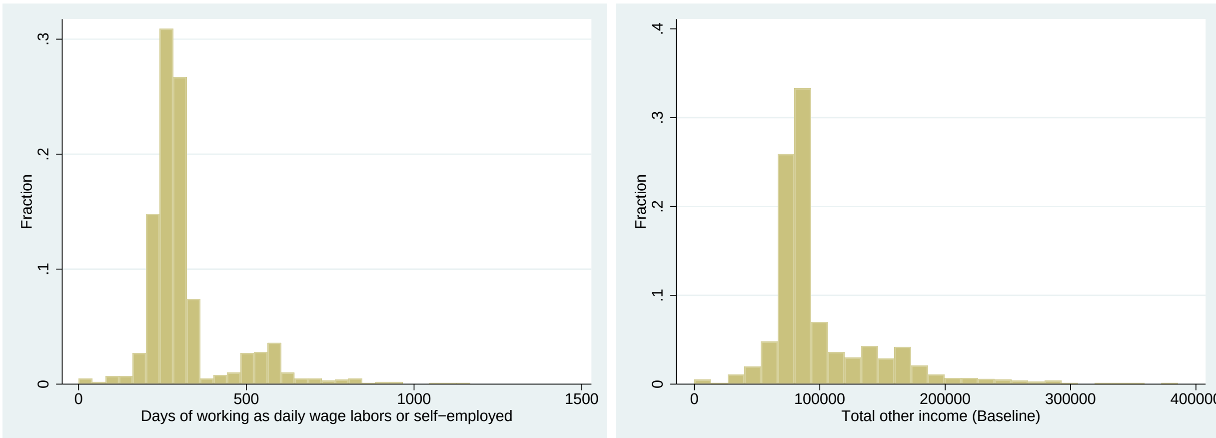




The left panel shows the histogram of the days of working for wage income in the last 12 months at the household level in the baseline data. The right panel is a box plot of the days of working as daily wage disaggregated at the monthly level, based on individual-level data

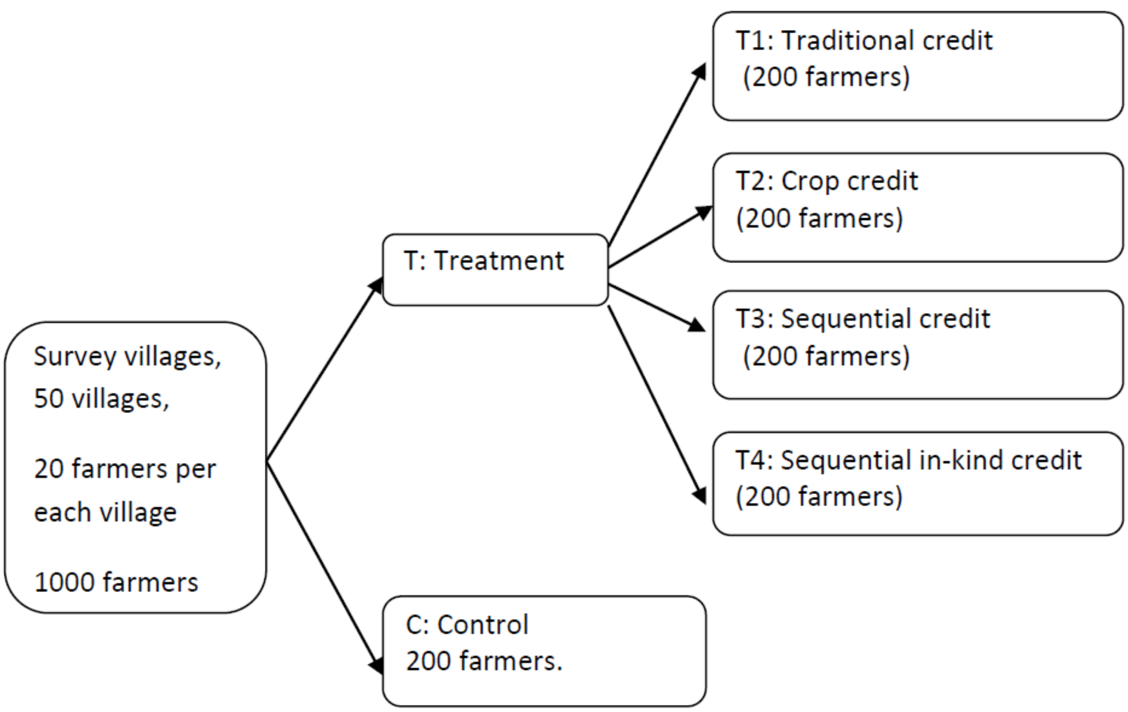
.

Appendix Figure 6: Total income sources other than farming at the baseline

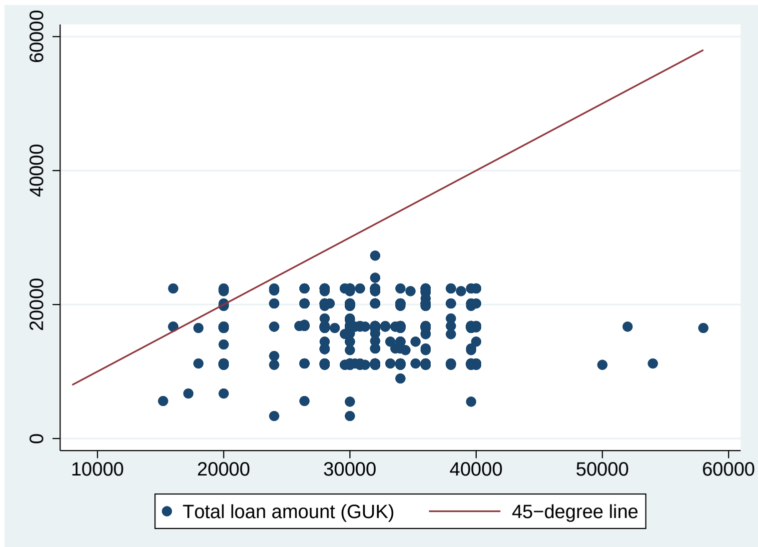


The left panel shows the histogram of the days of working for wage income and self-employment activity in the last 12 months at the household level. The right panel shows the distribution of the total income from wage labor, self-employment, fishery, and poultry. We exclude the revenue from livestock transactions as we do not have information on livestock purchase.

Appendix Figure 7: Experimental design

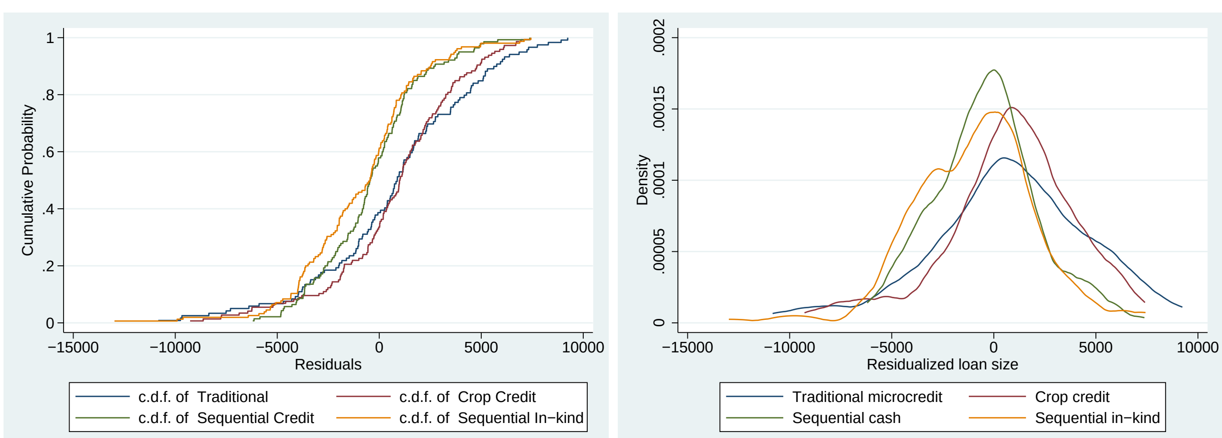


Appendix Figure 8: The computed loanable amount and the actual loan size



The vertical axis is the actual loan size, and the horizontal axis is the inferred loanable amount (horizontal axis). The red solid line shows a 45 degree line.

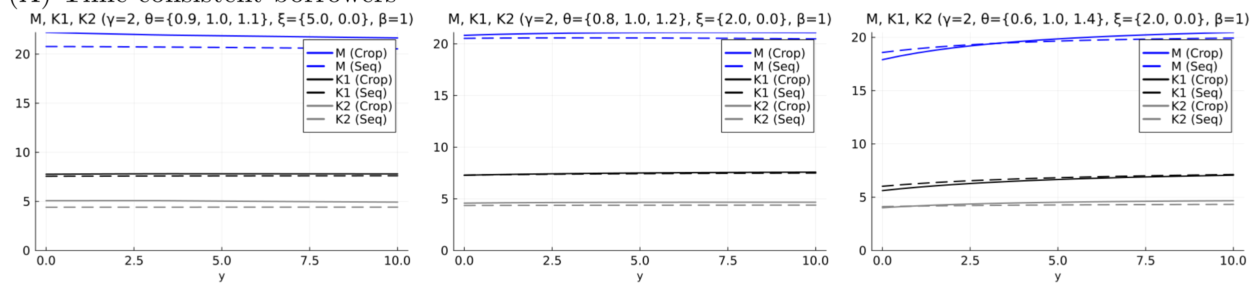
Appendix Figure 9: Distribution of the residualized loan size



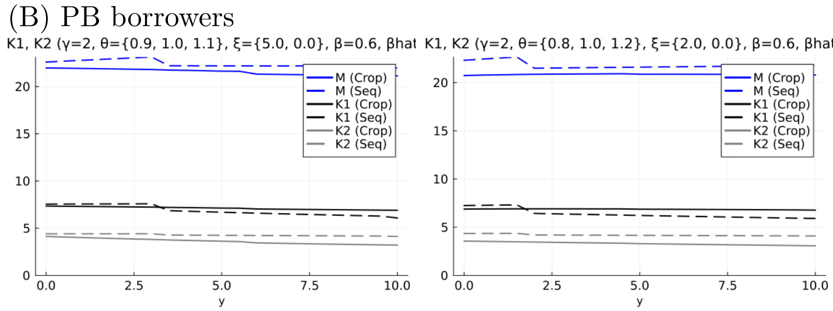
The cumulative and kernel distributions of the residualized loan size is plotted. The control variables to obtain the residuals are the same as the one used in equation (8) except the treatment indicators.

Appendix Figure 10: Choice of (M, K_1, K_2) under crop credit and sequential credit when $\gamma = 2$

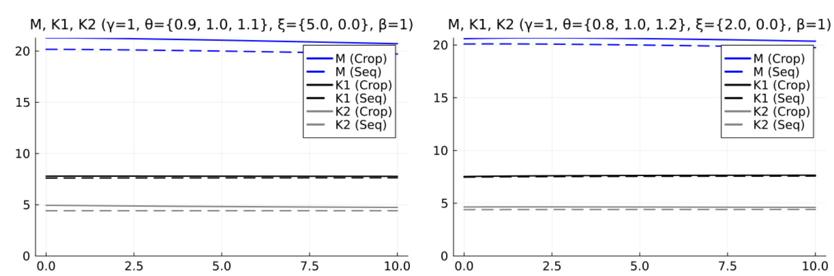
(A) Time-consistent borrowers



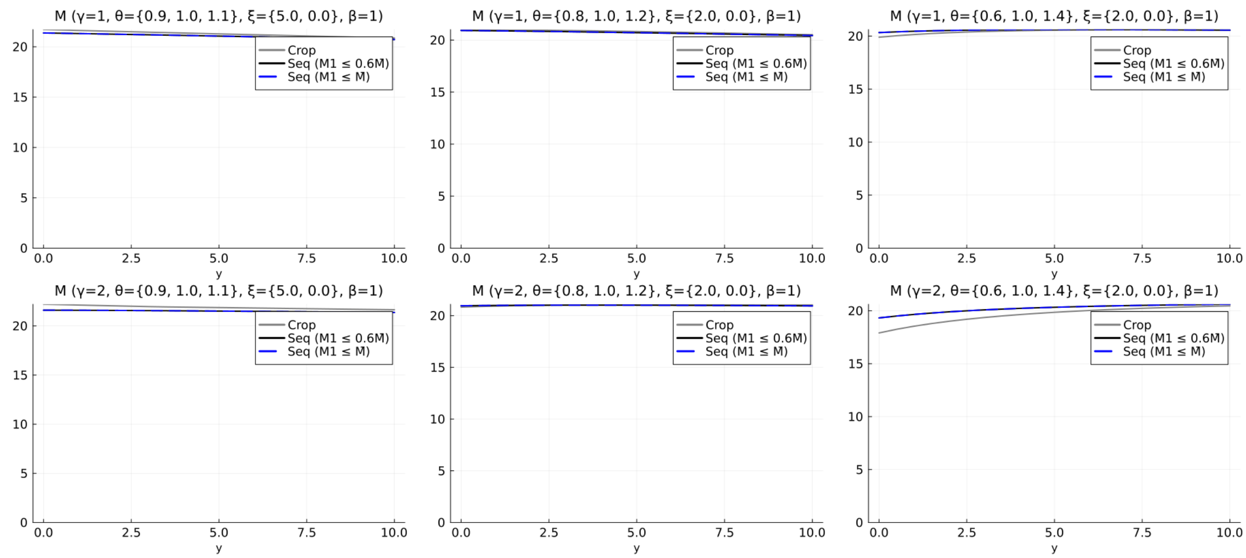
(B) PB borrowers



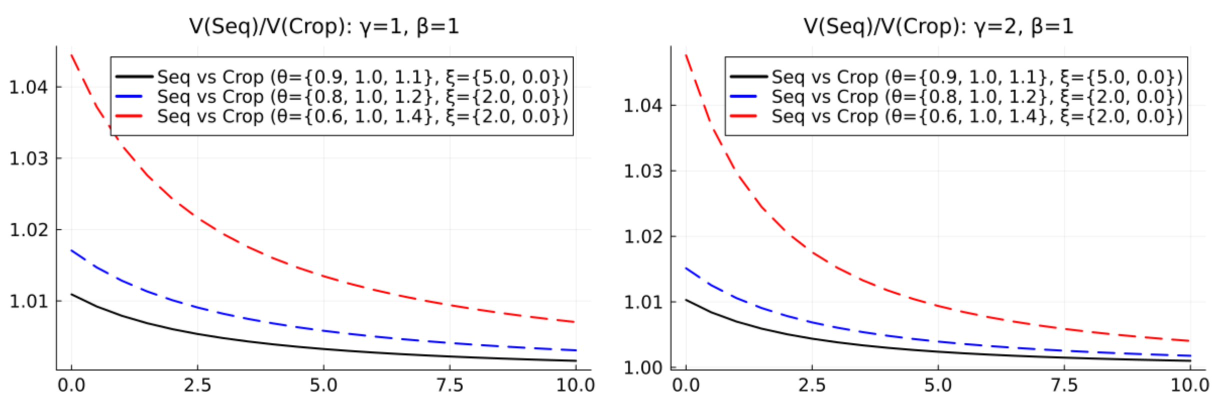
Appendix Figure 11: Choice of (M, K_1, K_2) under crop credit and sequential credit for time-consistent borrowers with income shocks at $t = 3$ ($\gamma = 1$)



Appendix Figure 12: Average loan size under crop credit and sequential credit

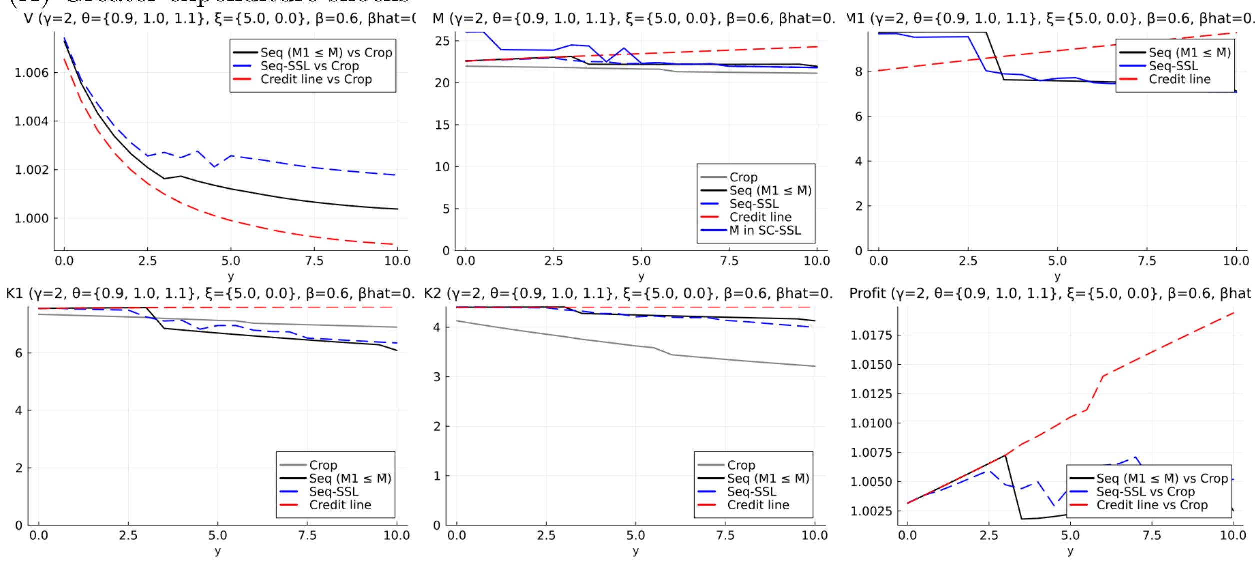


Appendix Figure 13: Ex ante expected utility under sequential credit compared to that under crop credit for time-consistent borrowers

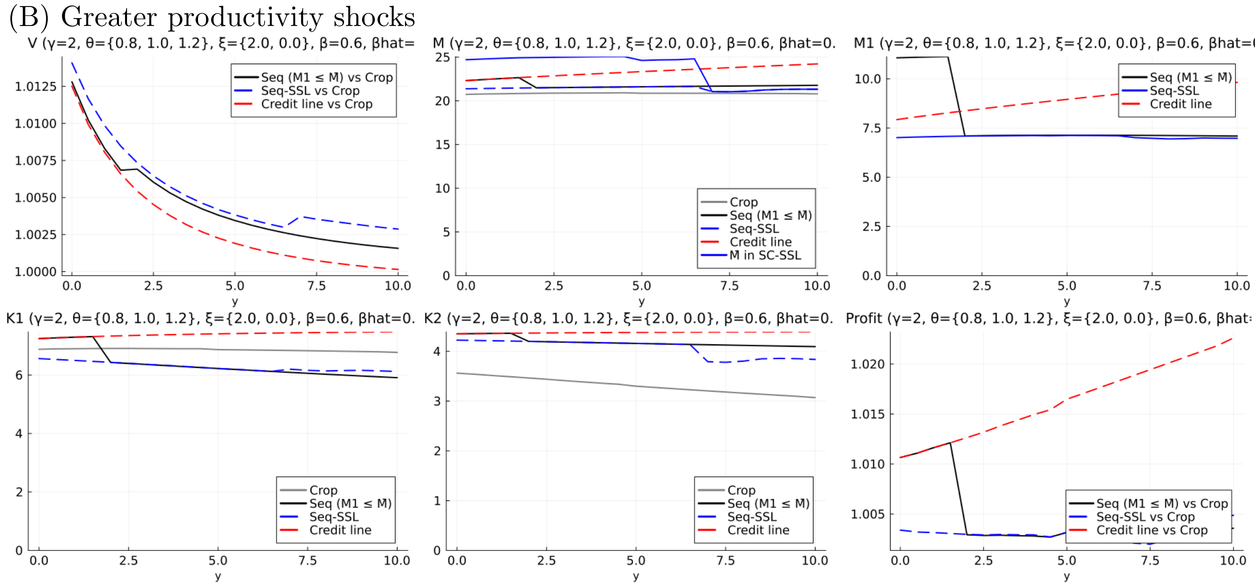


Appendix Figure 14: Counterfactual policy simulations ($\beta = \hat{\beta} = 0.6$ and $\gamma = 2$)

(A) Greater expenditure shocks

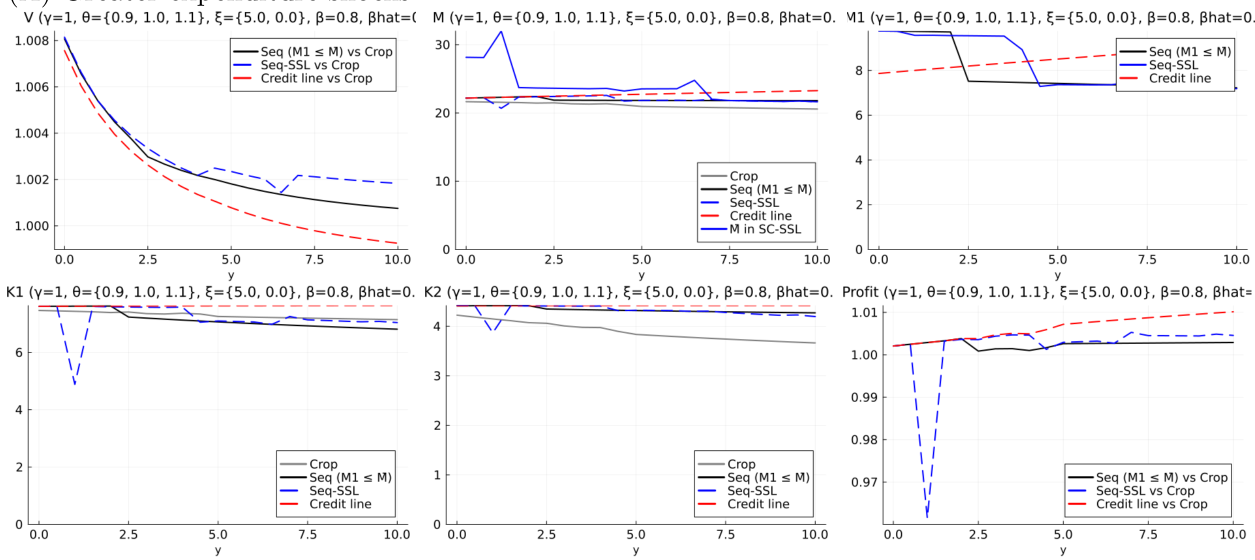


(B) Greater productivity shocks

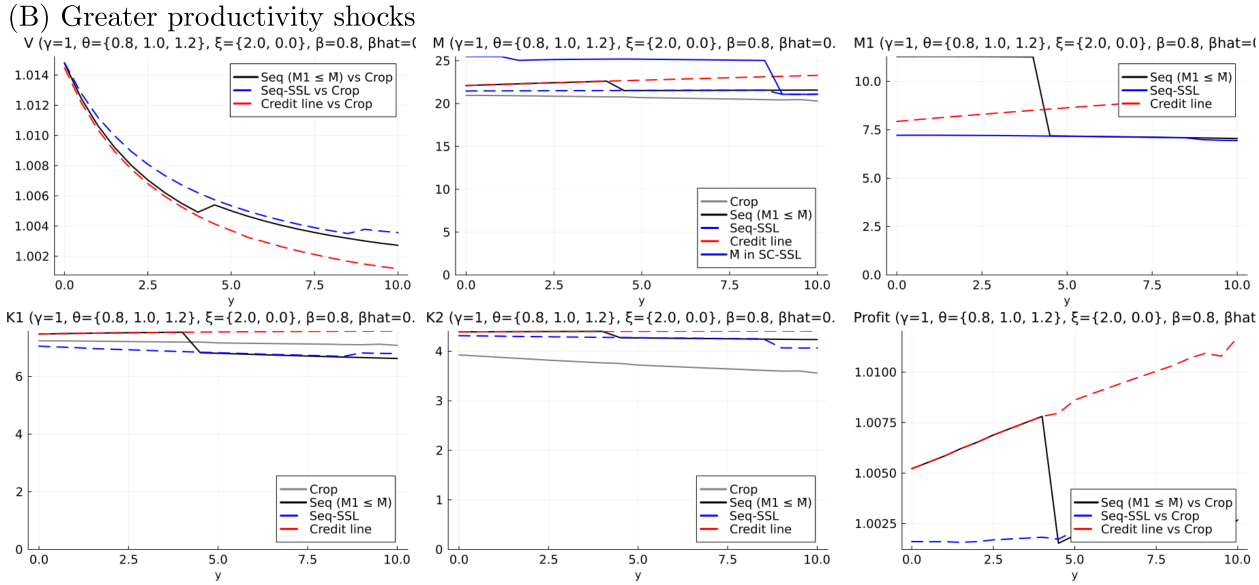


Appendix Figure 15: Counterfactual policy simulations ($\beta = \hat{\beta} = 0.8$ and $\gamma = 1$)

(A) Greater expenditure shocks

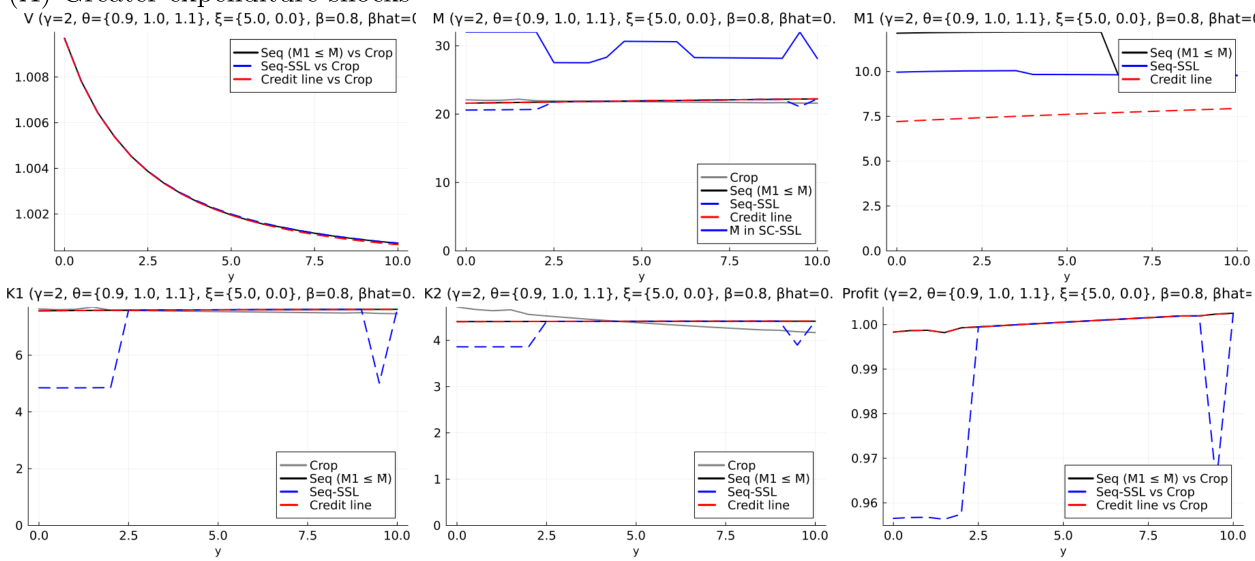


(B) Greater productivity shocks

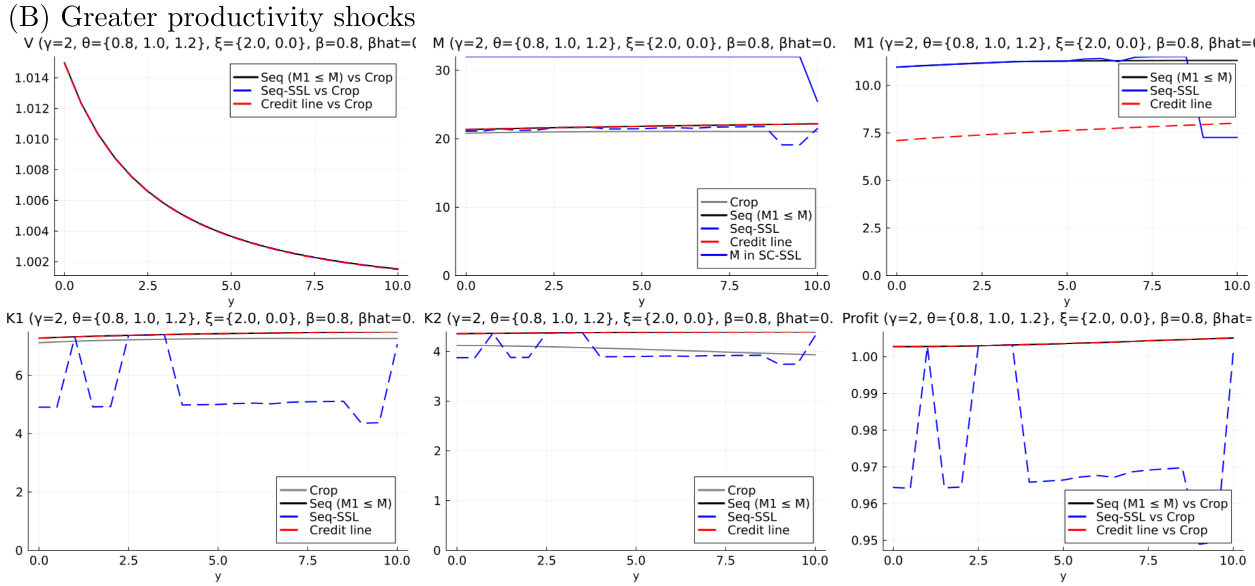


Appendix Figure 16: Counterfactual policy simulations ($\beta = \hat{\beta} = 0.8$ and $\gamma = 2$)

(A) Greater expenditure shocks

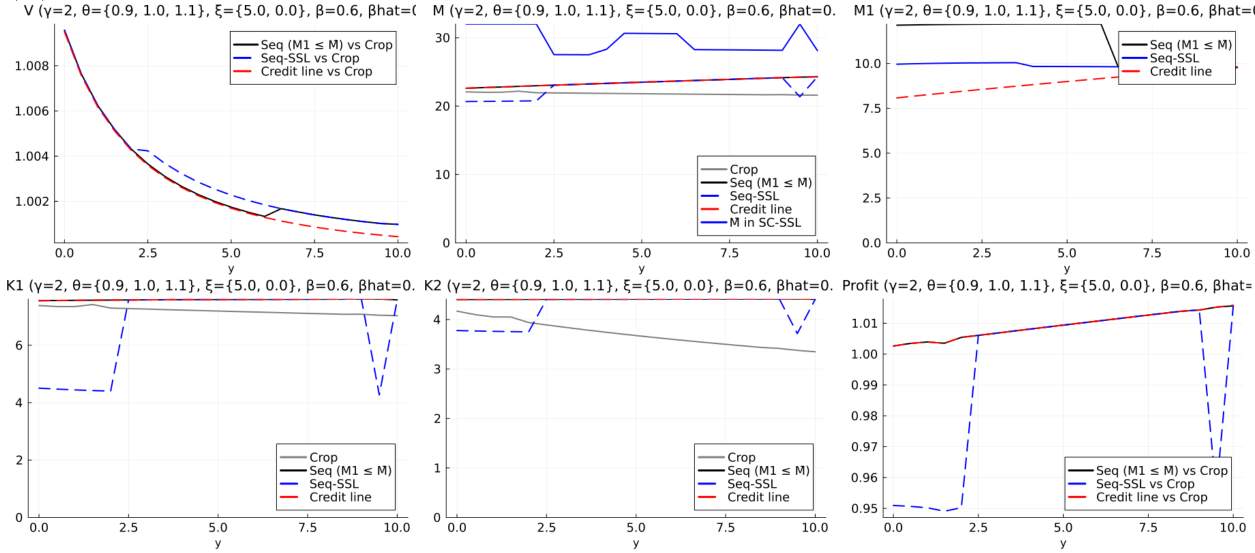


(B) Greater productivity shocks

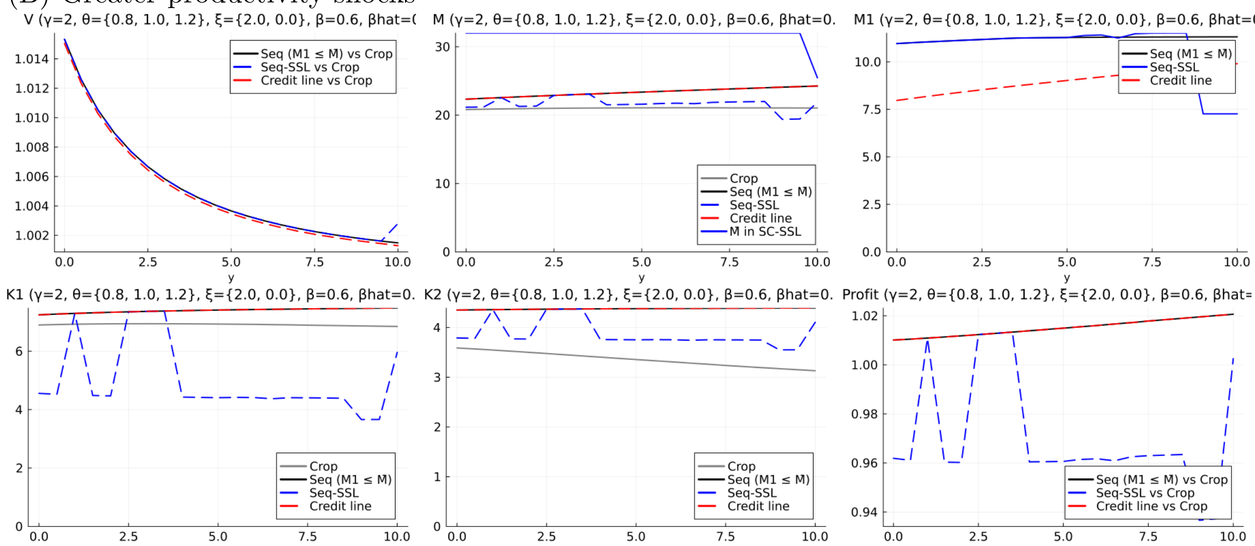


Appendix Figure 17: Counterfactual policy simulations ($\beta = 0.6, \hat{\beta} = 0.8$ and $\gamma = 2$)

(A) Greater expenditure shocks



(B) Greater productivity shocks



Appendix Table 1: Borrowings from other sources and net money inflows

	(1) Other borrowings	(2) Other borrowings	(3) Non-MFI Borrowing	(4) Non-MFI Borrowing	(5) Borrowing from other MFIs	(6) Borrowing from other MFIs	(7) Borrow+wage -saving	(8) Borrow+wage -saving
Traditional	6.591	-19.088	-6.490	-36.633	12.678	18.115	2867.130	5772.479
	(30.933)	(46.900)	(23.884)	(39.979)	(18.360)	(25.856)	(2973.763)	(4414.306)
Crop Credit	17.693	24.642	4.783	33.498	12.810	-8.628	-581.323	234.586
	(39.740)	(85.049)	(32.683)	(76.698)	(20.034)	(31.859)	(2999.890)	(4350.721)
Sequential	115.025	-20.451	-2.078	-1.715	116.345	-21.349	-3117.622	-3440.358
	(111.012)	(50.650)	(21.174)	(36.876)	(106.960)	(38.281)	(3303.615)	(4992.512)
In-kind	-52.516	129.566	13.439	13.800	-65.004	119.609	231.016	1168.665
	(110.202)	(127.171)	(23.459)	(49.746)	(102.599)	(96.858)	(2971.530)	(5024.267)
PB=1		-23.042		-17.470		-6.263		-2053.818
		(44.801)		(35.811)		(26.494)		(4443.597)
Traditional × PB=1		39.591		47.722		-10.216		-4841.304
		(61.759)		(50.269)		(37.596)		(6306.690)
Crop Credit × PB=1		-10.440		-47.167		36.031		-1138.332
		(95.968)		(80.664)		(47.348)		(6175.232)
Sequential × PB=1		244.308		-2.624		249.118		336.308
		(239.104)		(41.954)		(239.603)		(6789.778)
In-kind × PB=1		-322.331		0.508		-326.406		-1054.379
		(269.239)		(60.572)		(257.978)		(6168.863)
Observations	998	986	998	986	998	986	998	986
Mean_Control	40.452	40.452	40.452	40.452	0.000	0.000	74665.779	74665.779
Trad_vs_Crop	0.748	0.593	0.708	0.326	0.994	0.477	0.204	0.273
Trad_vs_SeqCash	0.309	0.978	0.823	0.212	0.320	0.393	0.054	0.092
Trad_vs_SeqKind	0.268	0.271	0.494	0.281	0.273	0.345	0.037	0.085
Crop_vs_SeqCash	0.379	0.586	0.824	0.631	0.323	0.722	0.396	0.498
Crop_vs_SeqKind	0.433	0.551	0.857	0.795	0.284	0.245	0.389	0.589
PB_Trad_vs_Crop		0.870		0.380		0.484		0.575
PB_Trad_vs_SeqC		0.342		0.588		0.306		0.280
PB_Trad_vs_SeqK		0.801		0.975		0.605		0.263
PB_Crop_vs_SeqCash		0.296		0.631		0.316		0.524
PB_Crop_vs_SeqKind		0.628		0.348		0.794		0.527

The table shows the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. We include the baseline outcome, group dummies, baseline savings, and variables selected by post-double-selection (PDS) lasso as control. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$.

Appendix Table 2: Investment

	(1) Invest:1st, Low other income	(2) Invest:1st, High other income	(3) Invest:2nd, Low other income	(4) Invest:2nd, High other income
Traditional	79.097	-233.993	44.909	-182.440
	(143.290)	(158.760)	(149.179)	(176.088)
Crop Credit	121.227	170.082	33.495	72.942
	(163.235)	(159.599)	(147.961)	(146.505)
Sequential	396.739*	108.912	399.171*	-62.041
	(165.875)	(157.671)	(171.746)	(164.033)
In-kind	69.023	-217.662	-59.797	-28.104
	(175.581)	(154.629)	(194.572)	(147.008)
Observations	401	396	401	396
Mean_Control	7429.978	7660.048	4102.960	4566.526
Trad_vs_Crop	0.791	0.008	0.937	0.116
Trad_vs_SeqCash	0.053	0.032	0.043	0.491
Trad_vs_SeqKind	0.013	0.416	0.089	0.571
Crop_vs_SeqCash	0.112	0.694	0.026	0.375
Crop_vs_SeqKind	0.042	0.078	0.063	0.252

The table shows the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. We include the baseline outcome, group dummies, baseline savings, and variables selected by post-double-selection (PDS) lasso as control. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$.

Appendix Table 3: Savings at NGO and MFI

	(1) Saving at NGO	(2) Saving at NGO	(3) Savings at MFI in Jul-Sept: IPW	(4) Savings at MFI in Jul-Sept	(5) Savings at MFI in Jul-Sept: IPW	(6) Cum. savings at MFI:IPW	(7) Cum. savings at MFI	(8) Cum. savings at MFI:IPW
Traditional	1118.654**	1174.026**						
	(100.330)	(170.734)						
Crop Credit	1374.794**	1446.810**	-1.476	64.884	23.606	24.391	23.882	8.969
	(97.843)	(154.713)	(62.928)	(111.176)	(101.398)	(62.040)	(102.132)	(98.510)
Sequential	1101.715**	1140.170**	-376.725**	-366.789**	-359.793**	-264.481**	-303.252**	-292.163**
	(91.534)	(141.375)	(61.643)	(105.014)	(94.472)	(58.294)	(83.181)	(81.478)
In-kind	63.696	86.056	-154.395**	-183.627*	-187.200*	-19.088	12.225	-23.793
	(91.091)	(139.812)	(56.051)	(86.443)	(78.562)	(43.168)	(68.057)	(63.925)
PB=1		83.352		13.490	19.863		-67.890	-22.096
		(109.050)		(109.345)	(102.912)		(102.843)	(106.007)
Traditional × PB=1		-99.246						
		(208.206)						
Crop Credit × PB=1		-136.627		-23.690	-25.068		64.682	37.851
		(189.817)		(143.456)	(134.515)		(138.009)	(137.081)
Sequential × PB=1		-97.056		23.364	-14.362		107.252	51.043
		(176.984)		(139.038)	(129.072)		(125.986)	(126.589)
In-kind × PB=1		-32.998		15.459	53.434		-50.509	1.618
		(187.675)		(113.363)	(104.897)		(96.860)	(92.458)
Observations	998	986	558	551	549	558	551	549
Mean_Control	266.884	266.884		1749.202			2432.437	
Trad_vs_Crop	0.022	0.154						
Trad_vs_SeqCash	0.874	0.850						
Trad_vs_SeqKind	0.650	0.763						
Crop_vs_SeqCash	0.007	0.060	0.000	0.000	0.000	0.000	0.001	0.001
Crop_vs_SeqKind	0.031	0.154	0.000	0.000	0.000	0.000	0.001	0.000
PB_Trad_vs_Crop		0.098		0.652	0.986		0.324	0.590
PB_Trad_vs_SeqC		0.820		0.000	0.000		0.031	0.007
PB_Trad_vs_SeqK		0.873		0.000	0.000		0.009	0.003
PB_Crop_vs_SeqCash		0.049						
PB_Crop_vs_SeqKind		0.095						

The table shows the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. We include the baseline outcome, group dummies, baseline savings, and variables selected by post-double-selection (PDS) lasso as control. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$.

Appendix Table 4: Default (including interactions with PB)

	(1) Arrear	(2) Arrear	(3) Default	(4) Default	(5) Uncollected: OLS	(6) Uncollected: OLS	(7) Uncollected: Tobit	(8) Uncollected: Tobit
Crop Credit	-0.090	-0.166	0.052	0.082	0.033	0.086	0.292	0.383
	(0.099)	(0.100)	(0.078)	(0.080)	(0.057)	(0.059)	(0.307)	(0.297)
Sequential	-0.059	-0.123	0.005	0.004	0.023	0.046	0.089	0.069
	(0.097)	(0.092)	(0.074)	(0.071)	(0.056)	(0.052)	(0.314)	(0.294)
In-kind	-0.087	-0.130	-0.012	-0.042	-0.014	-0.034	-0.082	-0.141
	(0.094)	(0.087)	(0.062)	(0.059)	(0.047)	(0.045)	(0.296)	(0.270)
PB=1	-0.005	-0.124	0.012	0.010	-0.003	0.032	0.039	0.023
	(0.096)	(0.097)	(0.070)	(0.064)	(0.051)	(0.047)	(0.314)	(0.273)
Crop Credit × PB=1	0.020	0.116	-0.114	-0.169	-0.044	-0.131	-0.443	-0.645
	(0.126)	(0.128)	(0.092)	(0.091)	(0.066)	(0.069)	(0.436)	(0.416)
Sequential × PB=1	-0.016	0.051	-0.036	-0.037	-0.028	-0.063	-0.282	-0.326
	(0.125)	(0.123)	(0.093)	(0.087)	(0.068)	(0.063)	(0.449)	(0.429)
In-kind × PB=1	0.052	0.094	-0.015	-0.007	0.018	0.025	0.143	0.225
	(0.121)	(0.114)	(0.078)	(0.075)	(0.056)	(0.054)	(0.445)	(0.403)
Observations	551	549	551	549	551	549	551	549
Mean_Control	0.588		0.160		0.094		0.094	
Crop_vs_SeqCash	0.739	0.626	0.513	0.307	0.845	0.496	0.470	0.277
Crop_vs_SeqKind	0.549	0.353	0.380	0.092	0.606	0.168	0.313	0.071
PB_Trad_vs_Crop	0.372	0.518	0.206	0.061	0.736	0.199	0.612	0.336
PB_Trad_vs_SeqC	0.340	0.367	0.580	0.543	0.892	0.647	0.539	0.364
PB_Trad_vs_SeqK	0.148	0.149	0.243	0.085	0.978	0.435	0.655	0.454
PB_Crop_vs_SeqC	0.945	0.768	0.523	0.249	0.845	0.392	0.898	0.990
PB_Crop_vs_SeqK	0.564	0.386	0.919	0.883	0.695	0.452	0.951	0.737

The table shows the estimated coefficients of the regression, with HC3 robust standard errors in parentheses. We include the baseline outcome, group dummies, baseline savings, and variables selected by post-double-selection (PDS) lasso as control. Columns (5) and (6) report the coefficients in the Tobit models. Asterisks indicate statistical significance: * $p < .05$, ** $p < .01$.