# At a Right Time: Modifying Repayment and Disbursement Schedule in Microcredit


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**Abstract**

While microcredit programs have expanded the access to credit, its outreach is still limited, especially among farmers in rural areas. In this paper, we evaluate modified microcredit programs by changing the timing of repayment and loan disbursement. While farmers have little income until the harvest season when they receive a sizable income, most microcredit programs require weekly installment, which causes the mismatch between the timing of the cash inflow and repayment. In addition, farmers make investment sequentially instead of at one time, and hence farmers use only a part of the credit for the investment when they receive the loan, and need to save the remaining money for the future investment. This mismatch of the timing of investment and loan disbursement can harm present-biased farmers who are tempted to overconsume. In order to investigate the impact of adjusting the timing of repayment and disbursement, we implemented a randomized controlled trial in Bangladesh, in which we randomly offered to share-cropping farmers either (1) the standard microcredit, (2) agricultural loan that requires the one time repayment right after the harvest, or (3) sequential credit that disburses the credit sequentially and requires the one time repayment right after the harvest. We found that the agricultural loans and sequential credits achieved higher uptake rates compared to the standard microcredit, and borrowers are more satisfied with these modified products. These new products did not worsen the repayment rate, and the sequential credits lead to a smaller loan amount on average. We argue that this is due to the option value effect: borrowers of the sequential credits could reduce the amount of the loan disbursement after observing productivity and expenditure shocks. Our theoretical model suggests that a partially flexible sequential credit that provides the option value and the commitment mechanisms will make the microcredit program more attractive to the agricultural farmers.



**Keywords:** Microfinance; Commitment; Flexibility; Option value

**JEL Classification:** G21, O16, Q14

# 1 Introduction

Agriculture is the major source of employment and revenue for poor households in rural economy, and boosting agricultural production contributes to poverty reduction especially among the poorest of the poor (Christiaensen et al., 2011). While financial inclusion has been considered crucial to boost productive investment in agriculture, many smallholder farmers, especially landless tenant farmers, have not had adequate access to credit. Traditional farming credit through formal financial institutions are generally insufficient and could not target landless farmers who do not own sufficient collateral to pledge. Government-led subsidized agricultural loans, provided in the 1960s and 1970s, have mostly failed with low repayment rates (Adams et al., 1984; Zeller and Meyer, 2002). As a complement to the existing financial institutions, microcredit has played an important role in providing loans to otherwise unbanked low-income households. However, the outreach of microcredit is still limited among farmers, especially crop farmers, in most developing countries.

The low uptake rates of microcredit among farmers can be partly attributed to the mismatch of cash flow and credit flow. Standard microcredit programs require frequent installment, which will be suitable for those with frequent income flows such as non-farm self-employed or dairy producers. However, crop farming does not generate any income until the harvest season.[1] This mismatch of cash inflow and credit outflow may make the standard microcredit less attractive to them. Another mismatch is between cash outflow and credit inflow, relating to the timing of disbursement. Typically, microcredit or any formal loans are provided in a lump sum at the beginning of the project. However, crop production requires sequential investment that is dispersed during the production cycle, such as for land preparation, sowing, irrigating, fertilizing, and harvesting. If farmers are present biased and have difficulty in setting a fraction of the disbursed loan aside for future investment (Ashraf et al., 2006; Duflo et al., 2011), they can eventually make only a small investment at the later stage. Expecting this underinvestment, sophisticated farmers may choose not to uptake the credit. If borrowers are naive and do not aware of their present bias, then it will not affect the uptake rate but will finally increase the default rate due to the lower revenue, affecting the sustainability of financial institutions.

In this paper, we investigate if modification of the timing and repayment cycle of loans can extend the outreach of microcredit and contribute to the increase in productive investment and earnings of smallholders without lowering the repayment rate. We conducted randomized field experiments among rice-growing farmers in rural Bangladesh, most of whom were sharecroppers without collateral land assets and would more likely face liquidity constraints than owner-cultivators.

[1] By cultivating multiple vegetables that differ in the timing of their harvest, farmers can create frequent income flows. However, many smallholder farmers cultivate a single crop in their plot at a given period due to the production efficiency, and hence need to find some non-farm jobs if they want to earn additional income before the harvest.

Even though sharecrop contracts often implement cost-sharing with landowners, such practice has not been common in Bangladesh and sharecroppers in Bangladesh have depended largely on credit borrowed from informal money lenders and middlemen at high interest rates to finance farming costs (Khandker et al., 2016; Hossain et al., 2019).

First we introduce a simple theoretical model to show the advantage of matching the cash flow and credit flow. Particularly, we show that the requirement of frequent repayment results in underinvestment and lower uptake rates, and the sequentially disbursed loan scheme, which provides the necessary amount of loans sequentially at the appropriate time for production, works as commitment device for present-biased borrowers and increase the uptake among sophisticated borrowers. Naive borrowers will make underinvestment in the later cycle of production, and the sequential loan disbursement can constrain their overconsumption and increases the investment at the later stage. To empirically examine the above theoretical predictions and explore the effectiveness and potential of alternative agricultural financial designs, we randomly offered the following four treatment arms: (T1) Traditional microcredit- a regular microcredit that provides loans before sowing and requires weekly repayments; (T2) Crop credit - an agricultural loan that provides loans before sowing and is repaid at harvest time. (T3) Sequential crop credit- a loan that offers loans sequentially at the time of sowing, irrigating, fertilizing, and harvesting, and is repaid at harvest time. (T4) Sequential in-kind credit – similar as (T4), but a part of the loan such as seeds or fertilizer is provided in-kind to reduce liquidity.

Consistent with the theoretical prediction, our intention-to-treat (ITT) estimator shows that uptake of the modified credit schemes were significantly greater than the traditional microcredit, without dampening repayment rates. We did not find that the uptake of the sequential credit was greater among present-biased borrowers. We also found that the sequential credit induced present-biased farmers to invest more in the later period of production cycle. These findings are consistent with the theoretical prediction that present-biased farmers were not so sophisticated. We also find that farmers' satisfaction and uptake in the subsequent season is higher for these modified microcredit schemes than the typical one. While the productivity is not significantly different across different treatment arms, farmers in the sequential credit arms borrowed less by 7%, suggesting some efficiency gains. We reconcile a seemingly puzzling result of reduced borrowing in the sequential credit by adding an option value in theory, where farmers can adjust total borrowing amount after observing production and expenditure shocks. This will reduce the final loan size as borrowers do not have to borrow additional credit as a buffer contrary to the traditional microcredit and the crop credit. This flexibility reduces the demands for precautionary savings, and borrowers can invest more if the productivity is high. We also calibrate the model to conduct numerical exercises, and showed that the model can explain many of the empirical findings.

Our study contributes to the literature on the introduction of flexibility into the standard microcredit. Field and Pande (2008) compared the weekly repayment and monthly repayment, finding no significant differences in the repayment rate between these two. Field et al. (2013) showed the introduction of two-month grace period into the standard microcredit increased risky investment and profits at the cost of increased default risk. Some other studies investigate the flexible repayment scheme adjusted for the income seasonality and fluctuation (Shoji, 2010; Czura, 2015; Shonchoy et al., 2014). Burke et al. (2019) experimented providing credits at untraditional timing, after the harvest, and found that post-harvest loans helped farmers wait to sell the crop until the price became high. On the other hand, it is argued that the rigidity of the microcredit repayment schedule benefits present-biased borrowers (Bauer et al., 2012). Afzal et al. (2019) investigated the demand for commitment and flexibility in the credit contract, whereas Fisher and Ghatak (2016) provided theoretical results showing that more frequent repayment can increase the maximum incentive compatible loan size. Several studies focused on the value of commitment in the savings product and ROSCAs (Ashraf et al., 2006; Basu, 2014; Gugerty, 2007; Basu, 2011; Fafchamps et al., 2014).

None of these studies, however, focused on modifying the disbursement scheme to match the cash inflow to the investment timing. Chowdhury et al. (2014) argued the advantage of sequential credit in the context of joint liability, but their focus is on preventing coordinated default. Our study is closest to Aragón et al. (2020) who allowed clients to withdraw or repay at any time a flexible amount, and found a positive effect on gross profits. Their study, however, targeted street vendors who had frequent income flows and short payout period, which is quite different from agricultural farmers who need to manage sequential investment without investment returns until the harvest.[2] Our theoretical model shows that the requirement of regular installment results in under-investment under this pattern of cash flow in the agricultural production, and present-biased farmers will demand for some commitment on the limit of the first disbursement amount to ensure that they can have enough resources for the subsequent investment at the later stage. Further, we showed that allowing the sequential disbursement can reduce the borrowing amount as clients do not have to borrow additional amounts for precaution. We also provide a theoretical framework and numerical exercises that facilitate predicting the impacts of various lending schemes in agricultural setting, and show that the sequential credit can outperform the credit lines for present-biased borrowers. To the best of our knowledge, this is the first study that evaluates the impacts of flexible borrowing and repayment in the agrarian context, and argues the benefit of the sequential disbursement loan as it provides both the option value and commitment device.

[2] Hossain et al. (2019) and Das et al. (2019) investigate the impact of credit schemes for sharecroppers in Bangladesh, but its credit scheme is the standard one with the monthly installment and lumpy upfront disbursement.

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 some numerical results. Section 6 concludes.

## 2 Conceptual Framework

Agricultural production is characterized by sequential investments and infrequent income (typically at the harvest). In case of rice production, farmers prepare land and seed at the beginning of the planting season. The land preparation requires expenses for land tillage and leveling, as well as costs for basal fertilizer (1st fertilizer hereafter). Then they plant the seeds, and in some cases transplant the seedling, which requires additional labor costs. About one and a half months after the seeding, farmers apply herbicides, topdressing fertilizer (2nd fertilizer hereafter), and pesticides. Weeding is labor-intensive and may requires farmers to hire additional labors. More than three and a half months after the seeding, farmers can harvest the rice, which requires additional labors for crop-cutting, threshing, and transporting. Until selling the harvest, farmers have few income flows unless they work as (agricultural or non-agricultural) labors. The typical schedule of the agricultural investment is depicted in Table 1.

Table 1: Typical schedule of agricultural investment and credit flow

| | Stage 0 | Stage 1 | Stage 2 | Stage 3 |
|---|---|---|---|---|
| Production | | (-) Seed<br>(-) Land preparation<br>(-) Basal fertilizer<br>(-) Transplanting<br>(-) Irrigation | (-) Topdressing fertilizer<br>(-) Weeding<br>(-) Herbicide<br>(-) Pesticide | (+) Sell harvest |
| Credit | Application | (+) Disbursement<br>(-) Regular installment | (-) Regular installment | (-) Regular installment |

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

Generally, farmers who need credit should apply for the loan in advance. If the application passes the screening, they will receive the whole amount of the loan when they start the production. In the standard microcredit, the regular installment will start a few weeks after the disbursement, even though farmers have little income flows. This causes the mismatch of cash flow and credit flow: farmers are required to pay when they need additional investment, as shown in Table 1. Further, the loan is disbursed at the beginning of the production stage ($t = 1$) while farmers need additional investment at later stage ($t = 2$). If farmers have difficulty in savings (Ashraf et al., 2006; Dupas and Robinson, 2013), this timing mismatch might cause the underinvestment in the later stage due to the shortage of the fund.

To understand how the repayment and disbursement schedule affects farmers' decisions, consider a farmer with endowment $A_0$ who is applying for a microcredit with a simple interest rate $r$ at $t = 0$. For simplicity, we ignore the labor decision and assume that the land is fixed. She makes the first investment $K_1$ at $t = 1$ and the second investment $K_2$ at $t = 2$, and then she will obtain the revenue from the harvest $Y = F(K_1, K_2)$ at $t = 3$. We assume a strictly concave $C^2$ production function $Y = F(K_1, K_2)$ that satisfies $F_1', F_2' > 0$, and whose second derivative matrix is negative definite.[3] Given this production function and the interest rate $r$, she decides the credit size $M \leq \overline{M}$ at $t = 0$, where $\overline{M}$ is the upper limit of the credit size. The microfinance institution (MFI) disburses $\alpha M$ at $t = 1$ and $(1 - \alpha)M$ at $t = 2$, where $0 \leq \alpha \leq 1$. The standard credit scheme corresponds to the case where $\alpha = 1$. The total repayment amount is $R = (1 + r)M$, which is equally split over $t = 1, 2, 3$ under the standard weekly installment: equal installment of $\frac{1}{3}R$ every period.[4] For generality, we denote the installment amount at $t = 1, 2$ by $\frac{\pi}{3}R$, where $\pi > 0$ governs the share of the repayment before the harvest. Then the amount repaid at $t = 3$, $R_3$, is expressed as $\left(1 - \frac{2\pi}{3}\right) R$. In each period, she obtains utility from consumption $c$, evaluated by a concave utility function $u(c)$ that satisfies the Inada condition. The timing of the decision making and credit flows are described in Table 2.

Table 2: Cash flow and timing of the decision making

| $t = 0$ | $t = 1$ | $t = 2$ | $t = 3$ |
|---|---|---|---|
| * Decide credit size $M \leq \overline{M}$ | Receive $\alpha M$<br>Repay $\frac{\pi}{3}R$<br>* 1st investment $K_1$<br>* Consume $c_1$ | Receive $(1 - \alpha)M$<br>Repay $\frac{\pi}{3}R$<br>* 2nd investment $K_2$<br>* Consume $c_2$ | Harvest $Y = F(K_1, K_2)$<br>Repay $R_3 = \left(1 - \frac{2\pi}{3}\right) R$<br>Consume $c_3 = Y - R_3$ |

Asterisks (*) indicates the decision variables. The consumption at $t = 3$ is determined by the harvest $Y$ and repayment amount $R_3$.

For simplicity, we assume no savings left over to $t = 3$, and ignore the time discounting.[5] Denote

[3]This ensures that the first order conditions characterize the solution of the maximization problem. For this matrix to be negative definite, $F_{11}'' < 0$, $F_{22}''$, and $F_{11}''F_{22}'' > (F_{12}'')^2$. To esure the last condition, $K_1$ and $K_2$ can be substitutes or complements, but the magnitude of the substitutability or complementarity should not be so strong, which is likely to hold in the agricultural production.

[4]Most microcredit institutions apply the simple interest rate over the loan maturity length, and the total repayment amounts are unaffected by the repayment schedule. Hence we set the total repayment amount fixed and independent of the repayment and disbursement schedule.

[5]Without uncertainty, borrowers will borrow as much as they need and will not put some money aside for savings at $t = 2$. We will relax this assumption when we introduce the uncertainty in the later section.

the resources available for consumption and investment at $t = 1$ and $t = 2$ as

$$A_1 = A_0 + \alpha M - \frac{\pi}{3}(1+r)M, \tag{1}$$
$$A_2 = A_1 - c_1 - K_1 + (1-\alpha)M - \frac{\pi}{3}(1+r)M. \tag{2}$$

## 2.1 A Time Consistent Borrower

The problem of a time consistent farmer can be written as

$$\max_{c_1,c_2,K_1,K_2,M} u(c_1) + u(c_2) + u(c_3)$$
$$\text{s.t. } c_1 + K_1 \leq A_1 \tag{3}$$
$$c_2 + K_2 = A_2 \tag{4}$$
$$c_3 = F(K_1, K_2) - \left(1 - \frac{2\pi}{3}\right)(1+r)M \tag{5}$$
$$M \leq \overline{M}.$$

The constraint (3) is the resource constraint at period 1, which need not be binding. The constraint (4) is the resource constraint at period 2, and the constraint (5) expresses that the consumption at $t = 3$ is equal to the revenue minus the period-3 installment, both of which are derived from the assumption that no savings are left over to $t = 3$. The optimal decision rules for the consumption and investment are characterized by the following first order conditions, where the asterisk indicates the optimal values:

$$u'(c_1^*) = u'(c_2^*) \tag{6}$$
$$F_1'(K_1^*, K_2^*) = F_2'(K_1^*, K_2^*) \tag{7}$$
$$u'(c_2^*) = F_2'(K_1^*, K_2^*)u'(c_3^*) \tag{8}$$

The proof is provided in Appendix A.1.1. The consumption should be perfectly smoothed between $t = 1$ and $t = 2$ (equation (6)), and the marginal product of capital are equalized between the first and the second investment (equation (7)). Equation (8) illustrates the trade-off between the consumption and investment. Additional unit of the second investment $K_2$ will increase the harvest and hence the utility at $t = 3$ by $F_2'(K_1^*, K_2^*)u'(c_3^*)$, but it should be financed by sacrificing consumption at $t = 2$, which reduces period-2 utility by $u'(c_2^*)$. These conditions give us the optimal decision rules for the first and second investment as the functions of credit size $M$ and initial endowment $A_0$, which we denote by $K_1^*(A_0, M^*)$ and $K_2^*(A_0, M^*)$.

Given these decision rules, she will decide the optimal credit size $M^*$ that satisfies

$$F_1'(K_1^*(A_0, M^*), K_2^*(A_0, M^*)) = 1 + \frac{r}{Q}, \tag{9}$$

where $Q = 1 - \frac{2\pi}{3}(1+r)$. If $\pi = 0$, then $Q = 1$ and hence $F_1'(K_1^*, K_2^*) = 1 + r$, which states that a farmer borrows the credit until the marginal product of the investment equals to its marginal cost, achieving the social optimal. However, if $\pi > 0$ as in the standard microcredit, then $Q < 1$ and $F_1'(K_1^*, K_2^*) = 1 + \frac{r}{Q} > 1 + r$, implying underinvestment. Remember that the borrower receives $M$ at $t = 0$, and repays $\frac{\pi}{3}(1+r)M$ at $t = 1, 2$. Hence, only $M - \frac{2\pi}{3}(1+r)M = QM$ is available for investment, and the effective interest rate for the investment decision becomes $\frac{r}{Q}$. If the solution to (9) exceeds $\overline{M}$, then $M^* = \overline{M}$.[6]

Comparative statics show

$$\frac{\partial K_1^*}{\partial \pi} < 0, \qquad \frac{\partial K_2^*}{\partial \pi} < 0,$$

implying that reducing the ratio of the installment payment before the harvest (lower $\pi$) can increase the agricultural investment. This also increases the borrower's utility (Appendix A.1.1), and hence will improve the uptake rates.

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

We can also show that $\frac{\partial c_1^*}{\partial \pi} < 0$ and $\frac{\partial c_2^*}{\partial \pi} < 0$ – weekly installment requirement reduces the consumption at periods 1 and 2. Further, equations (8) and (9) imply

$$\frac{u'(c_2^*)}{u'(c_3^*)} = 1 + \frac{r}{Q},$$

suggesting that the requirement of the weekly installment makes the consumption before and after the harvest less smooth.

The impact of $\pi$ on the credit size $M^*$, however, is undetermined without further assumptions on the utility and production functions even though the investment and consumption declines as $\pi$ rises. This is because the requirement of installment before the harvest induces borrowers to borrow for installment repayment. While 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," theoretically the abolition of the weekly repayment can reduce the loan size as borrowers do not have to borrow additional amounts for install repayment.

## 2.2 A Present-Biased Borrower

In the above setting, the disbursement schedule, captured by $\alpha$ (the share of the credit disbursed at $t = 1$), will not affect the borrower's decision unless $\alpha$ is sufficiently small so that the period-1

[6] Here we ignore other income flows than harvest. While we can incorporate other income flows by modifying the resource transition functions (1) and (2), we can capture them by the endowment $A_0$ as long as the other income flow at $t = 2$ is not too large. Unless other income flows are too large, the first order conditions (6) - (9) still holds.

constraint (3) binds. The borrower will not benefit from such a low level of $\alpha$ since it only imposes the additional binding constraint. However, if a borrower is present-biased, she may prefer a lower level of $\alpha$. Now consider a hyperbolic discounter who discounts the future by $\beta$, and believes her $\beta$ to be $\hat{\beta}$. For simplicity, set $\pi = 0$ and consider if a present-biased borrower has an incentive to set $\alpha$ low at $t = 0$.[7] The proof is provided in Appendix A.1.2, and we briefly provide a sketch of the results here. For the ease of proof, we consider a borrower who set the amount of the first disbursement $M_1 = \alpha M$ at $t = 0$.

The decision problem at $t = 2$ is written as

$$\begin{aligned} \max_{c_2, K_2} \quad & u(c_2) + \beta u(F(K_1, K_2) - (1+r)M) \\ \text{s.t.} \quad & c_2 + K_2 \leq A_2, \end{aligned}$$

which gives us the decision rules $c_2^*(A_2, K_1, M; \beta)$ and $K_2^*(A_2, K_1, M; \beta)$ that depend on $\beta$. Based on her belief $\hat{\beta}$, she solves the period-1 problem:

$$\begin{aligned} \max_{c_1, K_1} \quad & u(c_1) + \beta \left[ u\left( c_2^*(A_2, K_1, M; \hat{\beta}) \right) + u\left( F(K_1, K_2^*(A_2, K_1, \hat{\beta})) - (1+r)M \right) \right] \\ \text{s.t.} \quad & c_1 + K_1 \leq A_1, \end{aligned} \tag{10}$$

given the transition function (2). When the budget constraint (10) does not bind, the Euler equation

$$u'(c_1^*) = \left[ 1 - (1 - \hat{\beta}) \frac{\partial c_2^*(A_2, K_1, M; \hat{\beta})}{\partial A_2} \right] \frac{\beta}{\hat{\beta}} u'(c_2^*) \tag{11}$$

should be satisfied. Unlike the time-consistent borrower ($c_1^* = c_2^*$), a present-biased borrower overconsumes at $t = 1$ ($c_1^* > c_2^*$). Her consumption at $t = 1$ depends on the available resouce $A_1$ and the actual and perceived present bias parameters $\beta$ and $\hat{\beta}$, which we denote by $c_1^*(A_1; \beta, \hat{\beta})$.

Predicting her overconsumption at $t = 1$, she would set $\alpha$ low at $t = 0$ to constrain her period-1 decision. We can show that she prefers to make the budget constraint at $t = 1$ binding, and set $\alpha$ so that

$$\left[ 1 - (1 - \hat{\beta}) \frac{dc_1^*(A_1; \hat{\beta}, \hat{\beta})}{dA_1} \right] u'(c_1^*) = \left[ 1 - (1 - \hat{\beta}) \frac{\partial c_2^*(A_2, K_1, M; \hat{\beta})}{\partial A_2} \right] u'(c_2^*) \tag{12}$$

holds. The optimal level of $\alpha$ depends on her perception on her own present-biasedness $\hat{\beta}$. Compared with equation (11), the solution of equation (12) exhibits a smaller difference between $c_1^*$ and $c_2^*$. This gives the present-biased borrower an incentive to set $\alpha$ low at period 0 to make a commitment against overconsumption at $t = 1$. If they are naive, however, then they will choose $\alpha = 1$.

[7] MFIs can pre-specify the value of $\alpha$ when they offer the credits to match the disbursement schedule to the typical income flow of potential borrowers. Here we treat $\alpha$ as the choice variable to examine if a present-biased borrowers prefer to set $\alpha < 1$ (sequential disbursement).

The impact of the availability of this commitment device on the second investment, however, is ambiguous without further specifying the production and utility functions, as without the commitment, present-borrowers may borrow larger amount to ensure enough fund at $t = 2$ for the investment.

If $\alpha$ is exogenously determined by the MFIs, the conclusion will depend on the discrepancy of her desired level of $\alpha$ and the actual level of $\alpha$ set by the MFIs. It should be noted that the existence of uncertainty will increase the desired level of $\alpha$ as it will provide her with more flexibility (Amador et al., 2006). These imply that not all the present-biased borrowers will prefer the sequentially disbursed credit to the standard credit that disburses the loan at once. If borrowers are naive, then this pre-specified disbursement schedule will enable them to have sufficient fund for the second investment, resulting in greater $K_2$.

**Claim 2** *Present-biased farmers who are aware of their present-biasedness prefer the credit to be disbursed sequentially. If resent-biased farmers are overconfident about their present-biasedness ($\alpha$ is close to 1), then the sequential credit will not increase the uptake rate but will increase the investment at the later stage.*

# 3 Local Context, Product Design and Randomization

## 3.1 Local context

Motivated by the theory in Section 2, we conducted a randomized field experiment to investigate the effect of the repayment and disbursement schedules in Dinajpur district of northwest Bangladesh targeted at sharecropping farmers. Most tenant farmers are landless and poor, and did not have access to credit from formal banking sectors including microfinance. Most of them were engaged in rice production. While Dinajpur district is not a disaster-prone area, the region suffers a high poverty rate of 64.3%, which was much higher than the national average of 24.3% (Hill and Genoni, 2019).

Rice is a major agricultural product in Bangladesh, which makes half of the agriculture sector's contribution to GDP. Rice is cultivated throughout the year all over the country in three seasons: *Aush*, *Aman* and *Boro*. *Aman* (rainy season) is most important for Bangladesh (and the focus of our research), contributing to 35% of the annual rice output. Land preparation for *Aman* begins in late-June to mid-July, while sowing begins in mid-July to mid-August. Usually, the *Aman* paddy harvesting begins in November and lasts until January. The land preparation requires land tillage and leveling. Agricultural modernization has replaced traditional animal-powered plowing with tractors or power tillers. There exist local service providers for these activities, and farmers need to pay in cash for getting the mechanical plowing service on time. Farmers purchase fertilizers, pesticides and herbicides from local traders. While some local traders sell hybrid seeds, most tenant farmers uses traditional seeds.[8]

Due to the lack of farm income until harvest, many poor farmers work as a daily laborer to earn a living. Although the opportunity for urban migration to earn cash income was limited due to the lack of job-related networks, it turned out that most households had some other income sources.[9] The upper panel of Appendix Figure 2 shows the histogram of the days of working for wage income in the last 12 months at household level based on our baseline survey. While 22.5 percent of the surveyed household report no wage income, majority of households worked 240-360 days for wage income, with the mode of the daily wage being 300 BDT (about 3.66 USD). The lower panel of Appendix Figure 2 depicts the box plot of the days of working as daily wage disaggregated at monthly level, based on the individual level data. While the variance differs across months, the average days of working are similar across months. When we take the self-employment into consideration, almost all the households had some income sources other than the farm income.[10] The upper panel of Appendix Figure 3 reports the histogram of the days of working for wage income and self-employment activity in the last 12 months at household level. Most households spend substantial time for earning other income sources than the rice production. The lower panel of Appendix Figure 3 shows the distribution of the amount of total income from the wage labor, self-employment, fishery and poultry.[11] The graph indicates that some households earn substantial amount of income from these activities, which could finance agricultural investment at least in part.

Typically, farmers sell previous season's harvest stored at home to buy household essentials, but this cash-flow is usually not large enough for agricultural investments. Farmers frequently borrow from local informal moneylenders with an exorbitant interest rate to cover the cost of production.[12]. While cost sharing is often observed in sharecropping arrangements elsewhere, most of the sharecropping contracts are made by the absentee landlords in Bangladesh, and cost sharing is uncommon. Most tenancy arrangements requires the tenants to pay 30 percent of the harvest

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

[9]We presumed that alternative means of income other than agricultural production were limited, and if any, they were also seasonal and would not help them finance the livelihood and agricultural productions. The data revealed that farmers still had some alternative income sources, and hence the surveyed site would not be the ideal one. But we still found results consistent with our theory as presented later.

[10]For the histogram, we chose to aggregate at household level to see the opportunity of the wage earnings for the household. For the box plot, we investigate at individual level so that the days of work does not exceed the days of months.

[11]We exclude the revenue from livestocks transactions as we do not have the information on livestock purchase.

[12]The usual interest rate for such credit is 10% per month (Khandker and Mahmud, 2012)

to the landlord. The local Microfinance Institutes (MFIs) do not provide credits designed for the farmers, and mostly employed "Grameen-Style" rigid contract design with weekly installment. While BRAC has introduced an experimental product for sharecroppers (BCUP), but that also requires monthly repayment, which does not align with the cash flow of the farmers.

### 3.2 Product design

We collaborated with *Gana Unnayan Kendra* (GUK), which have worked in northern Bangladesh for 35 years in various development-related interventions, to implement experimental credit schemes targeted at sharecroppers. GUK had provided microcredit under the traditional weekly installment contract, but its managing committee was open to innovation and better product design catered for various groups like sharecropping farmers. Their typical credit product was individual liability loans, though they required borrowers to form borrowing groups for facilitating peer evaluation, peer monitoring and peer-pressure.

Before the main phase of the study (*Aman*-cropping season in 2015), we implemented a small piloting with GUK to understand the cash flow in agricultural production in Dinajpur, while assessing the feasibility of the proposed experimental design. From bookkeeping exercises on tenant farmers, we computed the total cost of entire cycle of rice production as well as the timing of each of the investment items for typical farmers. We also discussed these estimates with local agricultural extension officers and GUK. Based on these conversations and estimates, GUK agreed to provide a maximum loanable amount of 400 BDT (about 4.88 USD) per decimal of land to the sharecropping farmers in Dinajpur, with a 12% 6-month interest rate.

The credit products were individual liability loans disbursed through borrowing groups. To join the borrowing group, they had to be tenancy farmers and should not borrow from existing micro-credit programs. Once joining the borrowing groups, they were12 entitled to borrow up to the maximum loanable amount which was solely determined by the land size. The next round loan becomes available conditional on the repayment of the current loan. GUK accepted the loan application in May, and start credit disbursement early July. We provided following four different products.

**Traditional credit (T1)**: This is the standard microcredit product that GUK had implemented elsewhere. The full amount of the loan was distributed at the beginning of the crop season (July). Borrowers were liable to repay the loan in regular weekly installments of equal amount (with interest), beginning from the first month after loan disbursement. The loan matured after the harvesting period, when farmers were supposed to pay the last installment. For example, if a farmer takes 10,000 BDT (about 122 USD) credit with a 12% 6-month interest rate (loan accessed in July to be repaid by December 2015), this farmer will repay about 467 BDT installment per week (a total of 24 equal weekly installments).

**Crop credit (T2)**: In this treatment, the requirement of the weekly installment was abolished, and the borrowers were required to repay the full amount with interest at the end of the harvesting period which corresponded to the due date of the last installment in the traditional credit arm (if the credit is given in July, then the full repayment amount with interest is due in December). The product only differed from the traditional credit in the repayment schedule, and corresponding to the case of $\pi = 0$ and $\alpha = 1$ in our motivating model above. A farmer borrowerd 10,000 BDT at the beginning of the crop-cycle were required to repay 11,200 BDT at the end of the cycle (in December).

**Sequential credit (T3)**: This product is the same as the crop credit except the schedule of loan disbursement. Based on the bookkeeping exercise in the pilot survey, it was proposed to set the ratio of the credit disbursed at the first phase, the value of $\alpha$, at 0.6. At the field implementation, further flexibility was introduced by allowing farmers to receive up to 60% of the loanable amount at the first disbursement. Hence borrowers can choose the value of $\alpha$ with constraint of $\alpha \leq 0.6$. To match the sequence of agricultural investment, the disbursement was divided into three phase. At the timing 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. Hence 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. [13] At each disbursement, borrowers can decide the amount they would like to receive as long as it is within the specified limit, which enabled borrowers to adjust the loan size ex post, which we will revisit later.

**Sequential in-kind credit (T4)**: This product is the same as the sequential credit (T3) except that part of the agricultural inputs (seed and fertilizer) was provided as in-kind credit (valued within the loanable amount). This was expected to strengthen the commitment function of the sequential credit. In the sequential credit, borrowers who expect future cash flow may increase the current consumption. By disbursing the credit in kind, this product aimed at preventing such behavior. GUK partnered with reputed local agricultural dealers to organize this in-kind credit distribution with the help of a pre-approved voucher (coupon) signed by the loan officer.

For all these groups, GUK conducted the weekly meetings to monitor group activities and to facilitate loan collection for those who are repaying weekly. During this weekly meeting, GUK also encouraged borrowers to save and provide the savings deposit service, although there is no forced or mandatory savings amount. Members in the control group could use the savings deposit service of GUK. Due to the requirement of the weekly meetings for all the treatment arms, we would not be

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

able to infer the outcome under crop credit and sequential credit without regular weekly meetings.

### 3.3 Data and balance tests

To start the survey, we first listed all the sub-districts of Dinajpur and conducted a village survey to understand the existence of other MFI's coverage, prevalence of rice production, and sharecropping contract by the farmers. We cross-verified the information on MFI penetration with the Micro-credit Regulatory Authority (MRA)'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 other MFIs was low, rice production under share tenancy was widespread and accessibility from cities was limited. From these three unions, GUK formulated 50 potential borrowing groups of 20 potential borrowers 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 basic demographic and socio-economic information of 1,000 potential borrowers, including land-size under tenancy agreement. During the baseline GUK also informed farmers about the maximum loanable amount and the timing of the credit availability.

After collecting the baseline data, we randomly assign 200 members (4 members per group) to each of the following four credit products for *Aman*-cropping season in 2015. The remaining 200 members served as the control group.[14] Since outcome variables of our interests are investment and production, we stratified the individuals based on the score of economic status computed by factor analysis, where we include indicators for owning agricultural lands, borrowing money in the last three years, having electricity connection, having latrine toilet, owning livestocks, owning productive assets, and housing condition (if the house is made of mud); the area of agricultural lands; and the years of education.[15] We constructed strata of five households whose score are similar,

[14]See Appendix Figure 1. The capacity constraint of expanding branches in the field limited the total sample size. We had repeated discussion whether to include the sequential in-kind treatment given the relatively small sample size. Given that removing the sequential in-kind treatment would result in 250 farmers in each arm, instead of 200, and the resultant reduction of the standard errors being 12 percent, we finally decided to include the in-kind treatment to examine the role of commitment and flexibility. With the power of 0.8 and significance level of 0.05, the detectable effect size when assuming i.i.d. data generating process is 0.28 standard deviation. We would have the detectable effect size of 0.25 if we had had 250 farmers in each arm. Anyway the power of our study is not large, we did not expect to detect significant effects on noisy variables such as income and profits. When we present the results in the later section, we will report the minimum detectable effects to facilitate the interpretation of the statistical results.

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

and randomly divide the five households into five different treatment status.

There exists potential spill-over effects within group members, especially through informal transactions with other borrowers in the same group. However, during the piloting, we did not detect such transactions. Moreover, we also asked the respondents to list up any informal cash or in-kind transfer to other group members in the baseline and follow-up survey, finding no such transaction. While we cannot deny the existence of other spill-over channels such as becoming more careful in expenditure by looking at the behavior of members in other intervention arms, we believe that such spill-over effects are small. Further, the spill-over effects, if any, will likely make our estimates conservative, and hence the true effects will be larger than the estimated ones.

The average credit size among the borrowers was 16,095 BDT (approximately 196.4 USD). The smallest credit size among the borrowers of the traditional credit and the crop credit was 5,500 BDT. In the analysis, we excluded 2 observations whose loanable amounts computed from their self-reported plot areas are less than 4,000 BDT, in which case they did not report all the plots they cultivated and hence we would undervalue their total investment and output. Table 3 reports the summary statistics of our sample. The average uptake rate was 56.1 percent based on the whole sample. Excluding the farmers in the control group who were not offered the credit, the average uptake rate was 70%, which is relatively high. This relatively high uptake rate was due to the fact that our sample consists of the farmers in the self-formed borrowing groups who exhibit the interests in taking the loans.[16]

We should note that in the surveyed region, the harvest was considerably delayed due to the weather condition, and many borrowers did not finish the harvesting on the loan due date. This affected the ability of borrowers to repay the credit on due date.[17] Given this abnormal weather, GUK extended the due date by three weeks, but still nearly a half of borrowers (48.7%) could not repay the loan on this due date. After the due date, GUK exerted an intensive efforts to collect repayment and set the final due date one week after the extended due date. We define those who could not repay the full amount by this finalized due date as defaulters. The default rate was 11.8%, which is relatively high compared to the standard microcredit programs elsewhere.

minimize the data entry errors.

[16]Imperfect but 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). Given that exhibiting the interests in taking the loan was necessary for obtaining the loan but still left the option not to take it, it is not surprising to observe imperfect uptake. Besides, the uncertainty of obtaining the loans could induce some of them to find other borrowing sources such as their family members and neighbors.

[17]Borrowers in the traditional credit also faced difficulty in keeping the weekly installment. GUK admitted them to repay later, and allowed them to access future loans if they repaid all the loans by the due date. Hence the weekly installment was not strictly implemented in the field, which might have resulted in some behavioral changes of borrowers.

Table 3: Summary Statistics

| | count | mean | sd | min | max |
|---|---|---|---|---|---|
| Uptake | 998 | 0.561 | 0.496 | 0 | 1 |
| Total Loan Amount | 998 | 9031.323 | 8505.034 | 0 | 27300 |
| Not repaid on due date | 560 | 0.487 | 0.500 | 0 | 1 |
| Default | 560 | 0.118 | 0.323 | 0 | 1 |
| % of amount not repaid | 998 | 0.043 | 0.180 | 0 | .951 |
| Cumulative savings | 560 | 2320.920 | 495.466 | 300 | 3940 |
| Total amount of borrowing(Baseline) | 998 | 642.109 | 2541.840 | 0 | 40300 |
| Land area(Baseline) | 998 | 92.744 | 22.395 | 0 | 165 |
| ln(household asset) | 998 | 12.272 | 1.039 | 8.22 | 14.6 |
| ln(productive asset) | 998 | 7.689 | 1.101 | 5.52 | 13 |
| ihs(Livestock asset) | 998 | 10.460 | 2.361 | 0 | 12.9 |
| Total other income | 998 | 100626.011 | 45800.203 | 0 | 385650 |
| Outstanding debt(Baseline) | 998 | 642.109 | 2541.840 | 0 | 40300 |
| Savings(Baseline) | 998 | 1145.830 | 2859.368 | 0 | 50000 |
| 1st investment(Baseline) | 998 | 8237.270 | 2508.729 | 0 | 15720 |
| 2nd investment(Baseline) | 998 | 4398.618 | 1801.401 | 0 | 12405 |
| Output(Baseline) | 998 | 32127.776 | 10224.186 | 0 | 84000 |
| Profit(Baseline) | 998 | 3963.388 | 5700.976 | -15140 | 25738 |
| Yield(Baseline) | 995 | 5.247 | 0.886 | 2.47 | 8.65 |
| Present-biased | 986 | 0.590 | 0.492 | 0 | 1 |

Figure 1 depicts the scatter plot of the loanable amount (horizontal axis) and the actual loan size (vertical axis), with 45 degree line. We computed the loanable amount based on the land area they reported in the survey and hence it can differ from the actual loanable amount that GUK evaluated. The figure shows that most farmers borrowed less than the loanable amount, and hence the constraint in the model $M \leq \overline{M}$ would not bind in most cases.

Figure 1: The loanable amount and the actual loan size

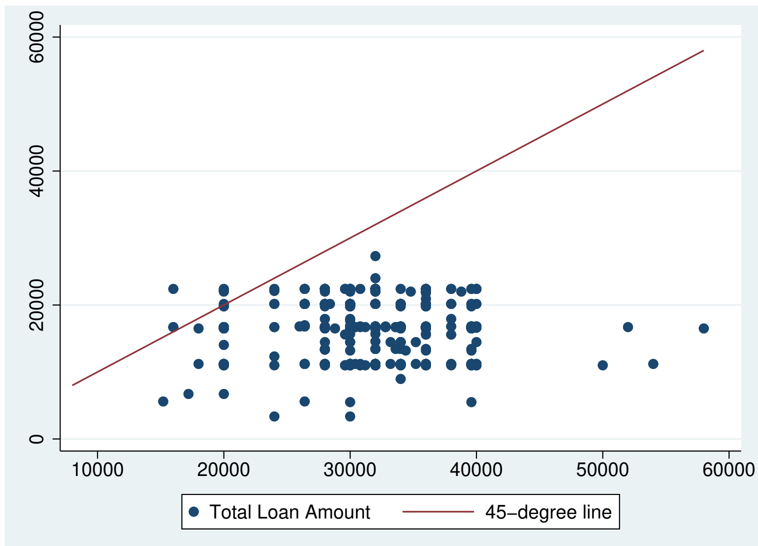



Table 4 shows the results of the balance tests, where we regress some of the baseline characteristics on the treatment status. Note that the coefficient on the in-kind captures the differential effect for the in-kind disbursement group compared to the sequential cash disbursement group.[18] While we do not find significant differences across treatment groups in most baseline characteristics, there are significant differences across treatments in the land holdings and the first investment. The traditional credit groups had significantly smaller baseline land sizes compared to the sequential credit groups, and the control group had significantly lower levels of the first investment at baseline. However, these standardized differences never exceed 0.17 in these variables. In sum, while the control group the characteristics of respondents are relatively well balanced. In the analysis, we include these variables in the regression to control for differences in baseline characteristics.

[18]Specifically, the variable named `Sequential` takes the value of one if the borrower is in the sequential credit (T3) or sequential in-kind credit (T4), and zero otherwise; and the variable named `In-kind` takes the value of one if the borrower is in the sequential in-kind credit (T4), and zero otherwise.

Table 4: Balance tests

| | (1) HH Asset | (2) Prod asset | (3) Land | (4) Borrowing | (5) 1st invest | (6) 2nd invest | (7) Other income | (8) Output |
|---|---|---|---|---|---|---|---|---|
| Crop Credit | -0.022 | -0.088 | 0.813 | 65.104 | 405.317** | 113.222 | -2271.621 | 28.990 |
| | (0.052) | (0.102) | (1.459) | (288.059) | (174.711) | (162.888) | (4417.361) | (758.307) |
| Sequential | 0.061 | 0.006 | 1.636 | 42.574 | 401.893** | 180.893 | -6398.083 | 723.800 |
| | (0.064) | (0.102) | (1.490) | (284.656) | (153.387) | (142.530) | (4214.086) | (656.175) |
| In-kind | -0.028 | -0.030 | 0.345 | -282.069 | -63.139 | 0.434 | -58.084 | 208.621 |
| | (0.058) | (0.102) | (1.502) | (234.605) | (167.081) | (140.496) | (3523.518) | (873.406) |
| Traditional | -0.045 | -0.071 | -1.465 | 8.973 | 230.554 | 180.720 | -4321.644 | -285.834 |
| | (0.059) | (0.107) | (1.394) | (347.806) | (148.219) | (161.306) | (4613.372) | (593.191) |
| Group FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 998 | 998 | 998 | 998 | 998 | 998 | 998 | 998 |
| Mean_Control | 12.275 | 7.654 | 90.957 | 676.975 | 8213.550 | 4461.546 | 1.00e+05 | 31657.050 |
| SD_Control | 0.998 | 0.999 | 21.185 | 2675.651 | 2464.009 | 1889.687 | 45688.444 | 9798.711 |
| Trad_vs_Crop | 0.755 | 0.858 | 0.104 | 0.890 | 0.345 | 0.668 | 0.627 | 0.670 |
| Trad_vs_SeqCash | 0.155 | 0.540 | 0.033 | 0.916 | 0.253 | 0.999 | 0.597 | 0.171 |
| Trad_vs_SeqKind | 0.249 | 0.670 | 0.019 | 0.410 | 0.489 | 0.997 | 0.555 | 0.116 |
| Crop_vs_SeqCash | 0.169 | 0.448 | 0.542 | 0.948 | 0.984 | 0.665 | 0.331 | 0.413 |
| Crop_vs_SeqKind | 0.387 | 0.572 | 0.484 | 0.299 | 0.726 | 0.606 | 0.336 | 0.255 |

The table reports the estimated coefficients of the regression, with standard errors clustered at the group level in parentheses. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$. The lower panel indicates the $p$ value for the null hypotheses that the coefficients of the corresponding treatment indicators are the same.

# 4 Results

To investigate the average intention-to-treat effect of different credit programs on the outcome measures, we estimate the following regression:

$$y_{ij}^F = \gamma_0 + \gamma_1 y_{ij}^B + \mathbf{T}_{ij}\boldsymbol{\tau} + \mathbf{X}_{ij}\boldsymbol{\gamma}_x + \zeta_j + \epsilon_{ij} \tag{13}$$

where $y_{ij}^F$ is the values of outcome variable at the follow up survey of household $i$ in borrowing group $j$, $y_{ij}^B$ is the lagged dependent variable measured at the baseline survey, $\mathbf{X}_{ij}$ is the set of other control variables including the baseline values of productive and non-productive asset (transformed into logarithms), livestock asset (transformed by the inverse-hyperbolic function), savings, land area, the first and second investment, the total output, the factor score used for the randomization, and the total income excluding the farm income. $\mathbf{T}_{ij}$ is a vector of indicators for each treatment, including the traditional weekly installment credit (T1), the crop credit (T2), and the sequential credit (T3 and T4). We also add an indicator for the in-kind credit, whose coefficient captures the differential effect of the sequential in-kind credit (T4) from that of the sequential cash credit (T3). The parameters to be estimated are $(\gamma_0, \gamma_1, \boldsymbol{\tau}', \boldsymbol{\gamma}_x')$. $\zeta_j$ is the fixed effects for the borrower group, and $\epsilon_{ij}$ is the idiosyncratic errors which are allowed to be correlated within the same lending group.[19]

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

$$y_{ij}^F = \gamma_0 + \mathbf{T}_{ij}^S\boldsymbol{\tau} + \mathbf{X}_{ij}\boldsymbol{\gamma}_x + \epsilon_{ij} \tag{14}$$

where $\mathbf{T}_i^S$ is a vector of indicators for each treatment other than the traditional credit, 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 $\mathbf{X}_{ij}$.

## 4.1 Uptake

Table 5 reports the regression results on loan uptake. Compared to the traditional weekly repayment loan whose uptake rate was 59.5%, the crop credit and sequential credit achieved a higher

[19] One might be tempted to use the treatment variables as the instruments for credit uptake to estimate the local average treatment effects (LATE). Given that we have multiple treatments, however, we avoid estimating the LATE as they will not be comparable across treatments when the treatment effects are heterogeneous. With the heterogeneous treatment effects, the LATE evaluates the average treatment effects over the people who switched to using the credit due to the treatment assignment. If farmers with greater treatment effects are more likely to uptake the loan, which is quite plausible, then one can increase the LATE by uniformly increasing the transaction costs for loan uptake without changing the true individual effect sizes. This is because the greater transaction costs discourages borrowers with smaller treatment effects from taking up the credit, which increases the average treatment effects among uptakers. Given that the sequential component requires additional procedures for farmers, we chose not to estimate the LATE.

uptake rate by 13.6 percentage points and 10.7 percentage points, respectively. Replacing cash disbursement in the sequential credit by in-kind disbursement did not improved the uptake rate significantly, but its coefficient is relatively large. As the standard errors are large due to the limited sample size, we cannot detect any significant differences in the uptake rates between the crop credit and sequential credit. However, the results clearly suggests that requiring weekly installment discourages potential borrowers from taking up microcredit, as our theory suggests. In column (2), we include the interaction terms of the treatment variables and the indicator for present bias.[20] While present bias had no significant influence on the uptake behavior in any credit schemes, the traditional microcredit again discouraged present-biased borrowers from uptaking the credit compared to the crop credit and sequential in-kind credit.[21] While the sequential credit could provide the commitment functions for present-biased borrowers, making the disbursement sequential did not significantly improve the uptake rates over the the crop credit. Given that the value of $\alpha$ was constrained to be no larger than 0.6, this result might indicate that present-biased borrowers valued the flexibility of the crop credit as large as the commitment provided by the sequential credit. This may suggest the importance of uncertainty for the uptake behavior, which we will revisit in the next section.[22]

The theory implies that the lower uptake rate of the standard microcredit is induced by the requirement of weekly installment when they do not have any income flows. Hence it is predicted that this effect will be mitigated if the borrower has other income sources to finance the installment. To examine this prediction, we run the regression for the subsample whose other total income than agricultural production at the baseline is low (lower than the 40 percentile) and the subsample whose other total income is high (higher than the 60 percentile).[23] The results reported in columns (3) and (4) show that discarding the weekly installment requirement improved the uptake rates among the farmers who had low other income sources substantially, while it did not have significant effects for the farmers whose other income was high. Although we did not find significant impacts

[20] The present bias indicator was constructed from hypothetical questions as in Ashraf et al. (2006)

[21] The numbers in the lower panel is the $p$-values against the null hypothesis that the impacts are equal. For the present-biased borrowers, it is the comparison of the linear combination of the level term and the interaction term. Given 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 $C_{ij}$ is an indicator for the crop credit, $S_{ij}$ for the sequential credit, $K_{ij}$ for the in-kind disbursement, and $PB_{ij}$ for the present bias, the $p$-value reported in the row `PB_Crop_vs_SeqC`, for example, is against the null hypothesis $H_0 : \tau_C + \delta_C = \tau_S + \delta_S$.

[22] Another potential reason for the insignificant impact of present bias on the uptake behavior is the measurement errors in the present bias variable. But since we do find significant impacts of present bias on investment behavior as shown below, we do not elaborate this possibility.

[23] We obtain the similar results when we divide the sample by the median.

Table 5: Uptake and loan size

| | (1) Uptake | (2) Uptake | (3) Uptake (low other income) | (4) Uptake (high other income) | (5) Loan size | (6) Loan size | (7) Loan size | (8) Loan size |
|---|---|---|---|---|---|---|---|---|
| Crop Credit | 0.136** | 0.130 | 0.193* | 0.057 | 119.028 | 24.381 | -427.721 | -487.190 |
| | (0.058) | (0.090) | (0.096) | (0.087) | (548.739) | (581.077) | (736.205) | (713.846) |
| Sequential | 0.107* | 0.101 | 0.058 | 0.052 | -1153.545** | -1135.208* | -1883.999** | -1792.696** |
| | (0.056) | (0.080) | (0.096) | (0.086) | (570.638) | (567.648) | (757.581) | (757.795) |
| In-kind | 0.073 | 0.043 | 0.189** | 0.062 | -453.635 | -435.921 | 218.998 | 187.485 |
| | (0.049) | (0.081) | (0.078) | (0.084) | (351.797) | (356.043) | (522.795) | (521.494) |
| PB=1 | | -0.032 | | | | | -674.971 | -635.330 |
| | | (0.061) | | | | | (819.047) | (829.598) |
| Crop Credit × PB=1 | | -0.003 | | | | | 920.413 | 840.939 |
| | | (0.096) | | | | | (1111.051) | (1125.373) |
| Sequential × PB=1 | | -0.010 | | | | | 1314.290 | 1180.698 |
| | | (0.080) | | | | | (1035.186) | (1045.636) |
| In-kind × PB=1 | | 0.064 | | | | | -1257.535* | -1161.926 |
| | | (0.089) | | | | | (690.510) | (693.252) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 799 | 788 | 326 | 314 | 560 | 560 | 551 | 551 |
| Mean_Control | 0.595 | 0.595 | 0.570 | 0.616 | 16910.420 | | 16910.420 | |
| Crop_vs_SeqCash | 0.455 | 0.720 | 0.041 | 0.949 | 0.006 | 0.016 | 0.017 | 0.033 |
| Crop_vs_SeqKind | 0.368 | 0.872 | 0.387 | 0.487 | 0.001 | 0.004 | 0.094 | 0.123 |
| PB_Trad_vs_Crop | | 0.053 | | | | | 0.547 | 0.685 |
| PB_Trad_vs_SeqC | | 0.153 | | | | | 0.464 | 0.433 |
| PB_Trad_vs_SeqK | | 0.001 | | | | | 0.045 | 0.051 |
| PB_Crop_vs_SeqC | | 0.422 | | | | | 0.048 | 0.093 |
| PB_Crop_vs_SeqK | | 0.170 | | | | | 0.001 | 0.005 |

The table report the estimated coefficients of the regression, with standard errors clustered at the group level in parentheses. The control variables not reported in the table include the baseline asset level and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$. The lower panel indicates the $p$ value for the null hypotheses that the coefficients of the corresponding treatment indicators are the same.

of the sequential cash credit on the uptake in either of these two subsamples, the results seem to suggest that requirement of the weekly installment limits the outreach of microcredit among agricultural households who do not have enough steady income.

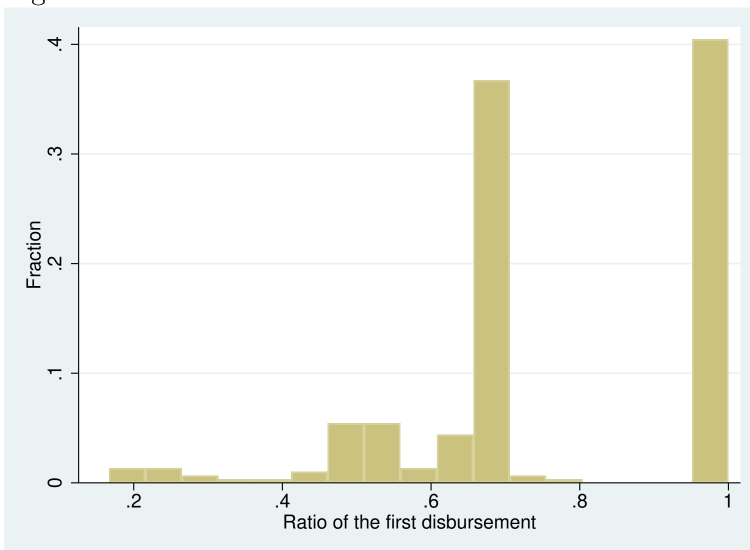
Column (5) reports the impact on the loan size. Since we only observe the loan size for those who actually took up the credit, the analysis is based on the selected sample of the uptakers. Among this selected sample, removing the weekly repayment (i.e. shifting from the traditional credit to the crop credit) had no significant impact on the loan size. It should be noted that the uptake decision was affected by the credit products that were offered, and hence the sample of the uptakers would be different across the treatment arms, causing the sample selection bias. To mitigate this, we use the inverse probability weighting (Robins et al., 1995; Wooldridge, 2010) in column (6), where we include as the predictors for the sample selection all the covariates of the regression, the production expenditure, an indicator for savings in the previous year, and the interaction terms of the treatment dummies and the production expenditure to allow for the differential demand for the credit across the treatments.[24] The identifying assumption is that conditioning on these variables, the sample selection process is independent of the error term. Correcting the sample selection made the coefficient of the crop credit smaller, which is again insignificant. This strengthens the conclusion that removing the weekly repayment did not result in a greater credit size.

Interestingly, we find that the sequential credit significantly reduced the loan size by 1,153.5 BDT, which is equivalent to 6.8 percent of the credit size in the traditional credit (Column (5)). When combined with the in-kind disbursement, it reduced the loan size by 9.5 percent. Correcting the sample selection barely changed the magnitude of these effects. In our theoretical model, the sequential disbursement will not affect the borrower's choice unless $\alpha$ is so low that the period-1 constraint binds. In the field, the maximum value of $\alpha$ was set to be 0.6, and borrowers could choose the amount of the first disbursement as long as it does not exceed 60% of the loanable amount. Figure 2 shows the distribution of the ratio of the first disbursement to the total credit size among the sequential credit borrowers. Note that this does not correspond to $\alpha$ in our model because borrowers can choose the disbursement amount at $t = 2$ smaller than $(1 - \alpha)M$. Specifically, borrowers could choose the amount of the second disbursement $M_2$ subject to $M_2 \leq (1 - \alpha)M$. Then the ratio in Figure 2 corresponds to $\frac{M_1}{\alpha M + M_2}$, which can be larger than 0.6 if $M_2 < (1 - \alpha)M$. It turns out that the majority of the borrowers chose $M_2 < (1 - \alpha)M$. Furthermore, 40% of the

[24]Specifically, we estimate a propensity score function $p(\mathbf{w}_i)$, where $\mathbf{w}_i$ is the predictors for the sample selection, based on the crop credit sample. Using the estimated coefficients, we computed the propensity score $\hat{p}(\mathbf{w}_i)$ for the other treatment arms. Then we run the regression for equation (14) using $1/\hat{p}(\mathbf{w}_i)$ as the weight. By this procedure, the characteristics of the uptakers across the treatment arms will be well balanced as in the standard propensity score weighting method. We do not report the control mean in the table as reporting the weighted mean of the traditional credit here is not so meaningful.

borrowers chose $M_2 = 0$ (the ratio of the first disbursement equals to 1).

Figure 2: Distribution of the ratio of the first disbursement




We argue that these results – a smaller credit size under the sequential credit and the amount of second disbursement satisfying $M_2 < (1 - \alpha)M$ for many borrowers – can be attributed to the option value provided by the sequential credit. We will provide a formal model of this option value argument in the next section, but let us introduce the essence here. Under the sequential credit, borrowers could adjust the loan size at later stages, after some uncertainties such as productivity shocks and expenditure shocks were resolved. In the standard credit or crop credit that distribute the credit at the outset, the credit size could not be adjusted ex post, and hence borrowers would choose a greater credit size to put aside some buffer for the potential productivity and expenditure shocks. By giving an option for borrowers to adjust the loan size ex post, the sequential credit enabled them to borrow only what they needed and resulted in the optimal investment level and efficient use of the credit.

One might argue that the result that the ratio of the first disbursement $\frac{\alpha M}{\alpha M + M_2}$ exceeds 0.6 can be explained by the demand for the flexibility and the local officers' imperfect compliance with the disbursement rule. However, the flexibility motive cannot explain the smaller credit size under the sequential credit. Further we observed no borrowers who received more than 60% of their maximum loanable amount.

Another potential mechanism explaining the smaller credit size is the commitment function of the sequential credit reducing the credit size of present-biased borrowers. However, present-biased borrowers would choose $M_2 = (1 - \alpha)M$ at period 2, which contradicts the empirical pattern. Further, when we include the interaction terms of the treatment variables and the present bias indicator in column (7), we found that the reduction in the loan size due to the sequential cash credit is evident among the time consistent borrowers. For present-biased borrowers, the credit size was not significantly different between the traditional credit and the sequential cash credit, though the difference between the crop credit and the sequential credit was still large and significant.

Interestingly, the sequential in-kind credit reduced the credit size both for the time consistent and present-biased borrowers compared to the traditional and crop credits. In the sequential cash credit, present-biased borrowers had incentives to borrow more for current consumption at $t = 2$. However, in the sequential in-kind credit, they could not increase the consumption by borrowing more unless they resell the in-kind disbursement. Hence the commitment story would partly explain the reduction in the credit size under the sequential in-kind credit.[25]

## 4.2 Investment

Next we look at the impact on investment. Our theory predicts that removing the weekly installment will increase investment both at period 1 and period 2, and our regression results are somewhat consistent with this prediction. Compared to the control group or the traditional credit group, the farmers in the crop credit and sequential credit made more first-stage investment (Table 6, Column (1)), though the effect for the former was smaller and not statistically significant. If we restrict to the time-consistent borrowers (Column (2)), we found that both the crop credit and sequential credit significantly increases the first investment compared to the traditional credit. Our theory implies that this increase in the first investment will make the investment decision close to the social optimal.

Columns (3) and (4) show the regression results for the second investment. We found no significant differences in the average amount of the second investment across the treatment groups as shown in Column (3). However, if we focus on the present-biased borrowers(Column (4)), we found that the sequential cash credit significantly increases the second investment, compared with the control, traditional credit, or crop credit, as our theory predicts (p-values are 0.022, 0.093, 0.070, respectively). This implies that the sequential credit can work as the commitment device. For the time-consistent borrowers, the sequential credit did not increase the second investment. But it does not mean that the sequential credit did not benefit them, as we found that it decreased the loan size for the time-consistent borrowers as shown above. The next section provides the framework that help understand these results in a unified manner.

In Columns (5) to (8), we investigate the impacts on the output and profit. The estimates are

[25] Appendix Table 1 shows the impacts on borrowing from other sources. The treatments did not significantly changed the borrowing from other sources (Columns (1) and (2)), even when we decomposed it into the credit from other MFIs and non-MFI borrowing (Columns (3) to (6)). Hence the differential effects on the credit size was not caused by the change in the debt composition.

Table 6: Investment and output

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Invest:1st | Invest:1st | Invest:2nd | Invest:2nd | Output | Output | Profit | Profit |
| Traditional | -53.701 | -198.530 | 1.049 | -114.598 | 53.237 | -495.169 | -102.185 | 1.963 |
| | (74.371) | (134.649) | (80.335) | (137.014) | (440.330) | (660.284) | (346.461) | (495.248) |
| Crop Credit | 96.105 | 100.615 | 29.045 | -41.000 | 397.819 | 228.281 | 51.085 | 122.456 |
| | (84.731) | (156.787) | (81.315) | (135.941) | (410.985) | (584.731) | (315.389) | (437.695) |
| Sequential | $242.967^{***}$ | 177.203 | 111.044 | -108.316 | 539.458 | -52.899 | -104.811 | 18.370 |
| | (83.595) | (156.771) | (81.867) | (126.220) | (444.888) | (597.311) | (341.269) | (455.698) |
| In-kind | $-152.413^{*}$ | -52.141 | 8.028 | 91.873 | -302.029 | -372.976 | 10.566 | -122.011 |
| | (90.017) | (145.772) | (82.831) | (118.041) | (477.477) | (632.987) | (413.574) | (561.324) |
| PB=1 | | -50.341 | | $-212.472^{*}$ | | -522.011 | | 204.848 |
| | | (132.384) | | (122.869) | | (797.603) | | (494.484) |
| Traditional × PB=1 | | 223.929 | | 189.986 | | 1022.076 | | -55.613 |
| | | (170.631) | | (172.992) | | (1008.630) | | (645.555) |
| Crop Credit × PB=1 | | -3.818 | | 106.572 | | 457.925 | | 47.863 |
| | | (192.863) | | (147.931) | | (884.203) | | (597.236) |
| Sequential × PB=1 | | 115.776 | | $392.692^{**}$ | | 1175.638 | | -81.909 |
| | | (220.076) | | (172.125) | | (1104.040) | | (685.286) |
| In-kind × PB=1 | | -156.275 | | -146.489 | | 68.683 | | 180.164 |
| | | (177.650) | | (176.284) | | (646.009) | | (646.872) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 998 | 986 | 998 | 986 | 998 | 986 | 998 | 986 |
| Mean_Control | 8334.402 | 8334.402 | 4150.241 | 4150.241 | 33568.040 | 33568.040 | 6069.880 | 6069.880 |
| Trad_vs_Crop | 0.089 | 0.026 | 0.749 | 0.605 | 0.364 | 0.177 | 0.591 | 0.804 |
| Trad_vs_SeqCash | 0.007 | 0.010 | 0.186 | 0.960 | 0.226 | 0.396 | 0.993 | 0.974 |
| Trad_vs_SeqKind | 0.105 | 0.010 | 0.195 | 0.407 | 0.670 | 0.914 | 0.978 | 0.856 |
| Crop_vs_SeqCash | 0.108 | 0.551 | 0.404 | 0.590 | 0.704 | 0.552 | 0.608 | 0.792 |
| Crop_vs_SeqKind | 0.953 | 0.823 | 0.380 | 0.863 | 0.730 | 0.352 | 0.690 | 0.660 |
| PB_Trad_vs_Crop | | 0.502 | | 0.929 | | 0.747 | | 0.596 |
| PB_Trad_vs_SeqC | | 0.071 | | 0.093 | | 0.354 | | 0.981 |
| PB_Trad_vs_SeqK | | 0.659 | | 0.236 | | 0.629 | | 0.900 |
| PB_Crop_vs_SeqCash | | 0.146 | | 0.070 | | 0.459 | | 0.584 |
| PB_Crop_vs_SeqKind | | 0.924 | | 0.179 | | 0.814 | | 0.675 |

The table the estimated coefficients of the regression, with standard errors clustered by the village in parentheses. The control variables not reported in the table include the baseline asset level, the baseline outcome variable and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

quite noisy, however, and we do not find any significant differences across the treatment arms. For example, the standard error of the coefficient on the sequential credit is 341 in Column (7). With this, the minimal detectable effect size (MDE) is 955, which corresponds to more than 15 percent increase in the profit. Given that the impacts of microcredit on profits were modest or insignificant in most previous studies (Augsburg et al., 2015; Banerjee et al., 2015), it is not surprising that we could not find significant impacts on the profit given our relatively small sample size.[26]

### 4.3 Savings

Table 7 reports the impacts on savings. In Column (1), the outcome variable is the savings amount reported by the household at the follow-up survey. Compared to the control group, the households in the treatment groups achieved greater savings. Given the results that credit did not significantly increase the output, we attribute this positive impacts on the savings to the encouragement of savings by GUK. It should be noted that compared with the traditional credit or sequential credit, the crop credit induced more savings. Present bias did not significantly influence the pattern of the savings as reported in Column (2).

We have argued that the option value of the sequential credit could explain the empirical results on the loan size. The fact that borrowers could adjust the loan size after observing (at least part of) the production and expenditure uncertainty enabled them to reduce the loan size. If this is the case, then borrowers of the traditional credit and crop credit would make more savings as a buffer to cope with the potential shocks. In Column (3), we restrict the sample to those who took up the credit in order to see if the borrowers of the traditional credit and crop credit made a greater savings, where we set the traditional credit group as the reference category. In this selected sample, we found exactly this pattern. Borrowers in the sequential credit made significantly less savings than the borrowers in traditional or crop credit.[27]

In column (4), we utilize the administrative record of the GUK on the monthly savings deposited to it. Appendix Figure 4 depicts the pattern of the monthly savings, showing that the savings accumulation is concentrated in the first three months. Note that the disbursement of the credit was mostly in July, and the second disbursement of the sequential credit is in mid or late August. The concentration of the savings accumulation in the first three months implies that borrowers deposited part of the disbursed credit into their savings account. To examine the differences in the savings behavior across the credit schemes, we aggregate the savings deposited at GUK in the

[26]If we were to implement 3 treatment instead of 4 treatment (by removing the sequential in-kind as we discussed in footnote 14), then the MDE would be 840, which is still large.

[27]Correcting the sample selection bias by the IPW does not change the conclusion. The results are available upon request.

Table 7: Savings

| | (1) Saving | (2) Saving | (3) Saving | (4) Savings at MFI during first 3 months | (5) Savings at MFI during first 3 months | (6) Net savings at MFI months | (7) Net savings at MFI |
|---|---|---|---|---|---|---|---|
| Traditional | 1477.865*** | 1374.174*** | | | | | |
| | (172.029) | (229.268) | | | | | |
| Crop Credit | 1624.555*** | 1715.506*** | -214.186 | -12.843 | -60.876 | 61.727 | 14.005 |
| | (122.665) | (169.230) | (236.636) | (66.160) | (80.844) | (72.151) | (104.176) |
| Sequential | 1341.303*** | 1414.683*** | -466.870* | -259.110*** | -314.432*** | -239.921*** | -310.706*** |
| | (141.652) | (185.010) | (238.723) | (67.025) | (77.684) | (72.112) | (88.365) |
| In-kind | 46.289 | -85.927 | -61.854 | -55.396 | -38.040 | -10.620 | 8.474 |
| | (125.441) | (202.990) | (92.876) | (42.602) | (58.285) | (41.735) | (57.505) |
| PB=1 | | 6.304 | | | -69.689 | | -76.791 |
| | | (112.661) | | | (89.792) | | (92.692) |
| Traditional × PB=1 | | 174.310 | | | | | |
| | | (320.762) | | | | | |
| Crop Credit × PB=1 | | -165.140 | | | 89.497 | | 87.329 |
| | | (208.196) | | | (127.629) | | (138.537) |
| Sequential × PB=1 | | -164.487 | | | 96.842 | | 119.030 |
| | | (205.236) | | | (100.759) | | (118.713) |
| In-kind × PB=1 | | 236.211 | | | -36.848 | | -39.651 |
| | | (218.355) | | | (90.678) | | (90.881) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 998 | 986 | 560 | 560 | 551 | 560 | 551 |
| Mean_Control | 266.884 | 266.884 | 2853.445 | 1809.916 | 1809.916 | 2432.437 | 2432.437 |
| Trad_vs_Crop | 0.503 | 0.169 | | | | | |
| Trad_vs_SeqCash | 0.546 | 0.843 | | | | | |
| Trad_vs_SeqKind | 0.678 | 0.833 | | | | | |
| Crop_vs_SeqCash | 0.011 | 0.125 | 0.014 | 0.000 | 0.005 | 0.000 | 0.004 |
| Crop_vs_SeqKind | 0.056 | 0.093 | 0.003 | 0.000 | 0.001 | 0.000 | 0.001 |
| PB_Trad_vs_Crop | | 0.995 | | | 0.773 | | 0.304 |
| PB_Trad_vs_SeqC | | 0.360 | | | 0.017 | | 0.058 |
| PB_Trad_vs_SeqK | | 0.624 | | | 0.002 | | 0.025 |
| PB_Crop_vs_SeqCash | | 0.025 | | | | | |
| PB_Crop_vs_SeqKind | | 0.251 | | | | | |

The table the estimated coefficients of the regression, with standard errors clustered by the village in parentheses. The control variables not reported in the table include the baseline asset level, the baseline outcome variable and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

first three months. The regression results shows that sequential credit borrowers made significantly smaller savings in the first three months compared to the traditional credit borrowers and crop credit borrowers by 250–260 BDT. Including the interaction terms with the present bias indicator did not change the results (Column (5)).

In column (6), we estimate the impact on the net savings at the MFIs at the followup survey, and find that the sequential credit resulted in lower net savings compared to the traditional and crop credits. This is mainly driven by the greater withdraw, especially in November when farmers need additional expenditure for pesticide and fertilizer. This indicates that they withdrew the savings instead of receiving the third disbursement to finance them.

### 4.4 Default

Table 8 reports the estimation results on the repayment performance. The outcome variable in Columns (1) and (2) is an indicator for not completing the repayment at the due date, where we applied the IPW in Column (2) to mitigate the sample selection bias. We found no significant differences in the rate of the loans in arrears across treatment arms.

In columns (3) and (4), we regress the default status (repayment not completed one week after the due date) on the treatment variables. The average default rate in the traditional credit was 16.0%, and more flexible repayment credit such as the crop credit and the sequential credit did not worsen the default rate.

We also investigate the differences in the percent of the loan amount that were not repaid in columns (5) and (6). Given the fact that the MFI can confiscate the savings at the MFI savings account, the percent of the loan yet repaid was computed as

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

Given that there are many observations whose value of the percent of amount yet repaid was zero, we use the Tobit regression. We again find no significant differences across the treatment groups.[28]

Including the interaction terms of the treatment variables and the present bias indicator does not change the results except that present-biased borrowers achieved less default under the crop credit compared to the traditional credit (Appendix Table 3). While the proponent of the weekly installment argues that it is required to keep the repayment rate high, we do not find any evidence supporting this argument. Rather, our point estimates consistently indicate that flexible repayment schemes performed better in terms of repayment, though not statistically significant. In the agricultural setting which is characterized by infrequent, lumpy income-flow at the harvest, requiring the one time repayment after the harvest does not worsen the repayment performance. Given

[28] Using the OLS does not change the results.

Table 8: Default

| | (1) Loans in arrears | (2) Loans in arrears | (3) Default | (4) Default | (5) % of amount yet repaid | (6) % of amount yet repaid |
|---|---|---|---|---|---|---|
| Crop Credit | -0.071 | -0.050 | -0.017 | -0.018 | -0.041 | -0.060 |
| | (0.050) | (0.057) | (0.047) | (0.051) | (0.221) | (0.232) |
| Sequential | -0.072 | -0.069 | -0.027 | -0.026 | -0.118 | -0.119 |
| | (0.059) | (0.060) | (0.049) | (0.049) | (0.228) | (0.228) |
| In-kind | -0.046 | -0.050 | -0.018 | -0.017 | -0.013 | 0.000 |
| | (0.052) | (0.052) | (0.046) | (0.047) | (0.282) | (0.280) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 560 | 560 | 560 | 560 | 560 | 560 |
| Mean_Control | 0.588 | | 0.160 | | 0.094 | |
| Crop_vs_SeqCash | 0.985 | 0.745 | 0.784 | 0.841 | 0.725 | 0.791 |
| Crop_vs_SeqKind | 0.429 | 0.277 | 0.470 | 0.551 | 0.688 | 0.803 |

The table the estimated coefficients of the regression, with standard errors clustered by the village in parentheses. The control variables not reported in the table include the baseline asset level, the baseline outcome variable and group dummies. Columns (5) and (6) report the average partial effects in the Tobit models. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

the results that the crop credit and sequential credit increased the uptake rates, it is indicated that microcredit can expand the outreach for agricultural sectors without deteriorating its financial performance by allowing more flexible repayment scheme.

## 4.5 Uptake in the second round

Finally we investigate the satisfaction to the credit scheme. In columns (1) and (2) in Table 9, we examine the demand for the loans in the second round when the farmers were offered the same product as the first rounds. While the uptake rate of the traditional credit was 44 percent at the second round, the crop credit and sequential credit achieved higher uptake rates by 12 to 15 percentage points. We find no systematic differences in the second season uptake rate between the time consistent borrowers and present-biased borrowers, but present-biased borrowers are more likely to uptake the credit if it is crop credit or disbursed in kind.

Columns (3) to (6) reports the regression 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 the crop credit reports the greatest satisfaction, followed by the sequential cash credit and then the sequential in-kind credit. This is consistent with the report from GUK saying that many farmers requested for the credit access, particularly the seasonal credit in the following season.

Table 9: Uptake in the second round

| | (1) Uptake:2nd | (2) Uptake:2nd | (3) Satisfaction | (4) Satisfaction | (5) Satisfaction | (6) Satisfaction |
|---|---|---|---|---|---|---|
| Crop Credit | 0.153*** | 0.150* | 1.879*** | 1.736*** | 1.867*** | 1.735*** |
| | (0.055) | (0.082) | (0.163) | (0.225) | (0.159) | (0.222) |
| Sequential | 0.123** | 0.147* | 1.074*** | 0.877*** | 1.049*** | 0.877*** |
| | (0.052) | (0.084) | (0.118) | (0.226) | (0.121) | (0.225) |
| In-kind | 0.049 | 0.043 | -0.300*** | -0.226 | -0.306*** | -0.225 |
| | (0.049) | (0.079) | (0.100) | (0.148) | (0.102) | (0.149) |
| PB=1 | | -0.009 | | -0.268 | | -0.238 |
| | | (0.059) | | (0.245) | | (0.250) |
| Crop Credit × PB=1 | | 0.003 | | 0.242 | | 0.235 |
| | | (0.089) | | (0.318) | | (0.315) |
| Sequential × PB=1 | | -0.065 | | 0.320 | | 0.287 |
| | | (0.093) | | (0.262) | | (0.265) |
| In-kind × PB=1 | | 0.030 | | -0.120 | | -0.131 |
| | | (0.099) | | (0.190) | | (0.191) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 799 | 788 | 564 | 555 | 553 | 544 |
| Mean_Control | 0.440 | 0.440 | 2.831 | 2.831 | | |
| Crop_vs_SeqCash | 0.501 | 0.972 | 0.000 | 0.000 | 0.000 | 0.000 |
| Crop_vs_SeqKind | 0.746 | 0.594 | 0.000 | 0.000 | 0.000 | 0.000 |
| PB_Trad_vs_Crop | | 0.016 | | 0.000 | | 0.000 |
| PB_Trad_vs_SeqC | | 0.165 | | 0.000 | | 0.000 |
| PB_Trad_vs_SeqK | | 0.009 | | 0.000 | | 0.000 |
| PB_Crop_vs_SeqC | | 0.213 | | 0.000 | | 0.000 |
| PB_Crop_vs_SeqK | | 0.976 | | 0.000 | | 0.000 |

The table report the estimated coefficients of the regression, with standard errors clustered at the group level in parentheses. The control variables not reported in the table include the baseline asset level and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

# 5 Option value

## 5.1 Model

We have argued that the option value could explain the pattern of the empirical results relating to the sequential credit. In this section, we provide a formal model to facilitate the understanding of the borrower's behavior and then consider some numerical exercises. First, we introduce uncertainty in productivity and expenditure. Particularly, we consider the production function

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

where $\theta_1 > 0$ and $\theta_2 > 0$ are the productivity shocks revealed at the beginning of period 1 and period 2, respectively. We can interpret $\theta_t > 1$, $t = 1, 2$, as the positive shock and $\theta_t < 1$ as the negative shock. We also incorporate expenditure shocks $\xi_1 \geq 0$ and $\xi_2 \geq 0$ at period 1 and 2, respectively, assuming the Stone-Geary utility function, $u(c_t - \xi_t)$. Given the fact that some borrowers made considerable savings, we allow that borrowers can carry over the savings to period 3. At period 0, the farmer maximizes her expected utility

$$E[u(c_1 - \xi_1) + u(c_2 - \xi_2) + u(c_3)],$$

where we take the expectation over $\theta_1, \theta_2, \xi_1, \xi_2$. At period 1, she knows the values of $\theta_1, \xi_1$ and maximizes $u(c_1 - \xi_1) + E[u(c_2 - \xi_2) + u(c_3) | \theta_1, \xi_1]$, while at period 2, all the uncertainty is resolved and she maximizes $u(c_2 - \xi_2) + u(c_3)$.

First we consider the choice under the crop credit. The timing of the decision making is summarized in the upper part of Table 10. Appendix A.2.1 provides the characterization of the full solution.

Table 10: Timing of the decision making under the crop credit

| | $t = 0$ | $t = 1$<br>Observe $\theta_1, \xi_1$ | $t = 2$<br>Observe $\theta_2, \xi_2$ | $t = 3$ |
|---|---|---|---|---|
| Crop | * Decide $M$ | Disburse $M$<br>* 1st investment $K_1$<br>* Consume $c_1$ | * 2nd investment $K_2$<br>* Consume $c_2$ | Harvest $Y = \theta_1 \theta_2 F(K_1, K_2)$<br>Repay $(1 + r)M$<br>Consume $c_3$ |
| Sequential | * Decide $M$ | Disburse $\alpha M$<br>* 1st investment $K_1$<br>* Consume $c_1$ | * Receive $M_2 \leq (1 - \alpha)M$<br>* 2nd investment $K_2$<br>* Consume $c_2$ | Harvest $Y = \theta_1 \theta_2 F(K_1, K_2)$<br>Repay $(1 + r)(\alpha M + M_2)$<br>Consume $c_3$ |

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

The period-2 problem is written as

$$\begin{aligned}
\max_{c_2, K_2} \quad & u(c_2 - \xi_2) + u(c_3) \\
\text{s.t.} \quad & c_2 + K_2 \leq A_2, \\
& c_3 = \theta_1 \theta_2 F(K_1, K_2) - (1+r)M + A_2 - c_2 - K_2, \\
& A_2 = A_1 - c_1 - K_1.
\end{aligned} \tag{15}$$

Denote the Lagrange multiplier associated with constraint (15) by $\eta$. Then the first order conditions are written as

$$u'(c_2^* - \xi_2) - u'(c_3^*) - \eta = 0,$$
$$[\theta_1 \theta_2 F_2'(K_1, K_2^*) - 1]\, u'(c_3^*) - \eta = 0.$$

If the constraint (15) does not bind, then the second investment satisfies

$$\theta_1 \theta_2 F_2'(K_1, K_2^*) = 1. \tag{16}$$

The first order conditions at period 1 can be written as

$$u'(c_1^* - \xi_1) = E[u'(c_2^* - \xi_2)|\theta_1, \xi_1],$$
$$E[u'(c_2^* - \xi_2)|\theta_1, \xi_1] = \theta_1 E[\theta_2 F_1'(K_1^*, K_2^*) u'(c_3^*)|\theta_1, \xi_1].$$

When making the period-1 consumption and investment decision, she has to consider the uncertainty at period 2 as is expressed by the expectation operator. Finally, the borrower at period 0 will choose the loan size so that

$$E[u'(c_2^* - \xi_2)] = (1+r)E[u'(c_3^*)]. \tag{17}$$

Now consider the sequential credits. Unlike the case without uncertainty in section 2, the borrowers can reduce the amount of the second disbursement $M_2$ at period 2 when the uncertainty is resolved. Specifically, at period 2, she will choose $M_2$ with the constraint $M_2 \leq (1-\alpha)M$ after observing the realized value of $\theta_1, \theta_2, \xi_1, \xi_2$. The repayment amount at period 3 is $(1+r)(\alpha M + M_2)$. The timing of the decision making is summarized in the lower part of Table 10. The full proof is provided in Appendix A.2.2. The full characterization of the solution in case of the preesnt-biased borrower is provided in Appendix A.2.3.

The maximization problem at period 2 is formulated as

$$\max_{c_2,K_2,M_2} \quad u(c_2-\xi_2)+u(c_3)$$
$$\text{s.t.} \quad c_2+K_2\leq \tilde{A}_2+M_2,$$
$$c_3=\theta_1\theta_2F(K_1,K_2)-(1+r)(\alpha M+M_2)+\tilde{A}_2+M_2-c_2-K_2.$$
$$M_2\leq(1-\alpha)M. \tag{18}$$
$$M_2\geq 0. \tag{19}$$

where $\tilde{A}_2=A_1-c_1-K_1$ is the available resources at period 2 excluding the second disbursement $M_2$. The first order conditions are

$$u'(c_2^*-\xi_2)=(1+r)u'(c_3^*)+\mu-\nu,$$
$$[\theta_1\theta_2F_2'(K_1,K_2^*)-(1+r)]u'(c_3^*)-\mu+\nu=0,$$

where $\mu$ and $\nu$ are the Lagrange multipliers associated with the constraints (18) and (19), respectively. If this constraint does not bind, we obtain

$$\theta_1\theta_2F_2'(K_1,K_2^*)=1+r, \tag{20}$$

which states that the second investment is made optimally ex post, which is lower than the case under the crop credit (16).

Based on this decision rule, the farmer at period 1 chooses $(c_1,K_1)$ to maximizes her expected continuation utility $u(c_1-\xi_1)+E\left[u(c_2-\xi_2)+u(c_3)|\theta_1,\xi_1\right]$ subject to the budget constraint

$$c_1+K_1\leq A_0+\alpha M. \tag{21}$$

Let the Lagrange multipliers associated with the constraints (21) be $\lambda$. Assuming the inner solution, then the choice of $M$ and $\alpha$ at period 0 satisfies

$$E(\lambda)=E(\nu). \tag{22}$$

Under the sequential credit, the borrower can reduce the second disbursement $M_2$ if she found the return to the second investment $\theta_1\theta_2F_2(K_1,K_2)$ is not high or the expenditure shock $\xi_2$ is not large. By setting $\alpha$ lower, she can leave more room for adjusting $M_2$ at period 2, but it makes it more likely that the period-1 budget constraint binds. The equation (22) states that the borrower will choose $M$ and $\alpha$ to take this trade-off into account. Further, we can obtain $E[\mu]=0$, which means that borrowers will choose $M$ and $\alpha$ so that the period-2 constraint $M_2\leq(1-\alpha)M$ never binds. This can be achieved by choosing sufficiently large $M$ and sufficiently small $\alpha$.

This is actually what we observed in the data. The Figure 2, which showed the distribution of the ratio of the first disbursement in the sequential credit, $\frac{\alpha M}{\alpha M+M_2}$, implied that 40% of the borrowers of the sequential credit chose $M_2 = 0$. Further, some borrowers recorded this ratio far below 0.6, suggesting that they set $\alpha$ quite low as the theory predicts.

The theory also predicts that the borrower will choose a large loan size $M$ at period 0. While we do not have the data on $M$ for the sequential credit borrowers (we only observe the realized credit size $\alpha M + M_2$), we can obtain its lower bound from the disbursed loans. Specifically, we take the larger value of either the final loan size or the amount of the first disbursement divided by 0.6, which is the maximum value of $\alpha$ that GUK set.[29] Since the final loan size is no more than the original loan size and the optimal $\alpha$ is expected to be lower than this, this will give us a lower bound of $M$. Table 11 shows the regression results. The inferred value of the original loan size of the sequential credit was larger than the traditional and crop credits, by more than 20%. Borrowers of the sequential credit applied for a larger loan size, and then adjusted the final loan size after the uncertainty was resolved, which eventually resulted in the smaller loan size as we showed in the previous section (Table 5)).

Under the crop credit, the loan size is determined at period 0 according to the first order condition (17). Unless binded by the maximum loan amount, the loan size is chosen so that the ratio of the expected marginal utility at period 2 and period 3 is equal to the cost of the loan. Under the sequential credit, the total loan size is determined at period 2 by choosing $M_2$ so that the marginal product of the second investment becomes equal to the cost of the loan as stated in equation (20) if $\mu = 0$, which is optimal ex post. To ensure enough room for adjustment, borrowers at $t = 0$ choose a large loan size and its small fraction to be disbursed at $t = 1$.

Note that with precautionary savings motives, borrowers will choose a greater credit size under the crop credit than the sequential credit especially when the expenditure shocks are important.[30] Hence in order to explain the lower credit size under the sequential credit, we need to establish that the expenditure shocks were important for borrowers' decision making. To examine if the expenditure shocks were actually important in the data, we use the implication of the model that the optimal second investment, $K_2^*$, is solely determined by the production side and independent of the consumption decisions including expenditure shocks. Given this optimal $K_2^*$, the borrower will decide $c_2$ and $M_2$ according to the equation (20), or

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

[29] Formally, we can write $\max\left(\alpha M + M_2, \frac{\alpha M}{0.6}\right) \leq \max\left(M, \frac{\alpha}{0.6}M\right) \leq M$, since $\alpha M + M_2 \leq M$ and $\alpha \leq 0.6$.

[30] If the productivity shocks are important, then the negative productivity shocks result in the reduction of period-3 consumption. If a borrower had borrowed a large amount of money, then she would eventually face a large debt burden with little investment return at period 3. Under the crop credit, borrowers with precautionary savings motives will try to avoid the situation of extremely low consumption at period 3 by holding the credit size down, compared to the case of the sequential credit.

Table 11: Choice of loan size at $t = 0$

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | $M^*$ | $M^*$ | $M^*$ | $M^*$ |
| Crop Credit | 53.660 | -528.828 | -101.566 | -595.282 |
| | (570.382) | (731.576) | (606.470) | (696.187) |
| Sequential | 3516.795*** | 3502.017*** | 3524.915*** | 3578.337*** |
| | (641.479) | (905.314) | (637.110) | (898.859) |
| In-kind | -1374.855*** | -1406.042** | -1361.236*** | -1438.531** |
| | (454.645) | (625.509) | (459.559) | (630.087) |
| PB=1 | | -878.950 | | -806.587 |
| | | (885.070) | | (886.393) |
| Crop Credit × PB=1 | | 987.382 | | 835.817 |
| | | (1160.432) | | (1190.194) |
| Sequential × PB=1 | | -13.583 | | -141.350 |
| | | (1119.495) | | (1127.980) |
| In-kind × PB=1 | | 111.742 | | 202.149 |
| | | (908.731) | | (932.057) |
| Control | Yes | Yes | Yes | Yes |
| Observations | 560 | 551 | 560 | 551 |
| Mean_Control | 16910.420 | 16910.420 | | |
| Crop_vs_SeqCash | 0.000 | 0.000 | 0.000 | 0.000 |
| Crop_vs_SeqKind | 0.000 | 0.001 | 0.001 | 0.001 |
| PB_Trad_vs_Crop | | 0.597 | | 0.798 |
| PB_Trad_vs_SeqC | | 0.000 | | 0.000 |
| PB_Trad_vs_SeqK | | 0.021 | | 0.023 |
| PB_Crop_vs_SeqC | | 0.000 | | 0.000 |
| PB_Crop_vs_SeqK | | 0.015 | | 0.017 |

The table the estimated coefficients of the regression, with standard errors clustered by the village in parentheses. The control variables not reported in the table include the baseline asset level, the baseline outcome variable and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

Under the standard utility function such as CRRA and CARA,[31] we can derive

$$\alpha M + M_2^* = R[K_2^* + K_1^* + \xi_2 + c_1^* + \theta_1\theta_2 F(K_1^*, K_2^*) - A_0] \tag{23}$$

where $R \equiv \frac{1}{1+(1+r)u'^{-1}(1+r)} > 0$. Note that the left hand side is the final loan size. If the variation in the final loan size is driven by the productivity shocks, then we should find $K_2$ and $K_1$ are positively correlated with the final loan size. However, if the variation in the final loan size is mainly driven by the expenditure shocks, then $K_2$ and $K_1$ will have a little prediction power for the final loan size. We approximate $A_0$ by using the baseline assets, land areas, other income flows, savings and production, which we denote by the vector $\mathbf{w}$. Table 12 reports the regression results where we regress the final loan size on the second investment, first investment, and $\mathbf{w}$. Column (1)-(3) use the sequential cash credit borrowers only, and column (4)-(6) use the borrowers of the sequential cash credit and sequential in-kind credit as the sample. Columns (1) and (4) are the specifications closest to the equation (23) with including the followup output value to capture $\theta_1\theta_2 F(K_1^*, K_2^*)$. In columns (2) and (5), we exclude $\theta_1\theta_2 F(K_1^*, K_2^*)$ as it is the function of $K_1$ and $K_2$ and hence the linear term $K_2^* + K_1^*$ in equation (23) will be subsumed in $\theta_1\theta_2 F(K_1^*, K_2^*)$, which could mask the impact of $K_2$ and $K_1$ on the final loan size in the estimation. In columns (3) and (6), we add the second order terms of $K_2$ and $K_1$ to the specification of columns (2) and (5) to capture nonlinearity of the production function. In most cases, we found the coefficients on $K_2$ and $K_1$ are not significant. Even when they are significant, their signs are negative and hence contradict with the argument that productivity shocks are the main driver of the variation in the loan size. These results indicate that the source of the variation in the loan amount is the expenditure shocks, and hence the precautionary motives will increase the loan size of the crop credit compared to the sequential credit.

## 5.2 Numerical Examples

We have argued that the model incorporating the option value can explain our empirical results. In order to further consider how the flexible repayment and disbursement microcredit can affect borrowers' behavior, we conduct numerical exercises as there is no closed form solutions to our models.

First consider the benchmark model where there are no uncertainty. We assume the Cob-

[31] More broadly, this equation holds for any utility functions $u$ whose first derivatives are multiplicative functions, i.e., $u'(ax) = u'(a)u'(x)$.

Table 12: Correlation between $M$ and $K_2$

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Seq cash | Seq cash | Seq cash | Seq cash & kind | Seq cash & kind | Seq cash & kind |
| $K_2$ | -0.506 | -0.504 | -2.405 | -0.658* | -0.656* | -0.742 |
| | (0.448) | (0.445) | (2.302) | (0.373) | (0.374) | (1.428) |
| $K_1$ | -0.435 | -0.451 | -0.100 | 0.081 | 0.068 | 1.500 |
| | (0.450) | (0.445) | (0.975) | (0.442) | (0.449) | (0.909) |
| Output(Followup) | 0.031 | | | 0.026 | | |
| | (0.125) | | | (0.081) | | |
| $K_2^2$ | | | -0.000 | | | -0.000 |
| | | | (0.000) | | | (0.000) |
| $K_1^2$ | | | -0.000** | | | -0.000** |
| | | | (0.000) | | | (0.000) |
| $K_1K_2$ | | | 0.001* | | | 0.000 |
| | | | (0.000) | | | (0.000) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 63 | 63 | 63 | 123 | 123 | 123 |
| $R^2$ | 0.239 | 0.238 | 0.275 | 0.103 | 0.102 | 0.132 |
| p_H0 | 0.137 | 0.124 | 0.048 | 0.117 | 0.109 | 0.003 |

The table the estimated coefficients of the regression, with standard errors clustered by the village in parentheses. The control variables not reported in the table include the baseline assets, land areas, other income flows, savings and production. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

Douglass production function and the CRRA utility function:

$$F(K_1, K_2) = \theta K_1^{\psi_1} K_2^{\psi_2}$$

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

The production function exhibits decreasing returns to scale, i.e., $\psi_1 + \psi_2 < 1$, which is plausible given the fixed land size. With the Cob-Douglass production function and ignoring the uncertainty, the condition (7) implies

$$\frac{\psi_1}{\psi_2} = \frac{K_1^*}{K_2^*}, \tag{24}$$

and the condition (9) reduces to

$$\psi_2 \theta K_1^{*\psi_1} K_2^{*\psi_2 - 1} = 1 + \frac{r}{Q}, \tag{25}$$

where $Q = 1$ for crop credit borrowers and $r = 0.12$ for our intervention. With the optimal inputs $(K_1^*, K_2^*)$, the output will be

$$Y = \theta K_1^{*\psi_1} K_2^{*\psi_2}. \tag{26}$$

These three equations have three unknown parameters $(\theta, \psi_1, \psi_2)$. Given that the sample averages of $K_1$, $K_2$, and $Y$ for the crop credit borrowers were 8,547 BDT, 4,179 BDT, and 33,767 BDT, respectively, we set $(K_1, K_2, Y) = (8.547, 4.179, 33.767)$ and solved these three equations to obtain these parameters as $(\theta, \psi_1, \psi_2) = (15.075, 0.283, 0.139)$.[32]

Figure 3 depicts the optimal choice of the credit size $M$ and the amount of the first investment $K_1$ against the endowment $A_0$ for different repayment schedules($\pi = 1, 0.5, 0.25, 0$) in the case of no uncertainty. The traditional weekly repayment corresponds to the case of $\pi = 1$, and the crop credit corresponds to the case of $\pi = 0$. For the utility function, we set $\gamma = 1$ in the left panel and $\gamma = 2$ in the right panel. The higher value of $\gamma$ implies the more demand for consumption smoothing.

While the credit size is decreasing in $A_0$,[33] the investment size is constant because it is solely determined by the marginal productivity as shown by the fist order condition (25). In the range

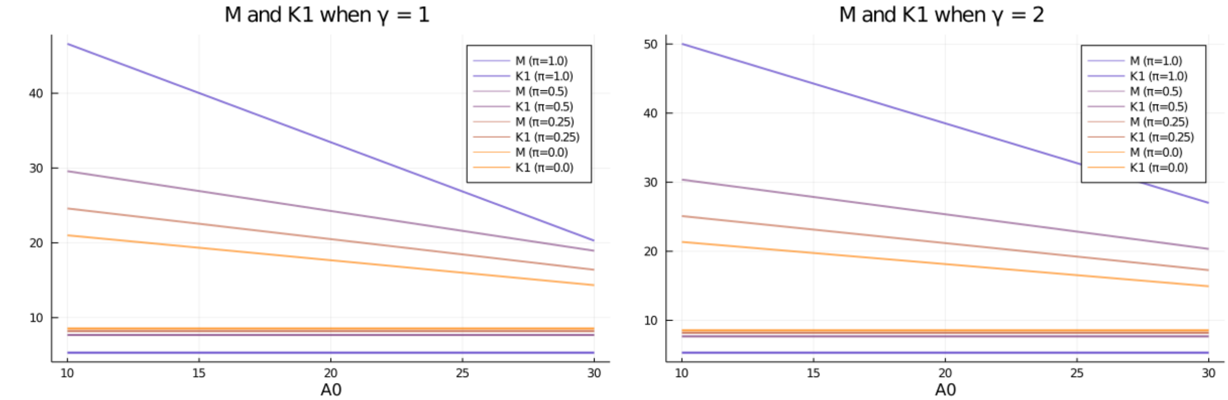
[32] This calibration only uses the information on the average input and output amount, and there is no guarantee that these parameter values are realistic ones. Another approach to get these parameters is estimating the production function, using the variation across households rather than only using the average. However, the observed inputs $(K_1, K_2)$ will be related to the unobserved productivity $\theta$, and without valid exogenous instruments, we cannot obtain the consistent estimates on the production function parameters.

[33] With these functional specifications, the optimal credit 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 3: Optimal level of $M$ and $K_1$ under different value of $\pi$




of $A_0$ described in the Figure, the requirement of weekly installment ($\pi = 1$) increases the credit size especially for those whose endowment is low. The regular repayment ($\pi = 1$) results in the largest credit size and the lowest investment size. The discrepancy between these two is substantial for those whose endowment is low, indicating the considerable amount of the credit is used for repayment before the harvest for the asset-poor borrowers. When the demand for consumption smoothing is high ($\gamma = 2$, the right panel), the credit size gets larger for the weekly repayment loan among those whose endowment is low, as they need more borrowing for consumption before the harvest.

Appendix Figure 7 shows the computed value of having the endowment amount $A_0$ for the different repayment schedule. As expected, the value is lowest when $\pi = 1.0$ (traditional weekly repayment), and highest when $\pi = 0$ (crop credit). The difference is greater when the borrower has less endowment. This is consistent with the greater uptake rate for the crop credit compared to the traditional credit among the farmers with low other income flows in Table 5.

Next we incorporate the uncertainty in the productivity and the expenditure shocks. To reduce the computational burden, we consider the cases where $\theta_t$, $\xi_t$, $t = 1, 2,$ are discrete and i.i.d. Especially we consider the following two cases:

Case 1 (Greater productivity shocks):

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

$\xi_t \in \{0, 2.5\}$, with $\Pr(\xi_t = 0) = 0.8$, $\Pr(\xi_t = 2.5) = 0.2$.

Case 2 (Greater expenditure shocks):

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

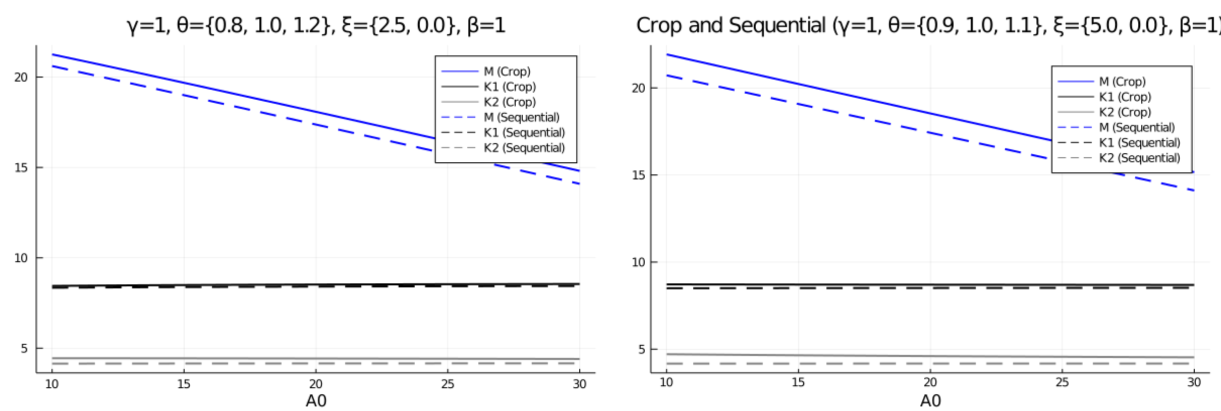
$\xi_t \in \{0, 5.0\}$, with $\Pr(\xi_t = 0) = 0.8$ , $\Pr(\xi_t = 5.0) = 0.2$.

Productivity shocks are more important in case 1, and expenditure shocks are more important in case 2. While the model includes many state variables, our three period model allows us to avoid the curse of dimensionality by directly solve the nonlinear system equations and nonlinear optimization. The computation details are provided in Appendix A.3.

Appendix Figure 4 depicts the model prediction of the borrower's choice on the actual credit size $M^*$ and the investment amounts, $K_1^*$ and $K_2^*$, under the crop credit and sequential credit when $\gamma = 1$.[34] The optimal value of $K_t$, $t = 1, 2$ are computed when the productivity is at average ($\theta_t = 1$) and there are no expenditure shocks ($\xi_t = 0$). The left panel shows the solutions under Case 1, and the right panel the solutions under Case 2.

The credit size is lower under the sequential credit in both cases, though the difference is larger when expenditure shocks are more important (Case 2). This indicates that the reduction of the credit size by introducing the sequential credit will be observed under modest expenditure shocks. The existence of potential expenditure shocks at period 2 will induce borrowers to borrow more for precaution under the crop credit.

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



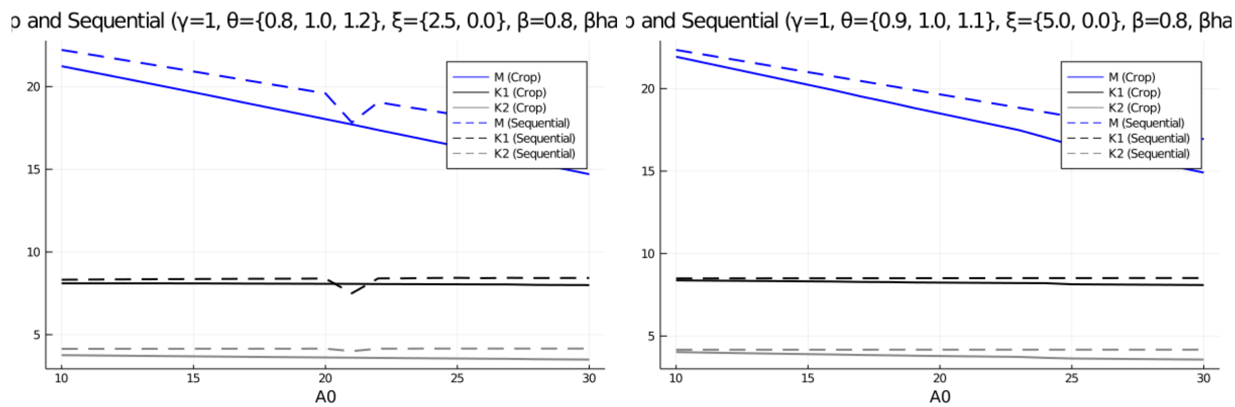

Given $\theta_1 = \theta_2 = 1$, the second investment is lower under the sequential borrowing as borrowers will overinvest under the crop credit, as shown in equation (16). The first investment, on the other hand, differs little between these two credit schemes. The ex ante expected utility is slightly higher under the sequential credit than the crop credit as reported in Appendix Figure 9, even though the latter resulted in higher output values at period 3 due to overinvestment at $t = 2$.

Figure 5 depicts the final credit size $M$ and the investment amounts, $K_1$ and $K_2$ for present-biased borrowers ($\beta = \hat{\beta} = 0.8$). Unlike the case of the time consistent borrowers, the sequential credit resulted in greater credit sizes. At period 0, present-biased borrowers expect that their future selves will overconsume, and hence have incentives to reduce credit size to prevent the overconsump-

[34] The analogous figures when $\gamma = 2$ are reported in the Appendix A.3.

tion under the crop credit. However, under sequential credit, she can constrain her consumption at period 1 by adjusting $M$ and $\alpha$, and can ensure that period-2 selves finance the second investment by the sequential disbursement. She can also constrain the period-2 selves through the choice of $M$ and $\alpha$ at period 0. This commitment function of the sequential credit results in the larger investment at period 2. Further, expecting the larger $K_2$ and resultant increase in the marginal product of the first investment, $F_1'(K_1, K_2)$, the borrower will make a larger investment at period 1 as well compared to the crop credit. This may explain we observe the larger first investment amount in Table 6.

Figure 5: Optimal level of $(M, K_1, K_2)$ for present-biased borrowers under crop credit and sequential credit

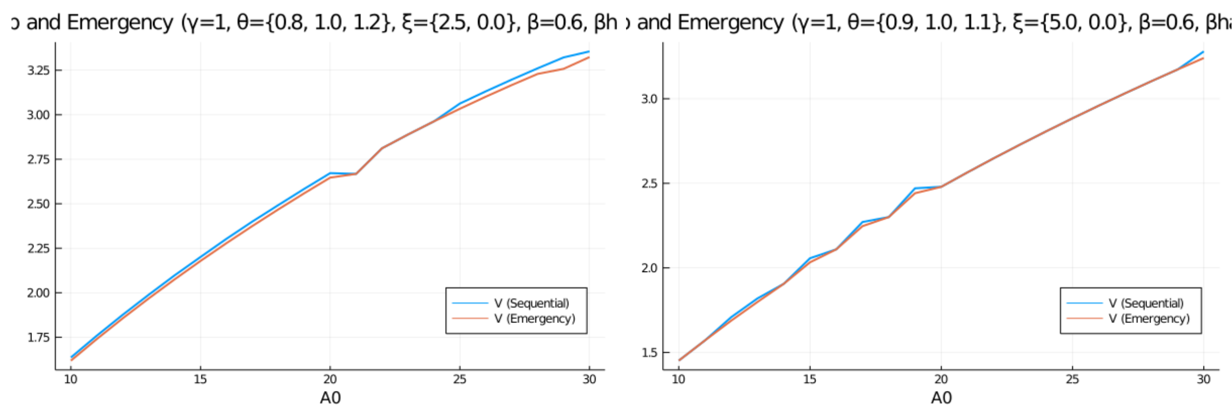



We have argued the advantage of the sequential credit over the traditional regular repayment credit and crop credit for the agricultural households. The sequential disbursement functions well for present-biased farmers when the investment decision is also sequential. Credit schemes that are similar to the sequential credit is the emergency loans and credit lines. Actually if a credit line allows borrowers to make the disbursement schedule, it is virtually the same as the sequential credit we discussed here. However, such credit line program is rare in microcredit, and the credit line program and the emergency loans can let present-biased borrowers borrow too much. We can interpret these credit line and emergency loans as the credit program that replace the constraint on second disbursement (18), $M_2 \leq (1-\alpha)M$, by some exogenously determined upper bound $\overline{M}_2$, $\overline{M}_2$. While the sequential credit allows borrowers to set the upper limit $(1-\alpha)M$, the emergency loans do not. Figure 6 shows the expected value at $t = 0$ for the sequential credit and the emergency loans where there is no limit on $\overline{M}_2$ for present-biased borrowers ($\beta = \hat{\beta} = 0.6$).[35] It shows that the

[35] If present bias is not so serious as in the case of $\beta = \hat{\beta} = 0.8$, then $M_2 \leq (1-\alpha)M$ under the sequential credit does not bind, and hence the outcome is similar between the sequential credit and the emergency loans. When we consider partially naive borrowers where $\beta = 06, \hat{\beta} = 0.8$, the results are quite similar to that of Figure 6.

sequential credit offers the higher expected utility at $t = 0$, as it prevents overborrowing. These results suggest that the sequential credit is a promising lending scheme for agricultural households who do not have steady income flow.

Figure 6: Ax ante expected utility of present-biased borrowers under sequential credit and emergency credit




## 6 Conclusion

We investigated the crop credit and the sequential credit in which the repayment schedule and disbursement schedule were modified to match the income flow of farmers. These products increased the uptake rate without worsening the default rate. Further, the sequential credit increased the second investment for present-bias borrowers, as it could work as a commitment device. The sequential credit also reduced the loan size, which we interpret was due to the option value. Under the sequential credit, borrowers could adjust the final loan size after observing productivity shocks and expenditure shocks. Hence borrowers did not have to borrow additional amount as a buffer, which resulted in smaller credit size and increased investment.

The argument of the option value is related to the emergency loans and credit lines. If such loans are available, borrowers can adjust the total loan size after observing the shocks. Hence the availability of emergency loans can increase the uptake rate of the original microcredit product, and also reduce the total loan size. However, these loans might exacerbate the problem of over-borrowing among present-biased borrowers. Our numerical analysis shows that sequential credit might outperform the emergency loans and credit lines as it can offer the commitment on the total borrowing amount. Understanding the borrowers' economic environment and their decision making process is a key to improve the design of microlending programs.

Since modifying the repayment and disbursement schedules did not change the repayment performance, we did not consider the issues relating to asymmetric information such as adverse selection and moral hazard. Incorporating them into the model of the sequential investment decision is left for the future research.

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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

$$\begin{aligned}
\max_{c_1,c_2,K_1,K_2,M} \quad & u(c_1)+u(c_2)+u(c_3) \\
\text{s.t.} \quad & c_1+K_1 \le A_1 \\
& c_2+K_2 = A_2 && \text{(A.1)} \\
& c_3 = F(K_1,K_2) - \left(1-\frac{2\pi}{3}\right)(1+r)M && \text{(A.2)} \\
& M \le \overline{M},
\end{aligned}$$

where $A_1$ and $A_2$ are the resources available for consumption and investment at periods 1 and 2, respectively:

$$A_1 = A_0 + \alpha M - \frac{\pi}{3}(1+r)M, \tag{A.3}$$

$$A_2 = A_1 - c_1 - K_1 + (1-\alpha)M - \frac{\pi}{3}(1+r)M. \tag{A.4}$$

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 credit size $M$ are chosen, there is no decision to be made at $t=3$. Hence start with the problem at $t=2$, where she chooses $(c_2, K_2)$. By using the equations (A.1) and (A.2), we can write the value function at $t=2$ as

$$V_2(A_2,K_1,M) = \max_{K_2}\ u\left(A_2-K_2\right) + u\left(F(K_1,K_2) - \left(1-\frac{2\pi}{3}\right)(1+r)M\right) \tag{A.5}$$

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

$$u'(c_2^*) = F_2'(K_1,K_2^*)u'(c_3^*), \tag{A.6}$$

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

$$\frac{\partial V_2}{\partial A_2} = u'(c_2^*) \tag{A.7}$$

$$\frac{\partial V_2}{\partial K_1} = F_1'(K_1,K_2^*)u'(c_3^*) \tag{A.8}$$

$$\frac{\partial V_2}{\partial M} = -\left(1-\frac{2\pi}{3}\right)(1+r)u'(c_3^*).$$

Now consider the problem at $t = 1$. Using the value function (A.5) and the transition equation (A.4), we can write the problem as

$$\begin{aligned}
\max_{c_1, K_1} \quad & u(c_1) + V_2(A_2, K_1, M) \\
\text{s.t.} \quad & c_1 + K_1 \leq A_1 \\
& A_2 = A_1 - c_1 - K_1 + (1-\alpha)M - \frac{\pi}{3}(1+r)M
\end{aligned} \tag{A.9}$$

Note that the constraint (A.9) will not bind as long as $\alpha$ is close to 1.[36] Then we can write the value function as

$$V_1(A_1, M) = \max_{c_1, K_1} \; u(c_1) + V_2\left(A_1 - c_1 - K_1 + (1-\alpha)M - \frac{\pi}{3}(1+r)M, K_1, M\right)$$

The first order conditions 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.7) and (A.8), these conditions reduce to

$$u'(c_1^*) = u'(c_2^*), \tag{A.10}$$
$$u'(c_2^*) = F_1'(K_1^*, K_2^*) u'(c_3^*). \tag{A.11}$$

Equation (A.10) implies

$$c_1^* = c_2^*, \tag{A.12}$$

and combined with equation (A.6), equation (A.11) implies

$$F_1'(K_1^*, K_2^*) = F_2'(K_1^*, K_2^*). \tag{A.13}$$

The partial derivatives of the value function are:

$$\frac{\partial V_1}{\partial A_1} = \frac{\partial V_2}{\partial A_2} = u'(c_2^*) \tag{A.14}$$

$$\frac{\partial V_1}{\partial M} = \left[(1-\alpha) - \frac{\pi}{3}(1+r)\right] \frac{\partial V_2}{\partial A_2} + \frac{\partial V_2}{\partial M} = \left[(1-\alpha) - \frac{\pi}{3}(1+r)\right] u'(c_2^*) - \left(1 - \frac{2\pi}{3}\right)(1+r)u'(c_3^*). \tag{A.15}$$

[36] Suppose the constraint (A.9) binds. Then $A_2 = A_0 - c_1 = K_1 - M_1 + \frac{\pi}{3}(1+r)M$ and

$$c_2 = A_2 + M - K_1 - \frac{2\pi}{3}(1+r)M - K_2 = (1 - M_1)M - K_2 - \frac{\pi}{3}(1+r)M.$$

If $\alpha$ is equal to 1, then $c_2$ is at most zero, which is not compatible with the first order condition (A.6) given the Inada condition.

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

$$\begin{aligned} \max_{M} \quad & V_1(A_1, M) \\ \text{s.t.} \quad & M \leq \overline{M}. \\ & A_1 = A_0 + \alpha M - \frac{\pi}{3}(1+r)M. \end{aligned} \tag{A.16}$$

If the constraint (A.16) does not bind, the first order condition is

$$\left[\alpha - \frac{\pi}{3}(1+r)\right] \frac{\partial V_1}{\partial A_1} + \frac{\partial V_1}{\partial M} = 0,$$

which can be rewritten by using equations (A.14), (A.15), and (A.6) as

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

where $Q \equiv 1 - \frac{2\pi}{3}(1+r)$. Hence the farmer chooses the credit size $M$ so that

$$F_2'(K_1^*, K_2^*) = 1 + \frac{r}{Q}. \tag{A.17}$$

If $\pi = 0$, then $Q = 1$ and $F_1'(K_1^*, K_2^*) = 1+r$ holds: the farmer borrows the credit until its marginal product equals to its cost. However, if $\pi > 0$ as in the standard microcredit, then $1 + \frac{r}{Q} > 1 + r$, resulting in underinvestment.

To study the effect of the repayment schedule $\pi$, we can apply the comparative statics to the first order conditions (A.6), (A.12), (A.13) and (A.17), and derive

$$\begin{aligned} &\frac{\partial K_1^*}{\partial \pi} < 0, \\ &\frac{\partial K_2^*}{\partial \pi} < 0, \\ &\frac{\partial c_1^*}{\partial \pi} = \frac{\partial c_2^*}{\partial \pi} < 0, \end{aligned}$$

implying that increasing the ratio of installment before the harvest (an increase in $\pi$) will reduce the investment and consumption at $t = 1, 2$. Its impact on the credit size $M$ is undetermined without further assumptions on the utility and production functions even though the investment and consumption decline.[37] Specifically, the effect of $\pi$ on $M$ can be written as

$$\frac{\partial M^*}{\partial \pi} = \frac{1}{Q}\left[\frac{\partial K_1^*}{\partial \pi} + \frac{\partial K_2^*}{\partial \pi} + 2\frac{\partial c_2^*}{\partial \pi} + \frac{2}{3}(1+r)M^*\right].$$

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

$$\begin{aligned} \frac{\partial K_j^*}{\partial \pi} &= \frac{2r(1+r)}{3Q^2} \frac{F_{12}'' - F_{jj}''}{(F_{12}'')^2 - F_{11}''F_{22}''} < 0 \qquad \text{for } j = 1, 2, \\ \frac{\partial c_1^*}{\partial \pi} &= \frac{\partial c_2^*}{\partial \pi} = \frac{2r(1+r)}{3Q}\frac{D_0}{D_1} < 0, \end{aligned}$$

where $D_0 \equiv u'(c_3^*) - (Q+r)u''(c_3^*)M^* > 0$ and $D_1 \equiv Qu''(c_2^*) + 2(Q+r)u''(c_3^*) < 0$. 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

The last term, $\frac{2}{3}(1+r)M^*$, captures the effect of borrowing for repayment – the requirement of installment before the harvest induces borrowers to borrow for installment repayment. Further, by denoting the optimized total utility by $V \equiv u(c_1^*) + u(c_2^*) + u(c_3^*)$, we can also derive

$$\frac{\partial V}{\partial \pi} = \frac{2r(1+r)}{3Q} u'(c_3^*) \left( \frac{2r}{Q} \frac{D_0}{D_1} - M^* \right) < 0, \tag{A.18}$$

where $D_0 > 0$ and $D_1 < 0$ are defined in footnote 37.[38] This suggests that increasing the ratio of installment before the harvest reduces the total utility, and thereby reduces the uptake rate.

Changing the disbursement schedule $\alpha$ does not affect the decisions as long as the budget constraint at $t = 1$, (A.9), does not bind. Further reduction in $\alpha$ will tighten the budget constraint at period 1 and hence will reduce the borrower's welfare.

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derive

$$\frac{\partial M^*}{\partial \pi} = \frac{2r(1+r)}{3Q^2} \left[ \frac{1}{Q} \frac{2F''_{12} - F''_{11} - F''_{22}}{(F''_{12})^2 - F''_{11}F''_{22}} + \frac{2D_0}{D_1} + \frac{Q}{r} M^* \right],$$

whose sign is undetermined without further assumptions. When $M^* = \overline{M}$,

$$\frac{\partial K_j^*}{\partial \pi} = -\frac{1}{3} \frac{(F''_{12} - F''_{jj})(1+r)\overline{M}[u''(c_1^*) + 2F'_1 u''(c_3^*)]}{[(F''_{12})^2 - F''_{11}F''_{22}]u'(c_3^*) + (2F''_{12} - F''_{11} - F''_{22})[u''(c_1^*) + (F'_1)^2 u''(c_3^*)]} < 0 \qquad \text{for } j = 1, 2,$$

$$\frac{\partial c_1^*}{\partial \pi} = \frac{\partial c_2^*}{\partial \pi} = -\frac{(1+r)\overline{M}}{6} \frac{(2F''_{12} - F''_{11} - F''_{22})[u''(c_1^*) + 2F'_1(F'_1 - 1)u''(c_3^*)] - [(F''_{12})^2 - F''_{11}F''_{22}]u'(c_3^*)}{[(F''_{12})^2 - F''_{11}F''_{22}]u'(c_3^*) + (2F''_{12} - F''_{11} - F''_{22})[u''(c_1^*) + (F'_1)^2 u''(c_3^*)]} < 0.$$

[38] Using the result $c_1^* = c_2^*$ and the first order condition $u'(c_2^*) = F'_2(K_1^*, K_2^*)u'(c_3^*)$, we obtain

$$\frac{\partial V}{\partial \pi} = u'(c_1^*)\frac{\partial c_1^*}{\partial \pi} + u'(c_2^*)\frac{\partial c_2^*}{\partial \pi} + u'(c_3^*)\frac{\partial c_3^*}{\partial \pi} = 2F'_2 u'(c_3^*)\frac{\partial c_2^*}{\partial \pi} + u'(c_3^*)\frac{\partial c_3^*}{\partial \pi}.$$

Note that the differentiation of the first order condition stated above by $\pi$ gives

$$u''(c_2^*)\frac{\partial c_2^*}{\partial \pi} = \left[ F''_{12}\frac{\partial K_1^*}{\partial \pi} + F''_{22}\frac{\partial K_2^*}{\partial \pi} \right] u'(c_3^*) + F'_2 u''(c_3^*)\frac{\partial c_3^*}{\partial \pi}.$$

Using this to substitute $\frac{\partial c_3^*}{\partial \pi}$, we can write the expression $\frac{\partial V}{\partial \pi}$ as

$$\frac{\partial V}{\partial \pi} = u'(c_3^*) \left[ 2F'_2 \frac{\partial c_2^*}{\partial \pi} + \frac{u''(c_2^*)\frac{\partial c_2^*}{\partial \pi} - \left[ F''_{12}\frac{\partial K_1^*}{\partial \pi} + F''_{22}\frac{\partial K_2^*}{\partial \pi} \right] u'(c_3^*)}{F'_2 u''(c_3^*)} \right].$$

Further, differentiating equation (A.17) by $\pi$, we can derive

$$F''_{12}\frac{\partial K_1^*}{\partial \pi} + F''_{22}\frac{\partial K_2^*}{\partial \pi} = \frac{2r(1+r)}{3Q^2}.$$

Using this and equation (A.17), we obtain

$$\frac{\partial V}{\partial \pi} = u'(c_3^*) \left[ 2\frac{Q+r}{Q}\frac{\partial c_2^*}{\partial \pi} + \frac{Q}{Q+r} \frac{u''(c_2^*)\frac{\partial c_2^*}{\partial \pi} - \frac{2r(1+r)}{3Q^2}u'(c_3^*)}{u''(c_3^*)} \right].$$

Using $\frac{\partial c_2^*}{\partial \pi} = \frac{2r(1+r)}{3Q}\frac{D_0}{D_1}$ and arranging terms gives the expression (A.18).

### A.1.2 A present-biased borrower

For a time consistent borrower, the disbursement schedule $\alpha$ will not affect the borrower's decision unless $\alpha$ is sufficiently small so that the period-1 budget constraint (A.9) binds. She will not benefit from reducing $\alpha$ and hence if she can choose the level of $\alpha$, she will set $\alpha = 1$ or sufficiently high so that the period-1 budget constraint does not bind. But if she has present-biased preference and is aware of it, then she might want to set $\alpha = 1$ low to constrain her decision at period 1.

Here we consider a quasi-hyperbolic discounter who discount the future by $\beta$, and treat $\alpha$ as the decision variable to investigate if she opts to choose a low value of $\alpha$ to make the period-1 budget constraint bind. For the ease of analysis, we use $M_1 \equiv \alpha M$ instead of $\alpha$ in the following expressions.[39] She has a belief that future selves will discount the future by $\hat{\beta} \in [\beta, 1]$. If $\hat{\beta} = \beta$, she correctly predicts her present biasedness. If $\hat{\beta} = 1$, she is unaware of her present bias (naivete).

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

$$A_1 = A_0 + M_1,$$
$$A_2 = A_1 - c_1 - K_1 + M - M_1.$$

Write the discounted value function that her 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 $\beta$ along with the state variables $(A_2, K_1, M)$. The first order condition is

$$u'(c_2^*) = \beta F_2'(K_1, K_2^*) u'(c_3^*), \tag{A.19}$$

where $c_3^* = F(K_1, K_2^*) - (1+r)M$. This gives the decision rules for $c_2$ and $K_2$ given the state variables $(A_2, K_1, M)$ and the present biasedness $\beta$ : $c_2^* = c_2(A_2, K_1, M; \beta)$ 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

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

[39] In the original specification, the choice of $M$ affects both of the budget constraints at $t = 1$ and $t = 2$. Using This $M_1$ instead of $\alpha$ makes the analysis easier because then the choices of $M_1$ and $M$ separately affect the budget constraint at $t = 1$ and $t = 2$, respectively.

Now consider the problem at $t = 1$, when she believes that her 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 using $A_1$, which makes the analysis simpler. Her discounted value function is

$$W_1(A_0, M, M_1; \beta, \hat{\beta}) = \max_{c_1, K_1} \quad u(c_1) + \beta \hat{V}_2(A_2, K_1, M; \hat{\beta})$$
$$\text{s.t.} \quad c_1 + K_1 \leq A_0 + M_1 \tag{A.20}$$
$$A_2 = A_0 + M - c_1 - K_1$$

where

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

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

If the constraint (A.20) does not bind, then the first order conditions are

$$u'(c_1^*) - \beta \frac{\partial \hat{V}_2(A_2^*, K_1^*, M; \hat{\beta})}{\partial A_2} = 0 \tag{A.21}$$
$$-\beta \frac{\partial \hat{V}_2(A_2^*, K_1^*, M; \hat{\beta})}{\partial A_2} + \beta \frac{\partial \hat{V}_2(A_2^*, K_1^*, M; \hat{\beta})}{\partial K_1} = 0, \tag{A.22}$$

where $A_2^* = A_1 - c_1^* - K_1^* + M - M_1$ is the level of $A_2$ on the optimal path.

If the constraint (A.20) binds, she maximizes $u(A_1 - K_1) + \beta \hat{V}_2(M - M_1, K_1; \hat{\beta})$, which gives the first order condition

$$-u'(c_1^*) + \beta \frac{\partial \hat{V}_2(M - M_1, K_1^*, M; \hat{\beta})}{\partial K_1} = 0 \tag{A.23}$$

that balances the current cost of reducing $c_1$ and the future benefit of increasing $K_1$. Note that combining equations (A.22) and (A.21) gives us the similar equation to (A.23). No matter whether the constraint (A.20) binds or not, the borrower balances the marginal benefit of $c_1$ and $K_1$.

To derive $\frac{\partial \hat{V}_2(A_2^*, K_1^*, M; \hat{\beta})}{\partial A_2}$ and $\frac{\partial \hat{V}_2(A_2^*, K_1^*, M; \hat{\beta})}{\partial K_1}$, we exploit the link between $\hat{V}_2(A_2, K_1, M; \hat{\beta})$ and $W_2(A_2, K_1, M; \hat{\beta})$ as in Harris and Laibson (2001). Given the decision rule $c_2^{*(\beta)}$ and $K_2^{*(\hat{\beta})}$, the discounted continuation value $W_2(A_2, K_1, M; \hat{\beta})$ can be 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 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

$$\hat{V}_2(A_2, K_1, M; \hat{\beta}) = \frac{1}{\hat{\beta}} \left[W_2(A_2, K_1, M; \hat{\beta}) - (1 - \hat{\beta}) u(c_2^{*(\hat{\beta})})\right]. \tag{A.24}$$

Then we can derive[40]

$$\frac{\partial \hat{V}_2(A_2,K_1,M;\hat{\beta})}{\partial A_2} = \frac{1}{\hat{\beta}}\left[\frac{\partial W_2(A_2,K_1,M;\hat{\beta})}{\partial A_2} - (1-\hat{\beta})u'(c_2^{*(\beta)})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right]$$
$$= \frac{1}{\hat{\beta}}\left[u'(c_2^*) - (1-\hat{\beta})u'(c_2^*)\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right] \quad \text{(A.25)}$$
$$\frac{\partial \hat{V}_2(A_2,K_1,M;\hat{\beta})}{\partial K_1} = \frac{1}{\hat{\beta}}\left[\frac{\partial W_2(A_2,K_1,M;\hat{\beta})}{\partial K_1} + (1-\hat{\beta})u'(c_2^{*(\beta)})\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}\right]$$
$$= F_1'(K_1,K_2^{*(\beta)})u'(c_3^{*(\beta)}) + \frac{1-\hat{\beta}}{\hat{\beta}}u'(c_2^{*(\beta)})\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}. \quad \text{(A.26)}$$

Using equation (A.26), the first order condition (A.23) is rewritten as

$$u'(c_1^*) = \beta F_1'(K_1^*,K_2^{*(\beta)})u'(c_3^{*(\beta)}) + \beta\frac{1-\hat{\beta}}{\hat{\beta}}u'(c_2^{*(\beta)})\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}. \quad \text{(A.27)}$$

The analogous first order condition for the time-consistent borrowers is $u'(c_1^*) = F_1'(K_1^*,K_2^*)u'(c_3^*)$, directly derived by (A.10) and (A.11). The first term in the right hand side of equation (A.27), $\beta F_1'(K_1^*,K_2^*)$, is the discounted future benefit of the first investment. Present bias ($\beta < 1$) works to increase the consumption at $t = 1$. The second term, $\beta\frac{1-\hat{\beta}}{\hat{\beta}}u'(c_2^{*(\beta)})\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}$, appears if the borrower understands her present bias ($\hat{\beta} < 1$). When making the consumption and investment decision at $t = 1$, she takes into account its influence on her future-self decision. As noted in footnote 40, $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}$ is negative under plausible parameter values. In this case, being aware of own present bias will further exacerbate the overconsumption at $t = 1$, as she expects that her future self will invest more if current self invests less.

When the constraint (A.20) binds, equations (A.27) and (A.20) governs the decision rules for $c_1$ and $K_1$, which depend on the true $\beta$ and her belief $\hat{\beta}$. When the constraint (A.20) does not bind

[40] By differentiating equation (A.19), we can derive the partial derivatives $\frac{\partial K_2^{*(\hat{\beta})}}{\partial A_2}$ and $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}$ as follows:

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

where $D_2 \equiv u''(c_2^{*(\hat{\beta})}) + \hat{\beta}(F_2')^2u''(c_3^{*(\hat{\beta})}) + \hat{\beta}F_{22}''u'(c_3^{*(\hat{\beta})}) < 0$. Comparing the enumerator and denominator directly shows $\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} < 1$. Further, 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 effects depend 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 $F_1'F_2'u''(c_3)+F_{12}''u'(c_3) = F_{12}''c_3^{-(1+\gamma)}\left[(1-\gamma)Y - (1+r)M\right]$. The parameter $\gamma$ governs the intertemporal substitution, and most empirical literature on the intertemporal substitution found $\gamma > 1$ (Ogaki et al., 1996; Yogo, 2004), in which case $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1} < 0$.

(i.e., when $M_1$ is large), the first order condition (A.21) needs to be satisfied as well. Substituting equation (A.25) into this condition gives

$$u'(c_1^*) = \left[1 - (1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right] \frac{\beta}{\hat{\beta}} u'(c_2^{*(\hat{\beta})}). \tag{A.28}$$

If she is naivete ($\hat{\beta} = 1$), this reduces to $u'(c_1^*) = \beta u'(c_2^{*(\hat{\beta})})$, implying the overconsumption at $t = 1$. When she is sophisticated, she takes into account the prediction that her savings today (increasing $A_2$) will increase the consumption at $t = 2$. Since $\beta < \left[1 - (1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right] \frac{\beta}{\hat{\beta}} < 1$,[41] sophisticated borrowers will also overconsume but by less degree compared to the naivete. We denote the decision rules for $c_1$ and $K_1$ by $c_1^{*(\beta,\hat{\beta})} \equiv c_1(A_0, M, M_1; \beta, \hat{\beta})$ and $K_1^{*(\beta,\hat{\beta})} \equiv K_1(A_0, M, M_1; \beta, \hat{\beta})$

With these decision rule, the discounted value function can be written as

$$W_1(A_0, M, M_1; \beta, \hat{\beta}) = u(c_1^{*(\beta,\hat{\beta})}) + \beta \hat{V}_2(A_0 + M - c_1^{*(\beta,\hat{\beta})} - K_1^{*(\beta,\hat{\beta})}, K_1^{*(\beta,\hat{\beta})}, M; \hat{\beta}), \tag{A.29}$$

and we can derive the partial derivatives of $W_1(A_1, M, M_1; \beta, \hat{\beta})$ as

$$\frac{\partial W_1(A_0, M, M_1; \beta, \hat{\beta})}{\partial A_1} = u'(c_1^{*(\beta,\hat{\beta})}) \tag{A.30}$$

$$\frac{\partial W_1(A_0, M, M_1; \beta, \hat{\beta})}{\partial M} = u'(c_1^{*(\beta,\hat{\beta})}) - \beta u'(c_3^{*(\beta,\hat{\beta})}) \left[1 + r - (1-\hat{\beta}) F_2' \frac{\partial K_2^{*(\beta,\hat{\beta})}}{\partial M}\right] \tag{A.31}$$

$$\frac{\partial W_1(A_0, M, M_1; \beta, \hat{\beta})}{\partial M_1} = -u'(c_1^{*(\beta,\hat{\beta})}). \tag{A.32}$$

Now consider the problem at $t = 0$. By choosing sufficiently low $M_1$, she can constrain her decision at $t = 1$. If she makes the constraint (A.20) bind, then $A_2 = M - M_1$. With her belief $\hat{\beta}$, she maximizes $\beta \left[u(c_1^{*(\hat{\beta},\hat{\beta})}) + \hat{V}_2\left(M - M_1, K_1^{*(\hat{\beta},\hat{\beta})}, M\right)\right]$. Using the analogous argument to equation (A.24), the maximization problem can be written as

$$\max_{M \le \overline{M},\ M_1 \le M} \quad W_1(A_0, M, M_1; \hat{\beta}, \hat{\beta}) - (1-\hat{\beta}) u(c_1^{*(\hat{\beta},\hat{\beta})}).$$

The first order conditions for $M$ and $M_1$ are

$$\frac{\partial W_1(A_0, M, M_1; \hat{\beta}, \hat{\beta})}{\partial M} - (1-\hat{\beta}) u'(c_1^{*(\hat{\beta},\hat{\beta})}) \frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M} = 0 \tag{A.33}$$

$$\frac{\partial W_1(A_1, M, M_1; \hat{\beta}, \hat{\beta})}{\partial M_1} - (1-\hat{\beta}) u'(c_1^{*(\hat{\beta},\hat{\beta})}) \frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M} = 0 \tag{A.34}$$

[41] The first inequality holds because

$$\left[1 - (1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right] \frac{\beta}{\hat{\beta}} - \beta = \frac{\beta}{\hat{\beta}} \left[1 - (1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} - \hat{\beta}\right] = \frac{\beta}{\hat{\beta}} (1-\hat{\beta}) \left(1 - \frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right) > 0,$$

where the last inequality follows from $\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} \le 1$ that were derived in footnote 40.

respectively. The credit size chosen under the standard credit is determined by equation (A.33) with $M_1 = M$.

Note that when the budget constraint (A.20) does not bind, $\frac{\partial W_1(A_1,M,M_1;\hat{\beta},\hat{\beta})}{\partial M_1} = 0$ and the left hand side of the first order condition (A.34) becomes

$$-(1-\hat{\beta})u'(c_1^{*(\hat{\beta},\hat{\beta})})\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M}. \tag{A.35}$$

Now consider the lowest value of $M_1$, $\underline{M}_1$, such that the budget constraint(A.20) does not bind. At this point, decreasing $M_1$ will increase the value of expression (A.35), and hence, the total utility increases. This implies taht a present-biased borrower will benefit from setting $M_1$ low as a commitment device.

With the budget constraint (A.20) binding, the first order condition (A.34) becomes

$$\left[1-(1-\hat{\beta})\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1}\right]u'(c_1^{*(\hat{\beta},\hat{\beta})}) = \left[1-(1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right]u'(c_2^{*(\hat{\beta})}). \tag{A.36}$$

which makes the consumption profile $(c_1^*, c_2^*)$ smoother than the case when the the budget constraint (A.20) binds as stated in equation (A.28).

However, the effects of the sequential credit on the second investment is ambiguous. After some algebra, we can write the first order condition (A.33) with the budget constraint (A.20) binding as

$$F_2'\left[1-(1-\hat{\beta})\left\{\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} - \frac{\partial K_2^{*(\hat{\beta})}}{\partial M} + (1-\hat{\beta})\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1}\right\}\right] - (1-\hat{\beta})F_1'\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1} = 1+r. \tag{A.37}$$

On the other hand, under the crop credit, the budget constraint (A.20) will not bind and the first order condition (A.33) implies

$$F_2'\left[1-(1-\hat{\beta})\left\{\frac{\partial K_2^{*(\hat{\beta})}}{\partial A_2} - \frac{\partial K_2^{*(\hat{\beta})}}{\partial M} - (1-\hat{\beta})\frac{\partial K_2^{*(\hat{\beta})}}{\partial A_2}\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1}\right\}\right] - (1-\hat{\beta})F_2'\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1} = 1+r. \tag{A.38}$$

Without further specifying the functional forms, it is unclear in which case $K_2$ will be larger. Under the crop credit, borrowers cannot make the commitment by setting $M_1$ low, but they can still choose larger $M$ to leave enough fund at $t = 2$ for the second investment.

## A.2 Uncertainty and option values

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

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

and the Stone-Geary utility function $u(c_t - \xi_t)$, where $\theta_t > 0$ and $\xi_t \geq 0$ are the productivity shocks and expenditure shocks revealed at the beginning of period $t = 1, 2$, respectively. 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 simplicity, we set $\pi = 0$.

### A.2.1 Crop credit

First we consider the decisions of a time-consistent borrower under the crop credit, where she chooses the credit size $M \leq \bar{M}$ at period 0. The resources available for consumption and investment at periods 1 and 2 are

$$\begin{aligned} A_1 &= A_0 + M \\ A_2 &= A_1 - c_1 - K_1. \end{aligned} \tag{A.39}$$

Consider the maximization problem at period 2, when the borrower knows the realized values of $\theta_1$, $\theta_2$, and $\xi_2$. The value function under the crop credit is

$$\begin{aligned} V_2^C(A_2, K_1, M, \theta_1, \theta_2, \xi_2) = \max_{c_2, K_2} \ & u\left(c_2 - \xi_2\right) + u\left(\theta_1\theta_2 F(K_1, K_2) - (1+r)M + A_2 - c_2 - K_2\right) \\ \text{s.t. } & c_2 + K_2 \leq A_2. \end{aligned} \tag{A.40}$$

Denoting the Lagrange multiplier associated with the constraint (A.40) by $\eta$, the first order conditions are written as

$$u'(c_2^* - \xi_2) - u'(c_3^*) - \eta = 0, \tag{A.41}$$

$$\left[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1\right] u'(c_3^*) - \eta = 0.$$

If the constraint (A.40) does not bind, then the second investment satisfies $\theta_1\theta_2 F_2'(K_1, K_2^*) = 1$. The partial derivatives of the value function are[42]

$$\frac{\partial V_2^C}{\partial A_2} = u'(c_2^* - \xi_2) \tag{A.42}$$

$$\frac{\partial V_2^C}{\partial K_1} = \theta_1\theta_2 F_1'(K_1, K_2^*) u'(c_3^*) \tag{A.43}$$

$$\frac{\partial V_2^C}{\partial M} = -(1+r)u'(c_3^*).$$

[42]Note that whether the constraint (A.40) binds does not matter for the partial derivatives of the value function. When the constraint (A.40) binds, then

$$V_2^C(A_2, K_1, M, \theta_1, \theta_2, \xi_2) = \max_{K_2} \ u\left(A_2 - K_2 \xi_2\right) + u\left(\theta_1\theta_2 F(K_1, K_2) - (1+r)M\right).$$

Then we obtain $\frac{\partial V_2^C}{\partial A_2} = u'(c_2^* - \xi_2)$. When the constraint (A.40) does not bind, then $\frac{\partial V_2^C}{\partial A_2} = u'(c_3^*)$. But in this case $\eta = 0$ and the first order condition A.41 implies $u'(c_2^* - \xi_2) = u'(c_3^*)$, resulting in $\frac{\partial V_2^C}{\partial A_2} = u'(c_3^*)$.

Next consider the problem at period 1, when the borrower only knows the value of $\theta_1$ and $\xi_1$. The value function conditional on $\theta_1$ and $\xi_1$ is

$$V_1^C(A_1, M, \theta_1, \xi_1) = \max_{c_1, K_1} \; u(c_1 - \xi_1) + E\left[V_2^C(A_2, K_1, M, \theta_1, \theta_2, \xi_2)|\theta_1, \xi_1\right]$$

The first order conditions and equations (A.39), (A.42) and (A.43) implies

$$u'(c_1^* - \xi_1) = E[u'(c_2^* - \xi_2)|\theta_1, \xi_1].$$
$$E[u'(c_2^* - \xi_2)|\theta_1, \xi_1] = \theta_1 E[\theta_2 F_1'(K_1^*, K_2^*) u'(c_3^*)|\theta_1, \xi_1].$$

The partial derivatives of the value function are

$$\frac{\partial V_1^C}{\partial A_1} = E\left[\left.\frac{\partial V_2}{\partial A_2}\right|\theta_1, \xi_1\right] = E[u'(c_2^* - \xi_2)|\theta_1, \xi_1] \tag{A.44}$$
$$\frac{\partial V_1^C}{\partial M} = E\left[\left.\frac{\partial V_2}{\partial M}\right|\theta_1, \xi_1\right] = -(1+r)E[u'(c_3^*)|\theta_1, \xi_1]. \tag{A.45}$$

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

$$\begin{aligned} \max_{M} \quad & E[V_1(A_1, M, \theta_1, \xi_1)] \\ \text{s.t.} \quad & M \leq \overline{M}. \\ & A_1 = A_0 + M. \end{aligned} \tag{A.46}$$

If the constraint (A.46) does not bind, the first order condition is

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

which can be rewritten by using equations (A.44) and (A.45) as

$$E[u'(c_2^* - \xi_2)] = (1+r)E[u'(c_3^*)]. \tag{A.47}$$

### A.2.2 Sequential credit

Next consider the decision under the sequential credit. A borrower determines the credit size $M \leq \overline{M}$ and the amount of the first disbursement $M_1 \leq M$ at period 0. At period 2, she can determine the amount of the second disbursement $M_2 \leq M - M_1$ 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, denote

$$A_1 = A_0 + M_1$$
$$\tilde{A}_2 = A_1 - c_1 - K_1.$$

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

$$V_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2) = \max_{c_2, K_2, M_2} u(c_2 - \xi_2) + u\left(\theta_1\theta_2 F(K_1, K_2) - (1+r)(M_1 + M_2) + \tilde{A}_2 + M_2 - c_2 - K_2\right)$$

$$\text{s.t. } c_2 + K_2 \leq \tilde{A}_2 + M_2 \tag{A.48}$$

$$M_2 \leq M - M_1 \tag{A.49}$$

$$M_2 \geq 0 \tag{A.50}$$

Note that $M_1$ enter as the state variable as it affects the upper limit of $M_2$. The first order conditions are

$$u'(c_2^* - \xi_2) - u'(c_3^*) - \eta = 0, \tag{A.51}$$

$$[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1]u'(c_3^*) - \eta = 0, \tag{A.52}$$

$$-ru'(c_3^*) + \eta - \mu + \nu = 0, \tag{A.53}$$

where $\eta$, $\mu$ and $\nu$ are the Lagrange multipliers associated with the constraints (A.48), (A.49) and (A.50), respectively. Note that $\mu$ and $\nu$ cannot take the value of zero simultaneously. Further, equation (A.53) implies $\eta = ru'(c_3^*) + \mu - \nu$, implying $\eta > 0$ 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.53) into equations (A.51) and (A.52), we obtain

$$u'(c_2^* - \xi_2) = (1+r)u'(c_3^*) + \mu - \nu,$$

$$[\theta_1\theta_2 F_2'(K_1, K_2^*) - (1+r)]u'(c_3^*) = \mu - \nu.$$

The partial derivatives of the value function are

$$\frac{\partial V_2^S}{\partial \tilde{A}_2} = u'(c_2^* - \xi_2) \tag{A.54}$$

$$\frac{\partial V_2^S}{\partial K_1} = \theta_1\theta_2 F_1'(K_1, K_2^*)u'(c_3^*) \tag{A.55}$$

$$\frac{\partial V_2^S}{\partial M} = \begin{cases} 0 & \text{if } \mu = 0 \\ u'(c_2^* - \xi_2) - (1+r)u'(c_3^*) & \text{if } \mu > 0 \end{cases} \tag{A.56}$$

$$\frac{\partial V_2^S}{\partial M_1} = \begin{cases} -(1+r)u'(c_3^*) & \text{if } \mu = 0 \\ -u'(c_2^* - \xi_2) & \text{if } \mu > 0 \end{cases}$$

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

$$V_1^S(A_1, M, M_1, \theta_1, \xi_1) = \max_{c_1, K_1} u(c_1 - \xi_1) + E\left[V_2^S(A_1 - c_1 - K_1, K_1, M, M_1, \theta_1, \theta_2, \xi_2) \middle| \theta_1, \xi_1\right]$$

$$\text{s.t. } c_1 + K_1 \leq A_1 \tag{A.57}$$

The first order conditions are

$$u'(c_1^* - \xi_1) - E\left[\left.\frac{\partial V_2^S}{\partial \tilde{A}_2}\right|\theta_1, \xi_1\right] - \lambda = 0$$
$$- E\left[\left.\frac{\partial V_2^S}{\partial \tilde{A}_2}\right|\theta_1, \xi_1\right] + E\left[\left.\frac{\partial V_2^S}{\partial K_1}\right|\theta_1, \xi_1\right] - \lambda = 0,$$

where $\lambda$ is the Lagrange multipliers associated with the constraint (A.57). Using equations (A.54) and (A.55), these conditions reduce to

$$u'(c_1^*) = E\left[u'(c_2^* - \xi_2)|\theta_1, \xi_1\right] + \lambda.$$
$$\theta_1 E\left[\theta_2 F_1'(K_1^*, K_2^*) u'(c_3^*)|\theta_1, \xi_1\right] = E\left[u'(c_2^* - \xi_2)|\theta_1, \xi_1\right] + \lambda.$$

The partial derivatives of the value function are:[43]

$$\frac{\partial V_1^S}{\partial A_1} = \begin{cases} E\left[u'(c_2^* - \xi_2)|\theta_1, \xi_1\right] & \text{if } \lambda = 0 \\ u'(c_1^* - \xi_1) & \text{if } \lambda > 0, \end{cases}$$
$$\frac{\partial V_1^S}{\partial M} = E[\mu|\theta_1, \xi_1]$$
$$\frac{\partial V_1^S}{\partial M_1} = -E\left[u'(c_2^* - \xi_2)|\theta_1, \xi_1\right] - E[\nu|\theta_1, \xi_1].$$

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

$$\max_{M \leq \overline{M}, M_1 \leq M} \quad E[V_1^S(A_1, M, M_1, \theta_1, \xi_1)]$$
$$\text{s.t.} \quad A_1 = A_0 + M_1.$$

The first order condition with respect to $M$ when $M^* \leq \overline{M}$ is $E\left[\frac{\partial V_1^S}{\partial M}\right] = 0$, which reduces to

$$E[\mu] = 0. \tag{A.58}$$

[43] Here we provide the derivation of $\frac{\partial V_1^S}{\partial M}$. 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.56),

$$\begin{aligned} \frac{\partial V_1^S}{\partial M} =& E\left[\left.\frac{\partial V_2^S}{\partial M}\right|\theta_1, \xi_1\right] \\ =& \Pr(\mu = 0|\theta_1, \xi_1) \cdot 0 + \Pr(\mu > 0|\theta_1, \xi_1) E\left[u'(c_2^* - \xi_2) - (1+r)u'(c_3^*)|\theta_1, \xi_1, \mu > 0\right] \\ =& \Pr(\mu > 0|\theta_1, \xi_1) E\left[\mu - \nu|\theta_1, \xi_1, \mu > 0\right] \end{aligned}$$

where the last equation follows from equations (A.51) and (A.53). Using the fact that $\nu = 0$ if $\mu > 0$ and that $E\left[\mu|\theta_1, \xi_1\right] = \Pr(\mu > 0|\theta_1, \xi_1) E\left[\mu|\theta_1, \xi_1, \mu > 0\right]$ if $\mu \geq 0$, we obtain

$$\frac{\partial V_1^S}{\partial M} = E\left[\mu|\theta_1, \xi_1\right].$$

This suggests that she will choose sufficiently high $M$ so that the period-2 constraint $M_2 \leq M - M_1$ never binds. The first order condition 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 credit size at $t = 2$ in case of low productivity).

### A.2.3 Present-biased borrowers under the sequential credit

Now consider the decision of the present-biased borrowers under the sequential credit. The discounted value function for her period-2 self is

$$\begin{aligned}
W_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \beta) = \max_{c_2, K_2, M_2} \; & u(c_2 - \xi_2) + \beta u(c_3) \\
\text{s.t. } & c_2 + K_2 \leq \tilde{A}_2 + M_2 && \text{(A.59)} \\
& M_2 \leq M - M_1 && \text{(A.60)} \\
& M_2 \geq 0 && \text{(A.61)} \\
& c_3 = \theta_1\theta_2 F(K_1, K_2) - (1+r)(M_1 + M_2) + \tilde{A}_2 + M_2 - c_2 + K_2
\end{aligned}$$

Analogous to the case of the time consistent borrowers, the first order conditions can be written as

$$\begin{aligned}
& u'(c_2^* - \xi_2) - \beta u'(c_3^*) + \eta = 0, && \text{(A.62)} \\
& \left[\theta_1\theta_2 F_2'(K_1, K_2^*) - (1+r)\right] \beta u'(c_3^*) - \eta = 0, && \text{(A.63)} \\
& -\beta r u'(c_3^*) + \eta - \mu + \nu = 0, && \text{(A.64)}
\end{aligned}$$

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.60) and (A.61) do not bind, then the second investment will be made optimally. The partial derivatives of the value function are

$$\frac{\partial W_2^S(\cdot;\beta)}{\partial \tilde{A}_2} = u'(c_2^{*(\beta)} - \xi_2) \quad \text{(A.65)}$$

$$\frac{\partial W_2^S(\cdot;\beta)}{\partial K_1} = \theta_1\theta_2 F_1'(K_1, K_2^{*(\beta)}) \beta u'(c_3^{*(\beta)}) \quad \text{(A.66)}$$

$$\frac{\partial W_2^S(\cdot;\beta)}{\partial M} = \begin{cases} 0 & \text{if } \mu = 0 \\ u'(c_2^{*(\beta)} - \xi_2) - (1+r)\beta u'(c_3^{*(\beta)}) & \text{if } \mu > 0 \end{cases} \quad \text{(A.67)}$$

$$\frac{\partial W_2^S(\cdot;\beta)}{\partial \alpha} = \begin{cases} -(1+r)\beta u'(c_3^{*(\beta)}) & \text{if } \mu = 0 \\ -u'(c_2^{*(\beta)} - \xi_2) & \text{if } \mu > 0 \end{cases} \quad \text{(A.68)}$$

Now consider the period-1 problem. With her present-bias parameter $\beta$ and her perception on it $\hat{\beta}$, the value function at the period-1 decision maker is written as

$$W_1^S(A_1, M, M_1, \theta_1, \xi_1; \beta, \hat{\beta}) = \max_{c_1, K_1} u(c_1 - \xi_1) + \beta E\left[\hat{V}_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \hat{\beta}) \middle| \theta_1, \xi_1\right]$$

$$\text{s.t. } c_1 + K_1 \leq A_1 \tag{A.69}$$

$$\tilde{A}_2 = A_1 - c_1 - K_1$$

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

$$\hat{V}_2^S(\cdot; \hat{\beta}) = u\left(c_2^{*(\beta)} - \xi_2\right) + u\left(\theta_1\theta_2 F(K_1, K_2^{*(\beta)}) - (1+r)(M_1 + M_2^{*(\beta)}) + \tilde{A}_2 + M_2^{*(\beta)} - c_2^{*(\beta)} - K_2^{*(\beta)}\right).$$

The first order conditions are

$$u'(c_1^* - \xi_1) - \beta E\left[\frac{\partial \hat{V}_2^S(\cdot; \hat{\beta})}{\partial \tilde{A}_2} \middle| \theta_1, \xi_1\right] - \lambda = 0, \tag{A.70}$$

$$\beta E\left[-\frac{\partial \hat{V}_2^S(\cdot; \hat{\beta})}{\partial \tilde{A}_2} + \frac{\partial \hat{V}_2^S(\cdot; \hat{\beta})}{\partial K_1} \middle| \theta_1, \xi_1\right] - \lambda = 0, \tag{A.71}$$

where $\lambda$ is the Lagrange multiplier associated with the constraint (A.69). These conditions give

$$u'(c_1^* - \xi_1) = \beta E\left[\frac{\partial \hat{V}_2^S(\cdot; \hat{\beta})}{\partial K_1} \middle| \theta_1, \xi_1\right]. \tag{A.72}$$

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 $W_2^S$:

$$\hat{V}_2^S(\cdot; \hat{\beta}) = \frac{1}{\hat{\beta}}\left[W_2^S(\cdot; \hat{\beta}) - (1 - \hat{\beta})u(c_2^{*(\hat{\beta})} - \xi_2)\right].$$

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

$$\begin{aligned}
\frac{\partial \hat{V}_2(\cdot; \hat{\beta})}{\partial \tilde{A}_2} &= \frac{1}{\hat{\beta}}\left[\frac{\partial W_2^S(\cdot; \hat{\beta})}{\partial \tilde{A}_2} - (1 - \hat{\beta})u'(c_2^{*(\hat{\beta})} - \xi_2)\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2}\right] \\
&= \frac{1}{\hat{\beta}}\left[1 - (1 - \hat{\beta})\frac{\partial c_2^*(\cdot; \hat{\beta})}{\partial \tilde{A}_2}\right] u'(c_2^{*(\hat{\beta})} - \xi_2)
\end{aligned} \tag{A.73}$$

$$\begin{aligned}
\frac{\partial \hat{V}_2(\cdot; \hat{\beta})}{\partial K_1} &= \frac{1}{\hat{\beta}}\left[\frac{\partial W_2^S(\cdot; \hat{\beta})}{\partial K_1} - (1 - \hat{\beta})u'(c_2^{*(\hat{\beta})} - \xi_2)\frac{\partial c_2^{*(\hat{\beta})}}{\partial K_1}\right] \\
&= \theta_1\theta_2 F_1'(K_1, K_2^{*(\hat{\beta})})u'(c_3^{*(\hat{\beta})}) - \frac{1 - \hat{\beta}}{\hat{\beta}}u'(c_2^{*(\hat{\beta})} - \xi_2)\frac{\partial c_2^{*(\hat{\beta})}}{\partial K_1}.
\end{aligned} \tag{A.74}$$

$$\frac{\partial \hat{V}_2(\cdot; \hat{\beta})}{\partial M} = \frac{1}{\hat{\beta}}\left[\frac{\partial W_2^S(\cdot; \hat{\beta})}{\partial M} - (1 - \hat{\beta})u'(c_2^{*(\hat{\beta})} - \xi_2)\frac{\partial c_2^{*(\hat{\beta})}}{\partial M}\right]$$

$$\frac{\partial \hat{V}_2(\cdot; \hat{\beta})}{\partial M_1} = \frac{1}{\hat{\beta}}\left[\frac{\partial W_2^S(\cdot; \hat{\beta})}{\partial M_1} - (1 - \hat{\beta})u'(c_2^{*(\hat{\beta})} - \xi_2)\frac{\partial c_2^{*(\hat{\beta})}}{\partial M_1}\right]$$

Then the first order conditions (A.70) and (A.71) can be written as

$$u'(c_1^{*(\beta,\hat{\beta})}-\xi_1)=\frac{\beta}{\hat{\beta}}E\left[\left\{1-(1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2}\right\}u'(c_2^{*(\hat{\beta})}-\xi_2)\middle|\theta_1,\xi_1\right]+\lambda, \tag{A.75}$$

$$\beta E\left[\theta_1\theta_2F_1'(K_1^*,K_2^{*(\hat{\beta})})u'(c_3^{*(\hat{\beta})})\middle|\theta_1,\xi_1\right]=\frac{\beta}{\hat{\beta}}E\left[\left\{1-(1-\hat{\beta})\left(\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2}-\frac{\partial c_2^{*(\hat{\beta})}}{\partial K_1}\right)\right\}u'(c_2^{*(\hat{\beta})}-\xi_2)\middle|\theta_1,\xi_1\right]+\lambda. \tag{A.76}$$

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

$$\begin{aligned}
\frac{\partial W_1^S(\cdot;\beta,\hat{\beta})}{\partial \tilde{A}_2} &= u'(c_1^{*(\beta,\hat{\beta})}-\xi_1)\\
\frac{\partial W_1^S(\cdot;\beta,\hat{\beta})}{\partial M} &= \frac{\beta}{\hat{\beta}}E\left[\mu-(1-\hat{\beta})u'(c_2^{*(\hat{\beta})}-\xi_2)\frac{\partial c_2^{*(\hat{\beta})}}{\partial M}\middle|\theta_1,\xi_1\right]\\
\frac{\partial W_1^S(\cdot;\beta,\hat{\beta})}{\partial M_1} &= -\frac{\beta}{\hat{\beta}}E\left[u'(c_2^{*(\hat{\beta})}-\xi_2)+\nu+(1-\hat{\beta})u'(c_2^{*(\hat{\beta})}-\xi_2)\frac{\partial c_2^{*(\hat{\beta})}}{\partial M_1}\middle|\theta_1,\xi_1\right]
\end{aligned}$$

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

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

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

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

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

$$E[\mu]=(1-\hat{\beta})E\left[u'(c_1^{*(\hat{\beta},\hat{\beta})}-\xi_1)\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M}+u'(c_2^{*(\hat{\beta})}-\xi_2)\frac{\partial c_2^{*(\hat{\beta})}}{\partial M}\right]$$

and

$$E[\lambda]-E[\nu]=(1-\hat{\beta})E\left[u'(c_1^{*(\hat{\beta},\hat{\beta})}-\xi_1)\left(\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial A_1}+\frac{\partial c_1^{*(\hat{\beta},\hat{\beta})}}{\partial M_1}\right)+u'(c_2^{*(\hat{\beta})}-\xi_2)\left(\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2}+\frac{\partial c_2^{*(\hat{\beta})}}{\partial M_1}\right)\right].$$

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

### 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 hence the curse of dimensionality.

#### A.3.1 Benchmark model

First consider the benchmark model without uncertainty. As stated in equations (6)-(7), the first order conditions are given by

$$c_1^* = c_2^* \tag{A.77}$$

$$F_1'(K_1^*, K_2^*) = F_2'(K_1^*, K_2^*) \tag{A.78}$$

$$u'(c_2^*) = F_2'(K_1^*, K_2^*)u'(c_3^*)$$

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

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.78) implies that $K_2^*$ can be written as a function of $K_1$:

$$K_2^*(K_1) = \frac{\psi_2}{\psi_1} K_1.$$

Then from equation (A.77) combined with equations (4) and (2), we can write 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

$$u'\left(c_2^*(K_1, M)\right) = F_2'\left(K_1, K_2^*(K_1)\right) u'\left(c_3^*(K_1, M)\right)$$

$$F_1'\left(K_1, K_2^*(K_1)\right) = 1 + \frac{r}{Q}$$

This is the nonlinear system equations with two unknowns, which can be solved quite quickly.

### A.3.2 Crop credit under uncertainty

The model with uncertainty can be solved backwardly. For generality, we consider the case of the present-biased borrower. The time consistent borrower is the special case where $\beta = \hat{\beta} = 1$.

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

$$u'(c_2^* - \xi_2) = \beta u'(c_3^*) + \eta \tag{A.79}$$

$$\left[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1\right] \beta u'(c_3^*) = \eta \tag{A.80}$$

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

Suppose the constraint does not bind ($\eta = 0$). With the Cobb-Douglass production function, equation (A.80) implies 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:

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

$$c_3^* = \frac{1}{2}\left[\theta_1\theta_2 F(K_1, K_2^*) - (1+r)M + A_2 - K_2^* - c_2^*\right].$$

If it turns out that $c_2^* + K_2^* > A_2$, then the constraint $c_2 + K_2 \leq A_2$ binds at optimal, 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 $c_3^* = \theta_1\theta_2 F_2(K_1, K_2^*) - (1+r)M$.

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 $\beta$. 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 $\beta$ as

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

The borrower who perceives her 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, she will solve

$$\max_{c_1, K_1} u(c_1 - \xi_1) + \beta E\left[V_2(A_2, K_1, M, \theta_1, \theta_2, \xi_2; \hat{\beta}) | \theta_1, \xi_1\right]$$

subject to $c_1 + K_1 \leq A_1$, where $A_2 = A_1 - c_1 - K_1$ and the expectation is taken over $(\theta_2, \xi_2)$. This can be solved by nonlinear optimization routines, which gives us the decision rules of $c_1$ 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 $\beta$ and her belief on it, $\hat{\beta}$. We can denote the value of being the state $(A_1, M, \theta_1, \xi_1)$ for this borrower as

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

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

Remember that $A_1 = A_0 + M$. Hence the borrower will choose the optimal credit 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 $(\theta_1, \xi_1)$. 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 which are visited through the optimization search routine.

### A.3.3 Sequential credit under uncertainty

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

$$u'(c_2^* - \xi_2) = \beta u'(c_3^*) + \eta \tag{A.81}$$

$$\left[\theta_1 \theta_2 F_2'(K_1, K_2^*) - 1\right] \beta u'(c_3^*) = \eta \tag{A.82}$$

$$- r\beta u'(c_3^*) + \eta - \mu + \nu = 0, \tag{A.83}$$

where $\eta$, $\mu$ and $\nu$ are the Lagrange multipliers associated with the constraints $c_2 + K_2 \leq \tilde{A}_2 + M_2$, $M_2 \leq M - M_1$, and $M_2 \geq 0$, 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 $c_2^* + K_2^* = \tilde{A}_2 + M_2^*$ 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 $c_2^* + K_2^* < \tilde{A}_2$ and $M_2^* = 0$. In case (iv), $c_2^* + K_2^* = \tilde{A}_2$ and $M_2^* = 0$.

By using (A.83), the conditions (A.81) and (A.82) reduce to

$$u'(c_2^* - \xi_2) = (1 + r)\beta u'(c_3^*) + \mu - \nu, \tag{A.84}$$

$$\left[\theta_1 \theta_2 F_2'(K_1, K_2^*) - (1 + r)\right] \beta u'(c_3^*) = \mu - \nu, \tag{A.85}$$

First consider case (i). With the Cobb-Douglass production function, equation (A.85) 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

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

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

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

If $M_2^*$ derived above exceeds $(1-M_1)$, then it corresponds to the 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

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

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

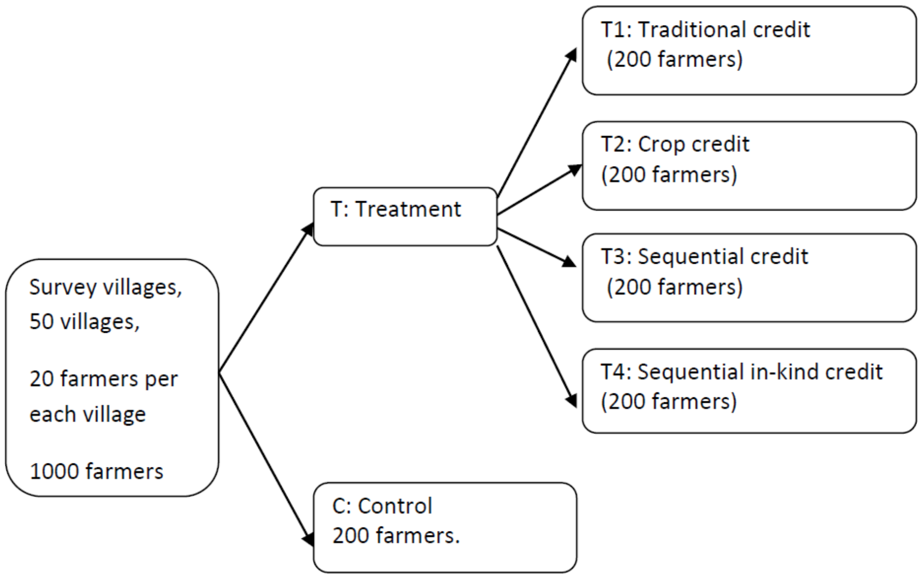
If, on the other hand, $M_2^*$ derived above is negative, then the optimal $M_2$ is 0, as in cases (iii) or (iv). Case (iii) is similar to the crop credit when $\eta = 0$, and case (iv) is analogous to the crop credit with $\eta > 0$.

Once we obtain the decision rules for $K_2$, $M_2$, $c_2$ and $c_3$ as a 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 the crop credit described above, except that the borrower chooses not only the level of credit $M$ but also the amount of the first disbursement $M_1$ at $t = 0$. Denote by $\underline{M}_1$ the lowest value of $M_1$ such that the budget constraint at $t = 1$ does not bind, i.e., $c_1^{*N(\hat{\beta},\hat{\beta})} + K_1^{*N(\hat{\beta},\hat{\beta})} = A_0 + \underline{M}_1$ where $c_1^{*N(\hat{\beta},\hat{\beta})}$ and $K_1^{*N(\hat{\beta},\hat{\beta})}$ are the values of $c_1$ and $K_1$ that would be selected under 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, the utility function will be flat for $M_1 > \underline{M}_1$, which causes the failure in the optimization routine. To deal with this problem, first we derive $c_1^{*N(\hat{\beta},\hat{\beta})}$ and $K_1^{*N(\hat{\beta},\hat{\beta})}$ to obtain $\underline{M}_1$, and conduct the optimization routine over the domain of $(0, \underline{M}_1)$.

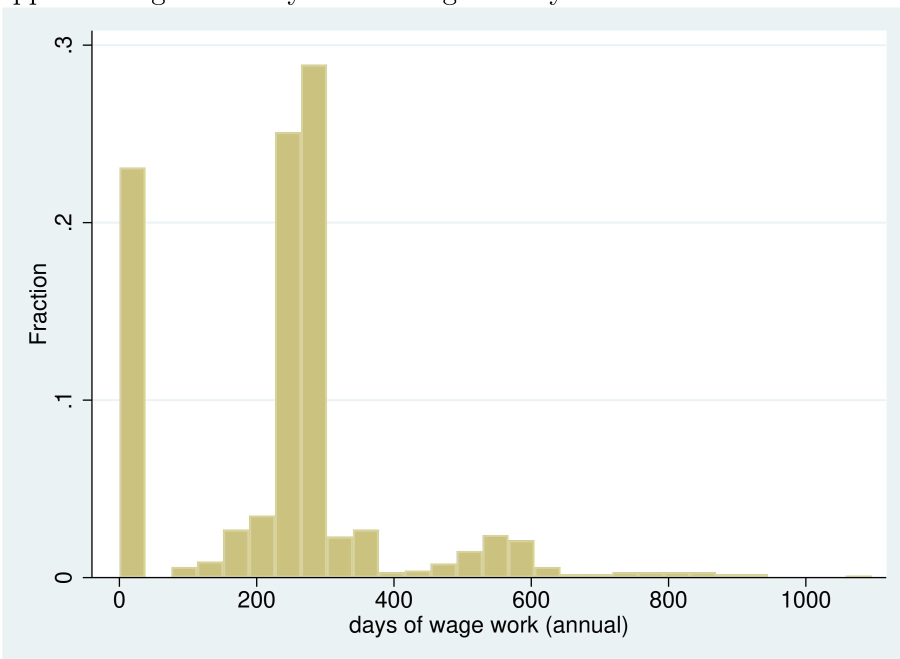
The emergency credit virtually corresponds to the case where the constraint $M_2 \leq M - M_1$ is not imposed, since in the emergency credit, borrowers does not constrain the size of the available credit at later stages.

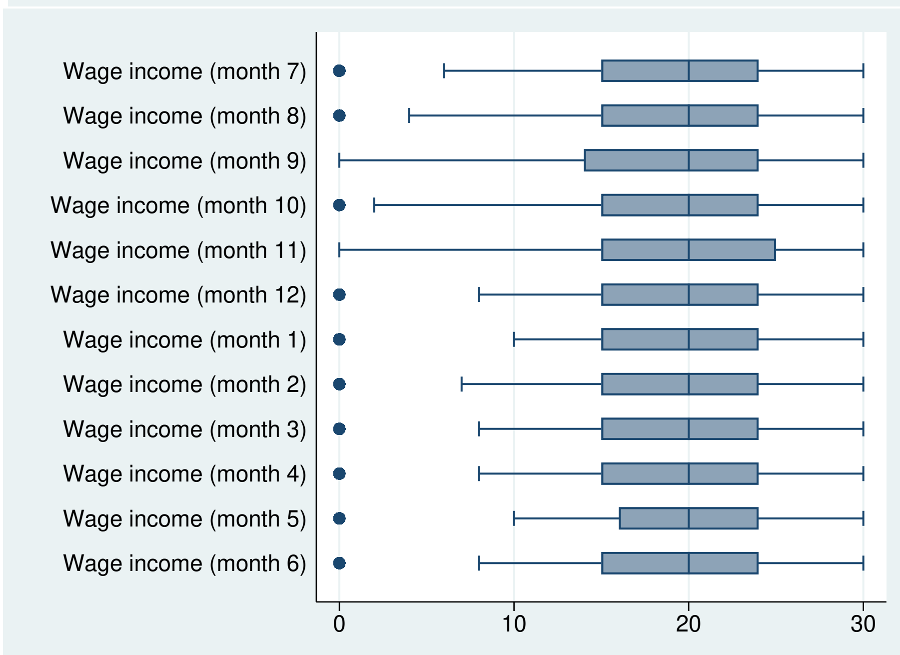
## A.4 Appendix Figures and Tables

Appendix Figure 1: Design of the experiment

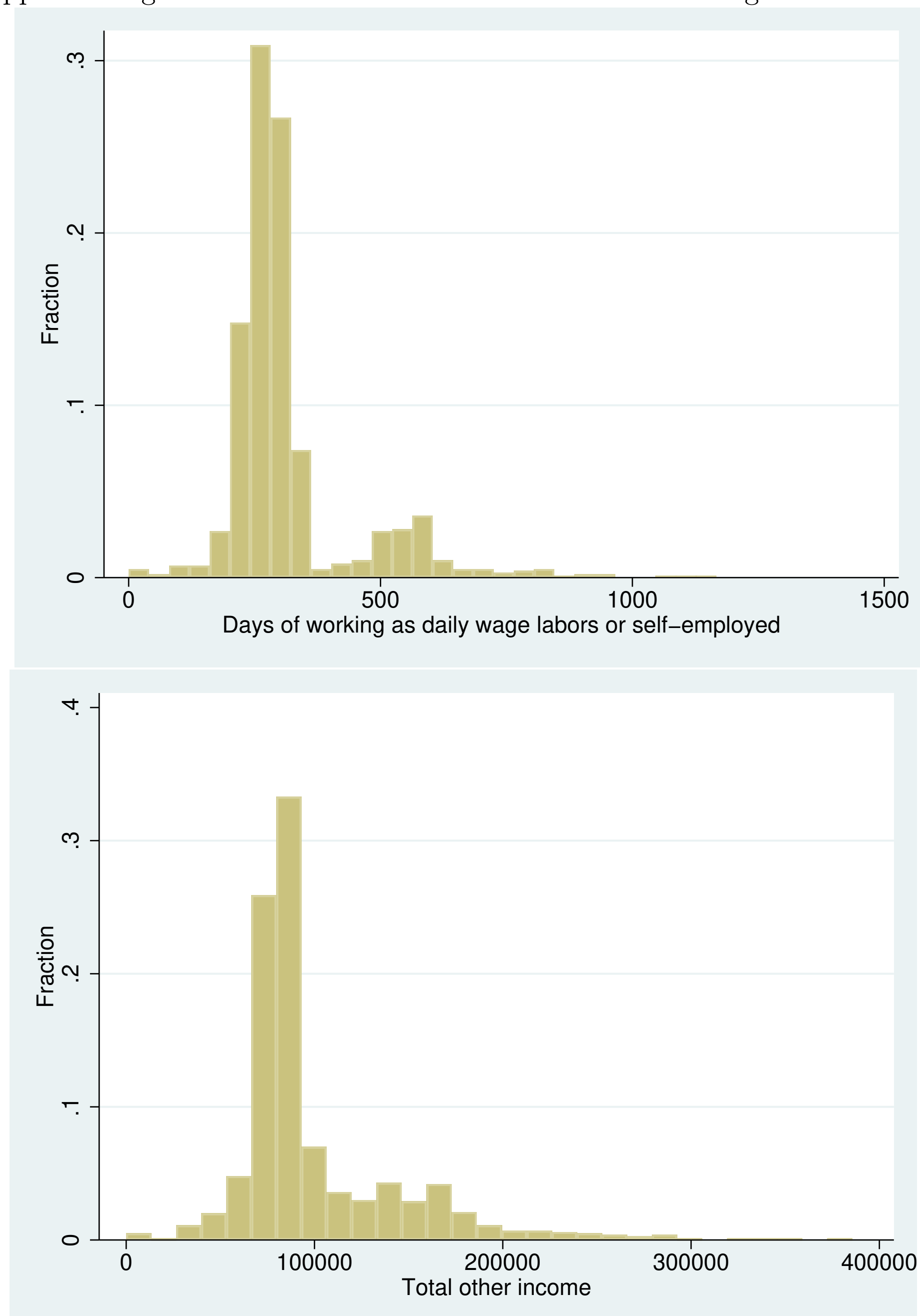


Appendix Figure 2: Days of working as daily labor in the last 12 months

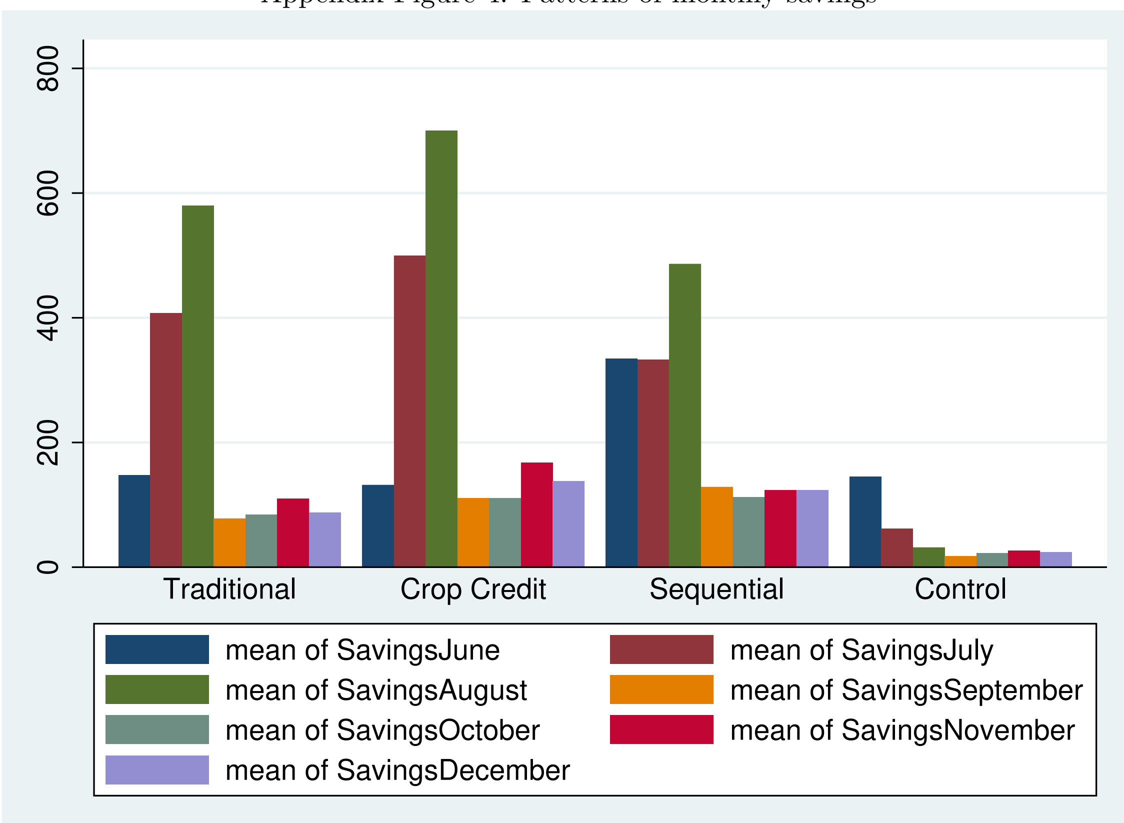


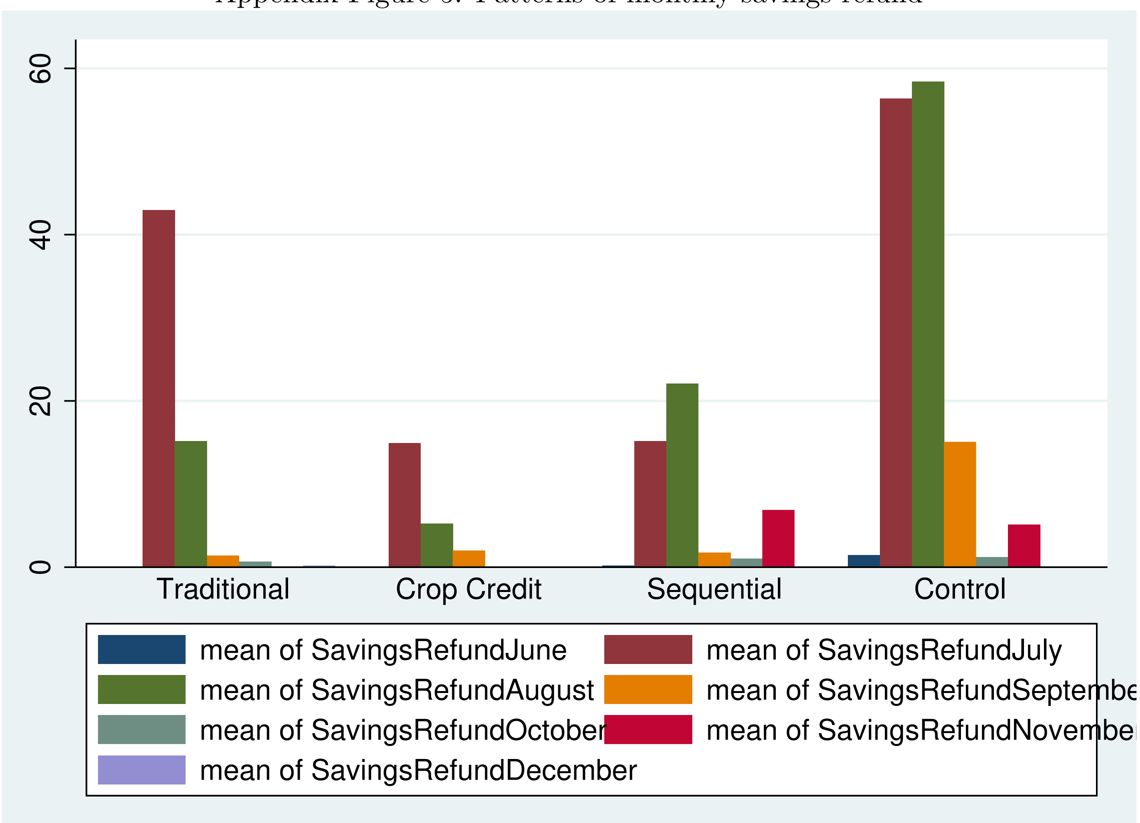
Appendix Figure 3: Total income sources other than farming at the baseline



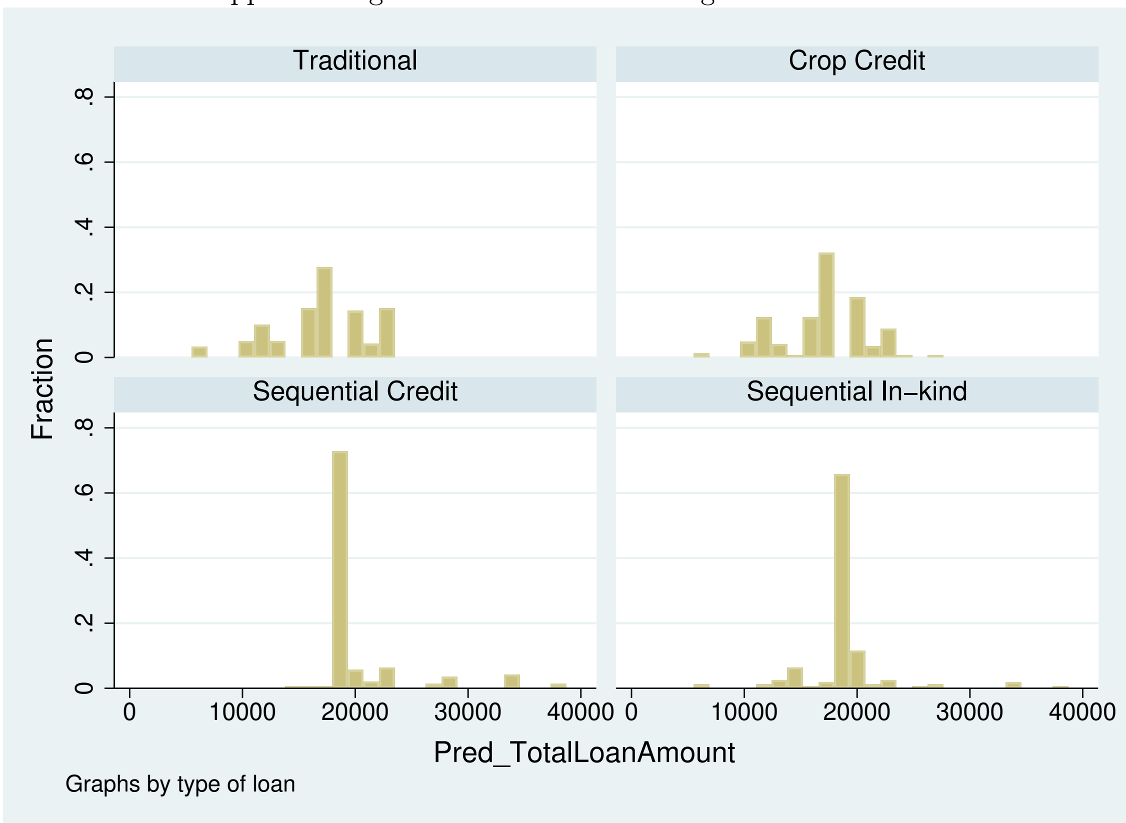
Appendix Figure 4: Patterns of monthly savings



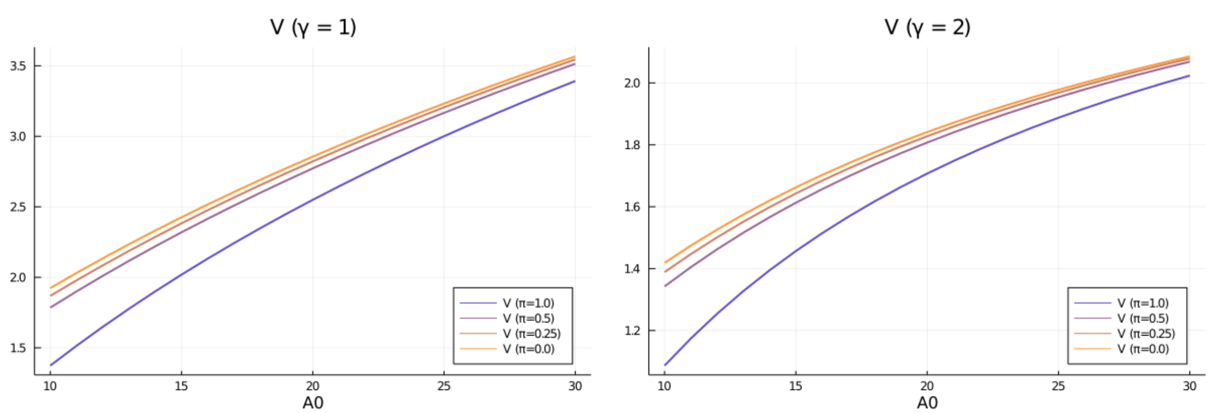
Appendix Figure 5: Patterns of monthly savings refund



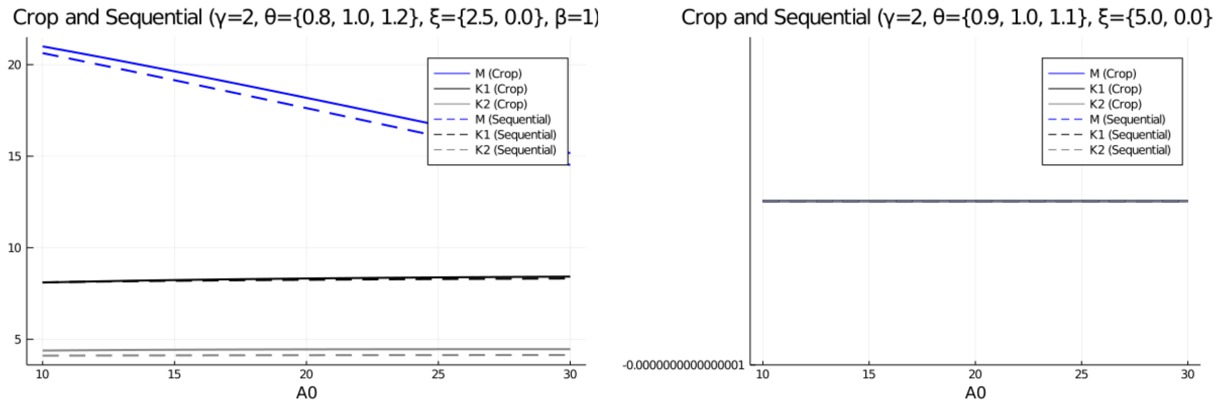
Appendix Figure 6: Distribution of original loan amount



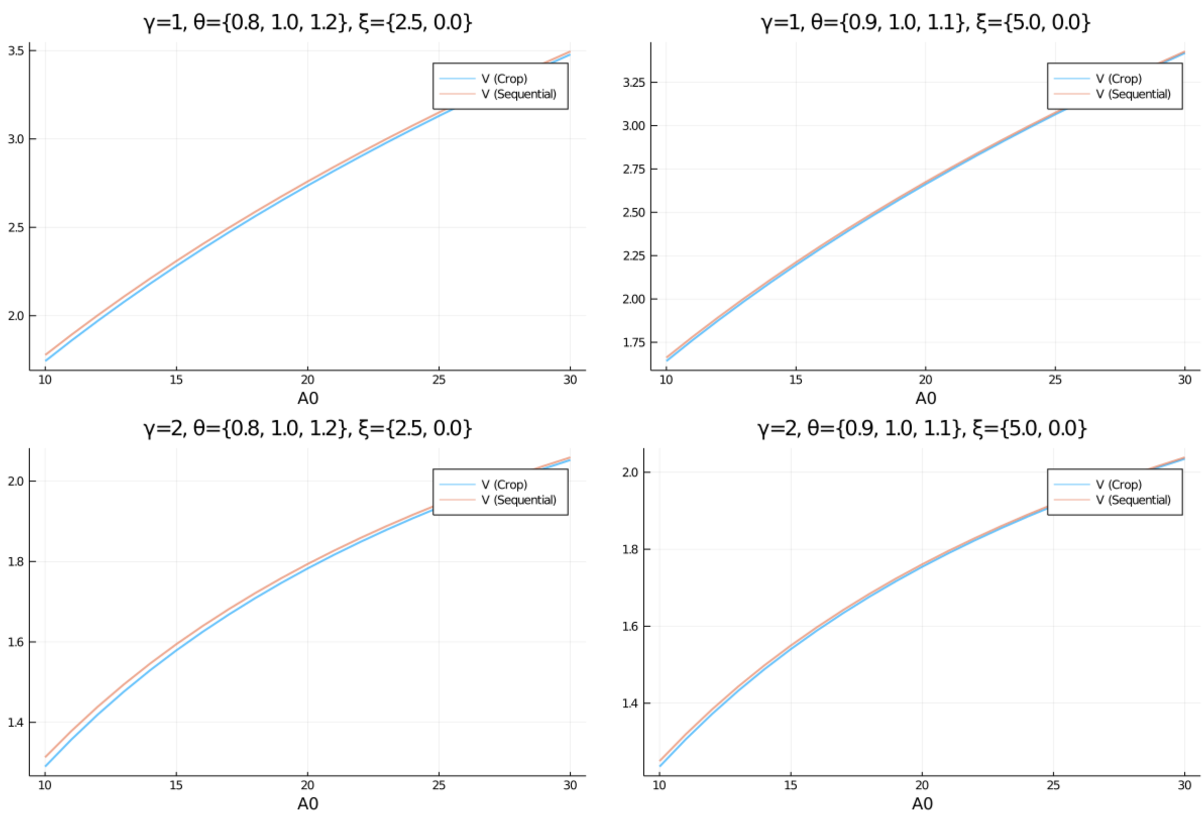

Appendix Figure 7: Value at the initial stage under different value of $\pi$: No uncertainty



Appendix Figure 8: Optimal level of $(M, K_1, K_2)$ under crop credit and sequential credit when $\gamma = 2$




Appendix Figure 9: Ex ante expected utility under crop credit and sequential credit



## Appendix Table 1: Borrowings

| | (1) Borrowing | (2) Borrowing | (3) Non-MFI Borrowing | (4) Non-MFI Borrowing | (5) Borrowing from other MFIs | (6) Borrowing from other MFIs |
|---|---|---|---|---|---|---|
| Traditional | -7.824 | -23.178 | -14.615 | -37.149 | 6.108 | 15.570 |
| | (32.203) | (42.568) | (31.225) | (40.796) | (7.233) | (15.868) |
| Crop Credit | 10.006 | 24.975 | 0.924 | 33.684 | 9.737 | -8.175 |
| | (35.549) | (81.911) | (35.005) | (80.593) | (7.913) | (14.562) |
| Sequential | 102.664 | -20.804 | -10.448 | -8.292 | 111.384 | -18.083 |
| | (115.717) | (43.997) | (20.556) | (37.885) | (112.704) | (19.161) |
| In-kind | -57.864 | 119.743 | 14.067 | 15.220 | -68.650 | 113.112 |
| | (113.953) | (122.028) | (20.244) | (43.150) | (107.541) | (91.599) |
| PB=1 | | -17.585 | | -15.914 | | -3.674 |
| | | (39.551) | | (37.948) | | (12.005) |
| Traditional × PB=1 | | 25.826 | | 35.409 | | -13.159 |
| | | (44.122) | | (44.866) | | (17.684) |
| Crop Credit × PB=1 | | -19.440 | | -54.257 | | 34.899 |
| | | (89.717) | | (83.661) | | (32.071) |
| Sequential × PB=1 | | 227.131 | | -5.825 | | 239.295 |
| | | (242.244) | | (48.321) | | (239.726) |
| In-kind × PB=1 | | -316.321 | | -1.524 | | -322.987 |
| | | (271.025) | | (57.126) | | (258.135) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 998 | 986 | 998 | 986 | 998 | 986 |
| Mean_Control | 40.452 | 40.452 | 40.452 | 40.452 | 0.000 | 0.000 |
| Trad_vs_Crop | 0.526 | 0.506 | 0.601 | 0.298 | 0.452 | 0.351 |
| Trad_vs_SeqCash | 0.327 | 0.942 | 0.814 | 0.078 | 0.340 | 0.284 |
| Trad_vs_SeqKind | 0.266 | 0.273 | 0.547 | 0.265 | 0.211 | 0.329 |
| Crop_vs_SeqCash | 0.414 | 0.535 | 0.698 | 0.574 | 0.350 | 0.338 |
| Crop_vs_SeqKind | 0.500 | 0.598 | 0.939 | 0.747 | 0.274 | 0.243 |
| PB_Trad_vs_Crop | | 0.935 | | 0.551 | | 0.223 |
| PB_Trad_vs_SeqC | | 0.368 | | 0.696 | | 0.330 |
| PB_Trad_vs_SeqK | | 0.863 | | 0.973 | | 0.556 |
| PB_Crop_vs_SeqCash | | 0.332 | | 0.758 | | 0.347 |
| PB_Crop_vs_SeqKind | | 0.881 | | 0.402 | | 0.279 |

The table the estimated coefficients of the regression, with standard errors clustered by the village in parentheses. The control variables not reported in the table include the baseline asset level, the baseline outcome variable and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

Appendix Table 2: Cumulative savings with MFI

| | (1)<br>Cumulative savings with MFI | (2)<br>Cumulative savings with MFI:IPW | (3)<br>Cumulative savings with MFI | (4)<br>Cumulative savings with MFI:IPW |
|---|---|---|---|---|
| Crop Credit | 61.727 | 39.004 | 14.005 | -1.984 |
| | (72.151) | (73.500) | (104.176) | (102.388) |
| Sequential | -239.921*** | -239.770*** | -310.706*** | -304.481*** |
| | (72.112) | (72.487) | (88.365) | (89.469) |
| In-kind | -10.620 | -9.777 | 8.474 | 5.396 |
| | (41.735) | (42.571) | (57.505) | (58.311) |
| PB=1 | | | -76.791 | -64.768 |
| | | | (92.692) | (95.148) |
| Crop Credit × PB=1 | | | 87.329 | 73.678 |
| | | | (138.537) | (138.135) |
| Sequential × PB=1 | | | 119.030 | 107.789 |
| | | | (118.713) | (120.370) |
| In-kind × PB=1 | | | -39.651 | -31.911 |
| | | | (90.881) | (91.816) |
| Control | Yes | Yes | Yes | Yes |
| Observations | 560 | 560 | 551 | 551 |
| Mean_Control | 2432.437 | | 2432.437 | |
| Crop_vs_SeqCash | 0.000 | 0.000 | 0.004 | 0.006 |
| Crop_vs_SeqKind | 0.000 | 0.000 | 0.001 | 0.002 |

The table the estimated coefficients of the regression, with standard errors clustered by the village in parentheses. The control variables not reported in the table include the baseline asset level, the baseline outcome variable and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

Appendix Table 3: Default

| | (1) Loans in arrears | (2) Loans in arrears | (3) Default | (4) Default | (5) % of amount yet repaid | (6) % of amount yet repaid |
|---|---|---|---|---|---|---|
| main | | | | | | |
| Crop Credit | -0.077 | -0.074 | 0.064 | 0.073 | 0.190 | 0.199 |
| | (0.086) | (0.084) | (0.084) | (0.089) | (0.345) | (0.340) |
| Sequential | -0.061 | -0.058 | 0.013 | 0.014 | 0.184 | 0.178 |
| | (0.088) | (0.087) | (0.082) | (0.083) | (0.363) | (0.359) |
| In-kind | -0.064 | -0.067 | -0.024 | -0.026 | -0.212 | -0.213 |
| | (0.093) | (0.092) | (0.074) | (0.074) | (0.370) | (0.367) |
| PB=1 | 0.008 | 0.007 | 0.015 | 0.010 | 0.014 | -0.019 |
| | (0.088) | (0.087) | (0.069) | (0.070) | (0.360) | (0.361) |
| Crop Credit × PB=1 | 0.007 | 0.036 | -0.131 | -0.145 | -0.472 | -0.553 |
| | (0.112) | (0.116) | (0.091) | (0.093) | (0.443) | (0.443) |
| Sequential × PB=1 | -0.016 | -0.016 | -0.055 | -0.054 | -0.516 | -0.505 |
| | (0.106) | (0.105) | (0.103) | (0.103) | (0.570) | (0.559) |
| In-kind × PB=1 | 0.024 | 0.024 | 0.000 | 0.005 | 0.366 | 0.393 |
| | (0.116) | (0.116) | (0.084) | (0.084) | (0.482) | (0.482) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 551 | 551 | 551 | 551 | 551 | 551 |
| Mean_Control | 0.588 | | 0.160 | | 4150.241 | |
| Crop_vs_SeqCash | 0.844 | 0.841 | 0.447 | 0.401 | 0.984 | 0.944 |
| Crop_vs_SeqKind | 0.617 | 0.592 | 0.233 | 0.195 | 0.460 | 0.413 |
| PB_Trad_vs_Crop | 0.312 | 0.633 | 0.178 | 0.162 | | |
| PB_Trad_vs_SeqC | 0.298 | 0.317 | 0.518 | 0.524 | | |
| PB_Trad_vs_SeqK | 0.152 | 0.145 | 0.136 | 0.157 | | |
| PB_Crop_vs_SeqC | 0.924 | 0.633 | 0.579 | 0.483 | | |
| PB_Crop_vs_SeqK | 0.473 | 0.293 | 0.967 | 0.786 | | |

The table the estimated coefficients of the regression, with standard errors clustered by the village in parentheses. The control variables not reported in the table include the baseline asset level, the baseline outcome variable and group dummies. Columns (5) and (6) report the coefficients in the Tobit models. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.