At the Right Time: Modifying Repayment and Disbursement Schedule in Microcredit

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Abstract

Despite the expansion of microcredit access, its outreach is still limited among farmers. Standard microcredit causes a timing mismatch between cash flow and credit flow for farmers. They have little income until harvest while standard microcredit requires weekly installment. This mismatch will cause underinvestment and borrowing for repayment. Agricultural investment is sequential while credit is disbursed in a lump-sum, and present-biased (PB) farmers may fail in setting aside sufficient amount of the fund for later investment. We randomly offered three microcredit programs that differ in repayment and disbursement timing to tenant farmers: (1) standard microcredit, (2) crop credit that disburses credit in a lump-sum and requires a one-time repayment after harvest, or (3) sequential credit that disburses credit sequentially and requires a one-time repayment after harvest. Crop credit and sequential credit increased uptake and borrower's satiscation, without worsening repayment rates. Sequential credit increased later investments among PB borrowers, and reduced credit sizes. We attribute the credit size reduction to the option value: sequential disbursement allowed borrowers to determine the total credit size after observing productivity and expenditure shocks. Numerical exercises suggest that sequential credit that let borrowers set the credit limit will be a better option for time consistent farmers.

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

JEL Classification: G21, O16, Q14

1 Introduction

Agriculture is the major source of revenue for poor households in a rural economy, and boosting agricultural production contributes to poverty reduction (Christiaensen et al., 2011). Although financial inclusion has the potential to boost productive investment, many smallholder farmers, especially landless tenant farmers, have no adequate access to credit. Formal financial institutions have provided farming credits but could not reach landless farmers who do not own sufficient collateral to pledge. Government-led subsidized agricultural loans, provided in the 1960s and 1970s, have mostly failed due to low repayment rates (Adams et al., 1984; Zeller and Meyer, 2002). While the expansion of microcredit programs have substantially improved the financial access among the poor, its outreach is still limited among farmers.[1]

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

Using a simple multi-stage model, we first show the benefit of matching the timing of cash flow and credit flow. Requiring installment payments before the harvest, as is the standard practice in microcredit, will result in underinvestment, borrowing for repaying installments, and lower uptake rates. Further, PB borrowers prefer to lower the amount of initial disbursement to constrain their overconsumption and increase later investments. To empirically examine these theoretical predictions, we randomly offer a credit contract to rice-growing farmers in rural Bangladesh, most of whom were sharecroppers without collateral land assets. Our treatment arms included four types of the contracts that differ in timing of disbursement and repayment: (T1) Traditional microcredit with a lump-sum disbursement and weekly installments; (T2) Crop credit with a lum-sum disbursement and a lump-sum repayment after harvest; (T3) Sequential credit with sequential disbursement and a lump-sum repayment after harvest; and (T4) Sequential in-kind credit, which is a variant of (T3) with a part of the loan disbursed in kind to strengthen the borrower's commitment by reducing liquidity. We found that changing the repayment timing (T2-T4) substantially improved the uptake rates, especially among poor households. Making the disbursement sequentially (T3 and T4) increased the investment among PB farmers, though it did not increase the uptake rate

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

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

relative to T2 even among the PB farmers, which is consistent to our numerical exercise. These modified schemes (T2-T4) did not worsen the repayment rates, and resulted in greater satisfaction and higher uptake rates in the subsequent season.

Interestingly, the sequential credit (T3-T4) resulted in smaller credit size by 7-10% compared with the standard microcredit (T1) and the crop credit (T2). We attribute this reduction of the credit size to the option value of the sequential disbursement: borrowers can decide the total credit size after observing the actual credit demand. The optimal credit size will depend on productivity and expenditure shocks, and the sequential disbursement enabled the borrowers to adjust the credit size after observing these shocks. This flexibility reduced the demands for precautionary borrowings, and also enabled borrowers to achieve the optimal investment level. We extend the baseline model by introducing the productivity and expenditure shocks, and calibrate the model to match the moments of the data. While the option value effect on the credit size depends on the degrees of productivity and expenditure shocks and the curvature of the utility function, the calibrated model is consistent with the empirical patterns: reduction in credit size and greater investment both in first and latter production stages. Under the implemented sequential credit, borrowers were still subject to present bias when determining the final credit size. To deal with this problem, we conduct a counterfactual simulation of a new product in which borrowers can determine the credit limit at the first place (sequential credit with self-set limit) using the calibrated model. We found this new product will benefit sophisticated borrowers, but can be less desirable to partially naive borrowers compared to our standard sequential credit scheme.

Our study is related to an emerging literature on the introduction of flexibility into the microcredit, including less frequent installments (Field and Pande, 2008), longer grace periods (Field et al., 2013; Battaglia et al., 2021), and flexible repayment schedules (Shoji, 2010; Czura, 2015; Shonchoy and Kurosaki, 2014; Barboni and Agarwal, 2018). Burke et al. (2019) shed light on the timing of credit provision by giving loans at harvest to allow farmers not to sell the maize at low post-harvest prices. More closely related to our study, Aragón et al. (2020) provided credit lines to street vendors in which borrowers could withdraw or repay a flexible amount at any time, finding a positive impact on gross profits.

We extend this literature in three ways. First, we formalize the problem of the timing mismatch of cash flow and credit flow for farmers under the standard microcredit programs using the dynamic model of investment and consumption: the frequent installment causes under-investment and "borrowing for repayment," and the the lump-sum disbursement causes overconsumption for PB borrowers.[3] Karlan and Mullainathan (2010) argued that the standard weekly repayment "greatly

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

limits the size of the loans the poor can borrow ... by basing borrowers' repayment capacity on bad weeks, instead of average weeks." However, we show that the weekly repayment may increase the loan size for farmers as they borrow for repaying installments to smooth consumption. Some studies focused on the benefit of the inflexible frequent installment as the commitment for PB borrowers (Bauer et al., 2012; Fischer and Ghatak, 2016; Afzal et al., 2019).[4] However, for farmers, the commitment should be provided by the sequential disbursement, not by the frequent installment.[5]

Second, we implemented the new microcredit program, the sequential credit (T3 and T4). Some studies abolished the frequent installment for farmers (Fink et al., 2020), but none of the previous studies made the loan disbursement sequential to match the timing of cash outfow and credit inflow. In the literature, Chowdhury et al. (2014) argued the advantage of sequential credit in the context of joint liability, but their focus is on preventing coordinated default. None of the previous studies argue the benefit of sequential disbursement as the commitment device for PB borrowers. By using the calibrated parameter values, we also conduct a counterfactual experiment to evaluate a new product, called sequential credit with self-set limit. We found that this new scheme would benefit sophisticated borrowers, but might underperform the standard sequential credit for partially naive borrowers as they would set the credit limit too small by incorrectly predicting their credit need. The latter result is consistent with (John, 2020), who found costly commitment can reduce the welfare of partially naive PB borrowers.

Third, we discuss the presence of a precautionary borrowing under a lump-sum disbursement credit schemes, and the option value of the sequential disbursement. With production and expenditure uncertainty, the actual credit need is uncertain at the loan application. With a lump-sum disbursement, borrowers borrow a precautionary fund in case of large investment needs or expenditure shocks, and the precautionary borrowing is larger when expenditure shocks are important. The sequential disbursement allows borrowers to determine the total credit size after observing production and expenditure uncertainty, eliminating the need for precautionary borrowing. This reduces the credit size and also made the later investment decision optimal. The sequential disbursement not only match the timing of cash outflow and credit inflow, but also match the timing of realizing the actual credit need and determining the total credit size. This argument provides a ratoinale for emergency loans. The fact that borrowers can access emergency loans in case of expenditure shocks will eliminate the need for precautoinary borrowing and reduce the credit size. Credit lines studied by Aragón et al. (2020) will also have the same effect. However, Aragón et al. (2020) assumed risk-neutral agents, which eliminates precautionary borrowing for expenditure

[4]The value of commitment in the savings product and ROSCAs were widely supported (Ashraf et al., 2006; Basu, 2014; Gugerty, 2007; Basu, 2011; Fafchamps et al., 2014)

[5]Brune et al. (2021) and Casaburi and Macchiavello (2019) argue that PB individuals prefer to receive payment later.

shocks and leads to an increased credit size, which is contrary to our results. In addition, their target was street vendors who had frequent income flows and a short payout period, which eliminates the need for "borrowing for repayment".

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 only after the harvest. In case of rice production, farmers prepare and seed the land at the beginning of the planting season. Land preparation involves expenses for land tillage and leveling, as well as the costs of basal fertilizer (1st fertilizer hereafter). Farmers then plant the seeds, and in some cases transplant the seedling, which incurs 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 require farmers to hire additional labor. More than three and a half months after the seeding, farmers can harvest the rice, which requires additional labor for crop-cutting, threshing, and transporting. Until the harvest is sold, farmers have few income flows unless they work as (agricultural or non-agricultural) labor. The typical schedule of 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 (-) Land preparation (-) Basal fertilizer (-) Transplanting (-) Irrigation	(-) Topdressing fertilizer (-) Weeding (-) Herbicide (-) Pesticide	(+) Sell harvest (-) Crop-cutting (-) Threshing (-) Transporting
Credit	Application	(+) Disbursement (-) Regular installment	(-) Regular installment	(-) Regular installment

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

Generally, farmers who need credit should apply for the loan in advance. If the application passes screening, they will receive the full amount of the loan when they begin production. In the standard microcredit, payment of regular installments will start a few weeks after the disbursement, even though farmers have little income flow in this period. This causes a timing mismatch between cash flow and credit flow: Farmers are required to pay when they need additional investment, and receive the credit inflow only at the beginning of the production, whereas they need additional investment at a later stage. The latter may lead to underinvestment in the later stages among farmers who have difficulty in saving (Ashraf et al., 2006; Dupas and Robinson, 2013).

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

Table 2: Cash flow and timing of the decision making

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

Asterisks (*) indicates the decision variables.

In each period, the farmer obtains utility from consumption c, evaluated by a concave utility function $u(c)$ that satisfies the Inada condition. She makes the first investment K_1 at $t = 1$ and the second investment K_2 at $t = 2$, and will then obtain the revenue from the harvest (net of harvesting costs) $Y = F(K_1, K_2)$ at $t = 3$.[6] Production function $F(K_1, K_2)$ is strictly increasing and concave, and its second derivative matrix is a negative definite.[7]

Given this production technology and the interest rate r, she decides the credit size

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

at $t = 0$, where $\overline{M}$ is the upper limit of the credit size. The microfinance institution (MFI) disburses $M_1 \leq M$ at $t = 1$ and $M - M_1$ at $t = 2$, where M_1 can be set by the MFI or chosen by the borrower. The standard microcredit scheme corresponds to the case where $M_1 = M$. The total repayment amount is $R = (1+r)M$, which is equally split over $t = 1, 2, 3$ under the standard weekly installment: equal installments of $\frac{1}{3}R$ at every period.[8] For generality, we denote the installment amount at $t = 1, 2$ by $\frac{\pi}{3}R$, where $\pi \geq 0$ characterizes the share of the repayment before the harvest.

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

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

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

Then the amount repaid at $t = 3$ is $R_3 = \left(1 - \frac{2\pi}{3}\right) R$. The consumption at $t = 3$ is $c_3 = Y - R_3$.[9] Note that if she borrows M, she repays $\frac{\pi}{3}(1+r)M$ at $t = 1, 2$. Hence, only $M - \frac{2\pi}{3}(1+r)M$ is available for investment. We denote this fraction by

$$Q \equiv 1 - \frac{2\pi}{3}(1+r). \tag{2}$$

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

$$A_1 = A_0 + M_1 - \frac{\pi}{3}(1+r)M, \tag{3}$$
$$A_2 = A_1 - c_1 - K_1 + M - M_1 - \frac{\pi}{3}(1+r)M. \tag{4}$$

Then the budget constraints at $t = 1$ and $t = 2$ are

$$c_1 + K_1 \leq A_1, \tag{5}$$
$$c_2 + K_2 = A_2, \tag{6}$$

respectively. Changing the value of π and M_1 influences the budget constraint through their effects on A_1 and A_2. Note that we have ignored other income flows than harvest. As long as the other income flow at $t = 2$ is not too large, we can consider additional other income flow simply by reinterpreting the endowment A_0 as the total amount of endowment and other income flows.

We mainly consider following three products: (1) traditional microcredit ($\pi = \frac{1}{3}, M_1 = M$), (2) crop credit ($\pi = 0, M_1 = M$), and (3) sequential credit ($\pi = 0, M_1 < M$).

2.1 A time-consistent borrower

A time-consistent farmer maximizes $\sum_{t=1}^{3} u(c_t)$ subject to the budget constraints (5) and (6), and the borrowing limit (1). We defer the full characterization of the model and solution to the appendix, and we only present important results here. The first main result is that if the borrowing limit (1) does not bind, the borrower will choose the credit size M^* that satisfies

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

If $\pi = 0$, then $Q = 1$ by equation (2), and hence $F'_j(K_1^*, K_2^*) = 1 + r$, which states that a farmer borrows the credit until the marginal product of the investment equals its marginal cost, achieving the social optimum. However, if $\pi > 0$ as in the standard microcredit, then $Q < 1$ and $F'_j(K_1^*, K_2^*) = 1 + \frac{r}{Q} > 1 + r$, implying underinvestment. Remember that if she borrows M at

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

$t = 0$, only QM is available for the second investment after repaying the installment, which makes the effective interest rate for the investment becomes $\frac{r}{Q}$. If the borrowing limit (1) binds, then $F'_j(K_1^*, K_2^*) > 1 + \frac{r}{Q}$, further underinvestment. Comparative statics show that

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

implying that the greater the ratio of the installment payment before the harvest, the less the agricultural investment.

We can also show that $c_1^* = c_2^* < c_3^*$, $\frac{\partial c_1^*}{\partial \pi} = \frac{\partial c_2^*}{\partial \pi} < 0$ and $\frac{\partial (c_1^*/c_3^*)}{\partial \pi} = \frac{\partial (c_2^*/c_3^*)}{\partial \pi} < 0$ — that is, the weekly installment requirement reduces consumption at periods 1 and 2, and makes the consumption before and after the harvest less smooth.

Removing the installment requirement before the harvest will increase the investment and smooth the consumption across time, which increases the borrower's utility, and hence will improve the uptake rates.

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

The impact of π 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 π rises. This is because the requirement of installment before the harvest induces borrowers to borrow to pay the installment while sustaining consumption levels.

To illustrate the effect of repayment schedules on borrower's behavior, Figure 1 presents the results of numerical exercises. We assume the Cob–Douglass production function $F(K_1, K_2) = \theta K_1^{\psi_1} K_2^{\psi_2}$, whose parameter values were calibrated to match the moment of our survey data as described in Appendix A.3.[10] The utility function is of CRRA type:

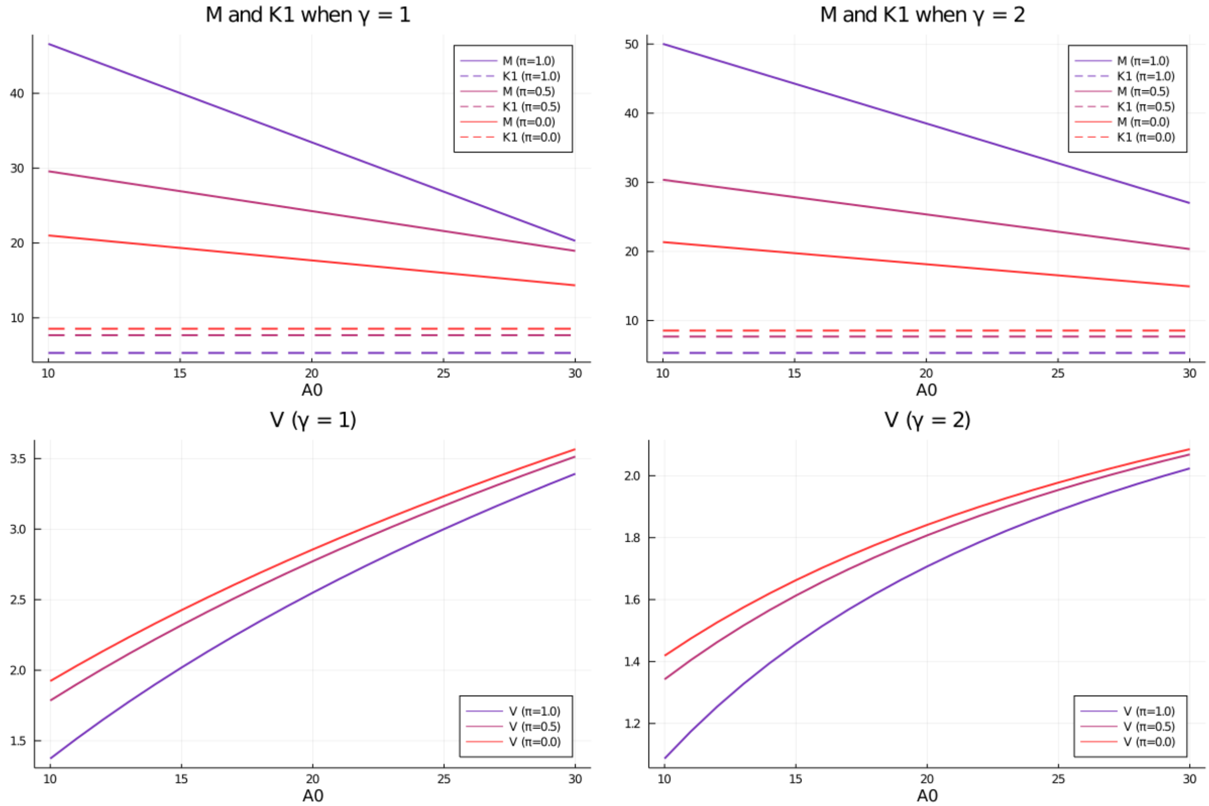
$$u(c) = \begin{cases} \frac{c^{1-\gamma}-1}{1-\gamma} & \text{if } \gamma \geq 0, \gamma \neq 1 \\ \ln(c) & \text{if } \gamma = 1. \end{cases}$$

Note that the specification of the utility function do not affect the levels of the input and output choice, but does affect the credit size and the levels of consumption at each period.

The upper panel of Figure 1 depicts the borrower's decision on the credit size M and the amount of the first investment K_1 against the endowment A_0 for different repayment schedules ($\pi = \{1, 0.5, 0\}$). For the utility function, we set $\gamma = 1$ in the left panel and $\gamma = 2$ in the right panel, where the higher value of γ implies the higher demand for consumption smoothing. Most empirical literature on the intertemporal substitution has found $\gamma > 1$ (Ogaki et al., 1996; Yogo, 2004).

[10] The calibrated parameter values are $(\psi_1, \psi_2, \theta) = (0.283, 0.139, 15.075)$.

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



As indicated in equation (7), the investment size is determined by the marginal productivity and the value of π, and not affected by the level of A_0. The credit size is decreasing in A_0.[11] In the range of A_0 described in the Figure, larger installment before the harvest (a greater value of π) increases the credit size, especially for those with low A_0. The traditional microcredit ($\pi = 1$) results in the greatest credit size and the lowest investment size. The discrepancy between these two is substantial for those with low A_0, indicating that a considerable amount of credit is used for repayment among asset-poor borrowers. When the demand for consumption smoothing is high ($\gamma = 2$, right panel), the credit size gets greater under the traditional microcredit, as they demand more borrowing for consumption before the harvest.

The lower panel of Figure 1 shows the maximum total utility with the endowment amount A_0 for different repayment schedules. As expected, the total utility is lowest when $\pi = 1.0$ (traditional microcredit), and highest when $\pi = 0$ (crop credit). The difference is greater for those with low A_0,

[11] 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 $P \equiv 1 + \frac{r}{Q}$.

indicating that it is the farmer with low asset or low income flows from other sources that benefits most from the elimination of the regular repayment.

2.2 A present-biased borrower

In the above setting, the disbursement schedule, captured by M_1/M (the share of the credit disbursed at $t = 1$), will not affect the borrower's decision unless M_1 is so small that the period-1 budget constraint (5) binds. The borrower will not benefit from such a low level of M_1 since it only imposes the additional binding constraint. However, if a borrower is present-biased (PB) and aware of it, she may prefer to set M_1 low to constrain her period-1 consumption. Now, consider a hyperbolic discounter who discounts the future utility by β, and believes her β to be $\hat{\beta}$. For simplicity, set $\pi = 0$ and consider if a PB borrower has an incentive to set a low M_1 at $t = 0$. The model is fully described in Appendix A.1.2, and we briefly summarize the main results here as the mechanism is quite similar to the standard argument of the demand for commitment (Laibson, 1997).

Claim 2 *PB farmers who are aware of their present-biasedness prefer the credit to be disbursed sequentially. Sequential credit will increase the second investment.*

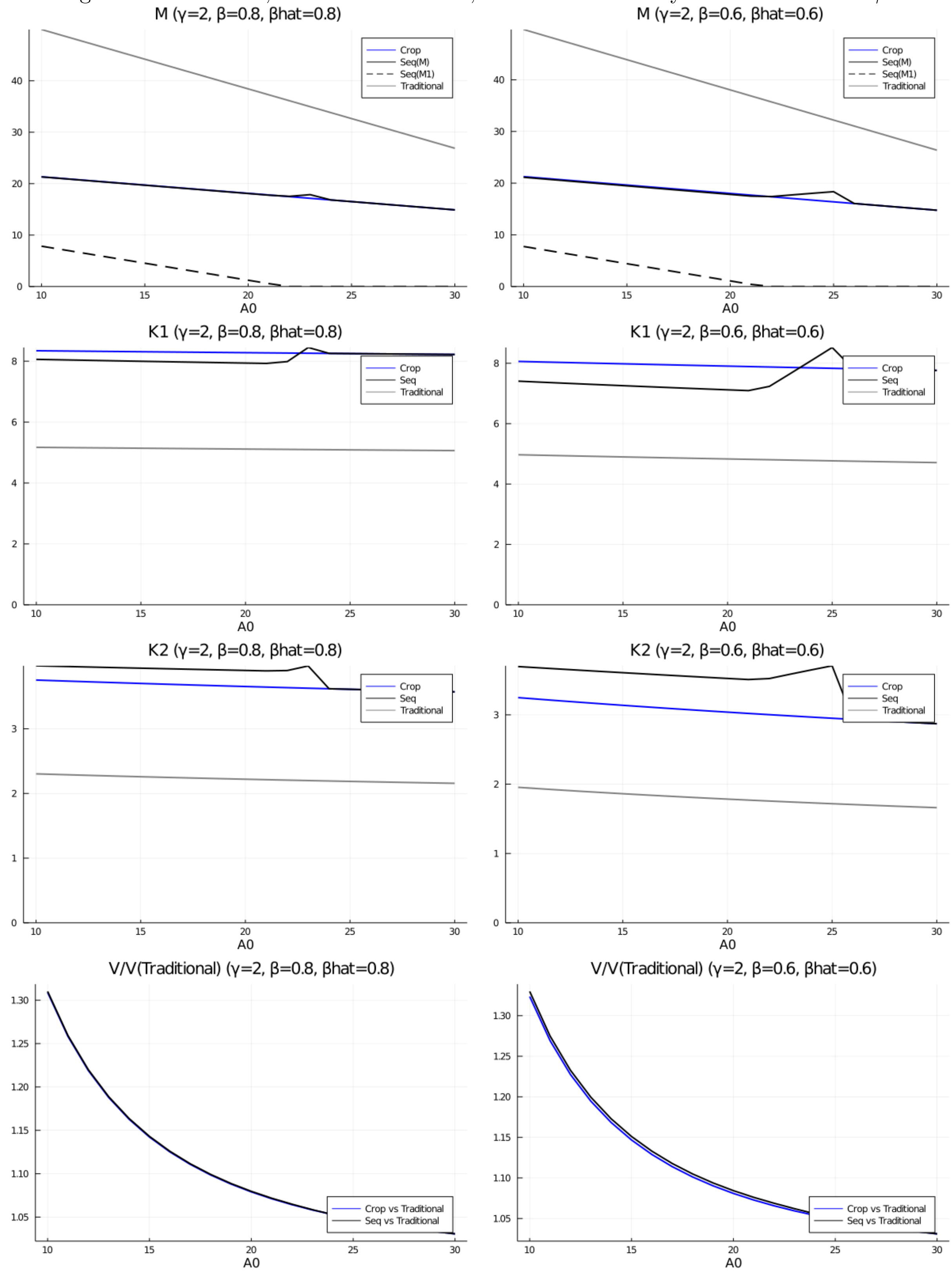
Figure 2 illustrate the PB borrower's decision on the credit size and investment, and the utility gain over the traditional microcredit under the crop credit and sequential credit when $\gamma = 2$ and $\beta = \hat{\beta} = \{0.8, 0.6\}$.[12] For the sequential credit, we present both the total credit size M and the first disbursement M_1.

The total credit size are similar between the crop credit and sequential credit. Under the sequential credit, the first disbursement M_1 is chosen so that the budget constraint at $t = 1$, $c_1 + K_1 \leq A_0 + M_1$, binds to constrain the overconsumption at $t = 1$. This budget constraint makes the first investment lower under sequential credit, but increases the second investment as she can secure enough resources to her period-2 self. However, if A_0 is large enough, she cannot make the budget constraint at $t = 1$ bind even with $M_1 = 0$. In this case, she cannot constrain her period-1 self's choice and the outcomes are the same between the crop credit and sequential credit.

Note that the graphs of the sequential credit have a hump around $A_0 = 23$. For these regions, $M_1^* = 0$ but the period-1 budget constraint binds. Considering her own present bias problem, her period-0 self allocates smaller resources for her period-1 self, resulting in $M_1^* = 0$. At $t = 1$, her period-1 self wants to consume more, making the budget constraint binding. Expecting this, her period-0 self increases M to secure more resources for her period-2 self to invest more to achieve

[12] Appendix Figures 1 and 2 present the case when $\gamma = 1$ and the case when $\beta = 0.6, \hat{\beta} = 0.8$ (partially naive), respectively, with results quite similar to those in Figure 2.

Figure 2: Credit size, investment amount, and the total utility of PB borrowers: $\gamma = 2$



greater income at $t = 3$. Eventually, she makes greater second investment, which also affects the first investment decision as the marginal productivity of the first investment is increased. In these regions, the credit size is greater under the sequential credit than the crop credit.

It turns out that the total utility evaluated at $t = 0$ does not differ much between the crop credit and sequential credit. The sequential credit only slightly achieved greater total utility in the range of A_0 where the budget constraint at $t = 1$ binds. When the degree of the present bias is modest ($\beta = \hat{\beta} = 0.8$), the utility gain from the sequential credit over the crop credit is less than 0.1%. Hence it is expected that the uptake rate will not differ between the crop credit and sequential credit.

Some points are worth noting here. If the MFI impose an upper bound on M_1, even PB borrowers prefer the crop credit if the upper bound is too low for them. Especially, the existence of uncertainty, which ignored in this baseline model, will increase the desired level of M_1 as it will provide her with more flexibility (Amador et al., 2006). If borrowers are naive ($\hat{\beta} = 1$), they have no demand for commitment and their decisions on consumption and investment do not differ between the sequential credit and the crop credit.

3 Local Context, Product Design, and Randomization

3.1 Local context

Motivated by these theoretical predictions, we conducted a randomized controlled trial to investigate the effect of modifying the repayment and disbursement schedules in the Dinajpur district of northwest Bangladesh, targeting at sharecropping farmers. The majority of tenant farmers are landless and poor, and do not have access to credit from formal banking sectors, including microfinance. Most of them are engaged in rice production. While Dinajpur district is not a disaster-prone area, the region suffers a high poverty rate of 64.3%, much higher than the national average of 24.3% (Hill and Genoni, 2019).

Rice is a major agricultural product in Bangladesh and comprises half 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 and lasts up to mid-July, while sowing spans mid-July to mid-August. Usually, the *Aman* paddy harvesting begins in November and lasts until January. Land preparation involves land tillage and leveling. Agricultural modernization has replaced traditional animal-powered plowing with tractors or power tillers. Local service providers exist for these activities, and farmers must pay in cash to avail the mechanical plowing service on time. Farmers purchase fertilizers, pesticides, and herbicides from local traders. Although some local traders sell hybrid seeds, most tenant farmers uses traditional seeds.[13]

A majority of the tenancy contracts require the tenants to pay 30 percent of the harvest to the landlord. Fixed-rent contracts are rare in this region, and only a fraction of the plots (less than 1%) were under fixed-rent contracts both in our baseline survey and the endline survey. Cost sharing, which is often observed in sharecropping arrangements elsewhere, is uncommon in Bangladesh, partly because most of the landlords live in the cities and cannot monitor the input costs. The local MFIs do not provide credits designed for the farmers, and mostly employ a "Grameen-Style" rigid contract design with weekly installment payments. Although the BRAC has introduced an experimental product for sharecroppers (BCUP), it requires monthly repayment as well, which does not align with the cash flow of the farmers. Borrowing from moneylenders is uncommon in this region. In our baseline survey, only 1% of the surveyed households borrowed from moneylenders in the past 12 months. The majority of the borrowing sources at baseline was from shop owners (59.7%) followed by other NGOs including Grameen Bank. Ninety two percent of the borrowing from shop owners were reported for food consumption purpose. Among all the borrowings at the baseline, only 9.0% were for crop farming.

Although sharecrop contracts often contain cost-sharing with landowners, this is not common practice in Bangladesh, where sharecroppers have financed farming crops with credit borrowed from informal money lenders and middlemen at high interest rates (Khandker et al., 2016; Hossain et al., 2019).

Due to the lack of farm income until harvest, many poor farmers work as daily laborers to earn a living. Although the opportunity for urban migration to earn cash income was limited due to the lack of job-related networks, most households in our survey had other income sources.[14] The left panel of Figure 3 shows the histogram of the days of working for wage income in the last 12 months at the household level in our baseline survey. While 22.5 percent of the surveyed household reported no wage income, a majority of households worked 240–360 days for wage income, with the mode of the daily wage being 300 BDT (about 3.66 USD). Among those who earned wage income, 57.0% worked in their village and 38.4% worked in another village in the same union. Only 1% of them migrated to another district (including Dhaka) for work. The right panel of Figure 3 is a box plot of the days of working as daily wage disaggregated at the monthly level, based on

[13] 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.

[14] Before the survey, we presumed that alternative means of income to agricultural production were limited, and if any, they were seasonal and insufficient to finance the livelihood and agricultural production. The data revealed that many farmers had stable income sources other than agriculture.

individual-level data. While the variance differs across months, the average days of working are similar across months.[15]

When self-employment is considered, almost all the households had income sources other than farming. The left panel of Figure 4 reports the histogram of the days of working for wage income and self-employment activity in the last 12 months at the household level. Most households spent substantial time in earning other incomes than rice production. The right panel of Figure 4 shows the distribution of the total income from wage labor, self-employment, fishery, and poultry.[16] It indicates that some households earned a substantial amount of income from these activities, which could finance agricultural investment at least in part.

Figure 3: Days of working as daily labor in the last 12 months

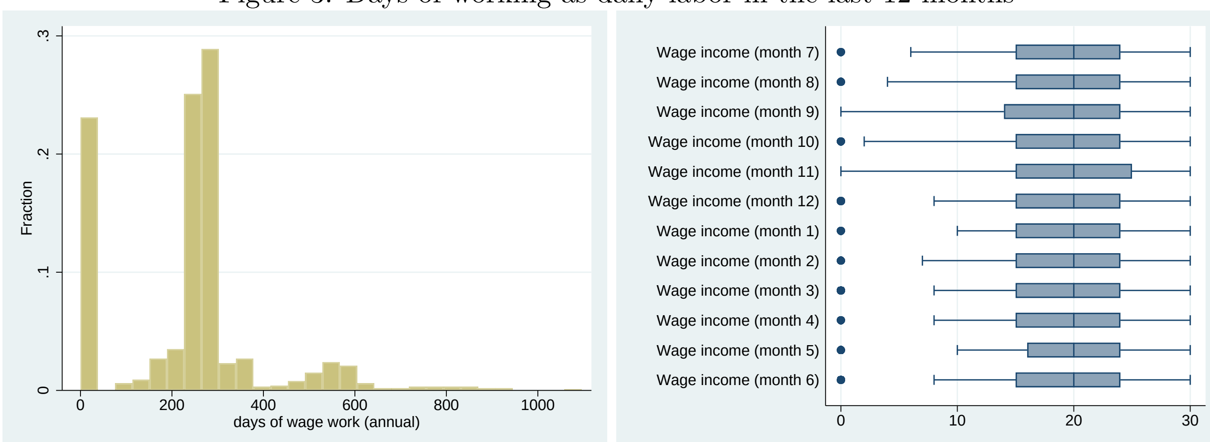
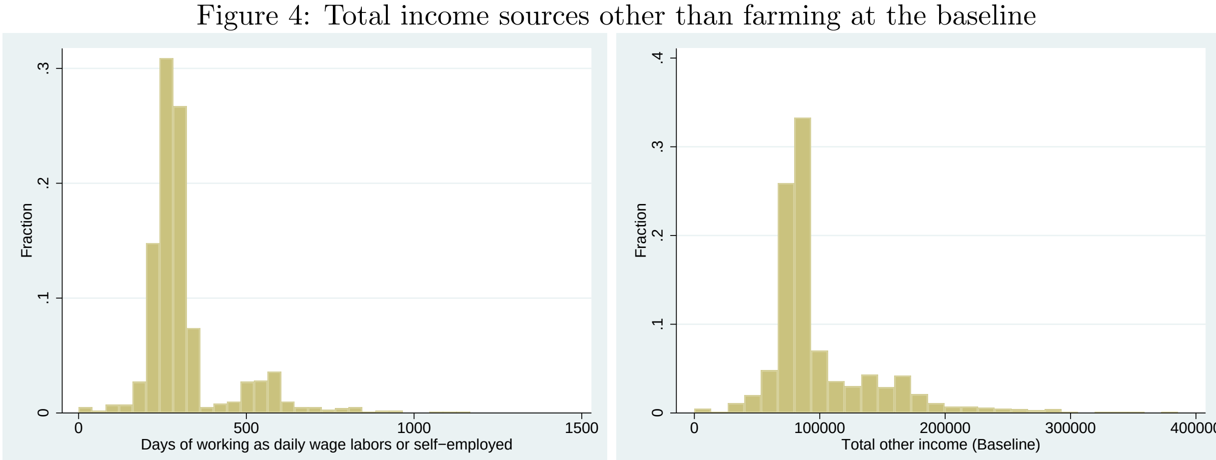


Figure 4: Total income sources other than farming at the baseline



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

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

3.2 Product design

To implement experimental credit schemes targeted at sharecroppers, we collaborated with *Gana Unnayan Kendra* (GUK), a grassroots organization that has worked in northern Bangladesh for 35 years in various development-related interventions. The GUK had provided microcredit under the traditional weekly installment contract, but its managing committee was open to innovation and better product design customized 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 and peer monitoring.

Before the main phase of the study (i.e., the *Aman*-cropping season in 2015), we implemented a small pilot study with the GUK to understand the cash flow in agricultural production in Dinajpur, while assessing the feasibility of the proposed experimental design. Based on bookkeeping exercises with tenant farmers, we computed the total cost of the entire cycle of rice production as well as the timing of each of the investment items for the typical farmer. We also discussed these estimates with the local agricultural extension officers and the GUK. Based on these conversations and estimates, the GUK agreed to provide a maximum loanable amount of 400 BDT (about 4.88 USD) per decimal of land to the sharecropping farmers in Dinajpur, with a six-month interest rate of 12%.[17]

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

Traditional credit (T1): This is the standard microcredit product that GUK had implemented elsewhere. The full loan amount 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 harvest, when farmers were supposed to pay the last installment. For example, if a farmer took 10,000 BDT (about 122 USD) credit with a 12% 6-month interest rate (loan accessed in July to be repaid by December 2015), she would repay about 467 BDT in each weekly installment (a total of 24 equal weekly installments).

Crop credit (T2): This product removes the weekly installment from Traditional credit (T1). The borrowers were required to repay the full amount at the end of the harvesting period, which

[17] 1 decimal equals to 40.5057 m^2.

corresponded to the due date of the last installment in T1. Thus, a farmer who borrowed 10,000 BDT at the beginning of the crop-cycle was required to repay 11,200 BDT in a single payment at the end of the cycle (in December). The product corresponds to the case of $\pi = 0$ and $M_1 = M$ in our motivating model above.

Sequential credit (T3): This product modifies the crop credit by changing the schedule of loan disbursement. To match the sequence of agricultural investment, the disbursement was divided into three phases. The bookkeeping exercise in the pilot survey revealed that it would be best to disburse up to 60% of the maximum loan size in the first phase so that the remaining 40% was still available for late-stage investment. Therefore, the borrower could choose the amount of the first disbursement such that $M_1 \leq 0.6\overline{M}$. At the time of the second disbursement (one month after the first disbursement), borrowers could receive up to 20% of the loanable amount in addition to the unused loanable amount at the first disbursement. This means that borrowers could receive up to 80% of the loanable amount by this time. The third and final disbursement was made one month after the second disbursement.[18] At each disbursement, borrowers could decide the amount they would like to receive as long as it was within the specified limit. While our model have assmued $M_2 = M - M_1$, the field team incorporate futher flexibility by allowing $M_2 < M - M_1$, i.e., borrowers can adjust the loan size ex post, which we will revisit in a later section.[19]

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. The GUK partnered with reputed local agricultural dealers to organize this in-kind credit distribution through pre-approved vouchers (coupons) signed by the loan officer.

For all these groups, the GUK conducted weekly meetings to monitor group activities and to facilitate loan collection for those who were repaying weekly. During the weekly meeting, the GUK also encouraged borrowers to save and provided a savings deposit service, although there was no mandatory savings amount. Members in the control group (described in the next section) could use the savings deposit service of the GUK. Due to the requirement of the weekly meetings for all the treatment arms, we would not be able to infer the outcome under crop credit and sequential credit without regular weekly meetings.

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

[19] Without uncertainty as in our baseline model, this modification will not change the results.

3.3 Data, randomization, and balance tests

To start the survey, we first listed all the sub-districts of Dinajpur and conducted a village survey to understand the other MFIs' 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'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, the GUK formed 50 potential borrowing groups of 20 potential borrowers each, at the beginning of May 2015. The groups were formed by the farmers themselves. During the group formation, farmers were informed that the access to credit offer and the type of credit contract would be randomized.

The baseline survey was conducted from June 2015 to obtain the basic demographic and socio-economic information, including land-size under tenancy agreement, of 1,000 potential borrowers. During the baseline, the GUK also informed farmers about the maximum loanable amount and the timing of the credit availability.

After collecting the baseline data, we randomly assigned 200 members (4 members per group) to each of the following four credit products for the *Aman*-cropping season in 2015. The remaining 200 members served as the control group.[20] Since the outcome variables of our interests are investment and production, we stratified the individuals based on the score of economic status that would be correlated with the latent productivity. Specifically, we computed the score 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 livestock, owning productive assets, and housing conditions (if the house is made of mud), the area of agricultural land, and the years of education.[21] We constructed a strata of five households with similar scores, and randomly divided

[20]See Appendix Figure 3. The capacity constraint of expanding branches in the field limited the total sample size. We had repeated discussions on whether to include the sequential in-kind treatment 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, with 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 a significance level of 0.05, the detectable effect size when assuming an i.i.d. data generating process is 0.28 standard deviation. We would have a detectable effect size of 0.25 if we had 250 farmers in each arm. However, as the power of our study was not large, we did not expect to detect significant effects on noisy variables such as income and profits. We report the minimum detectable effects to facilitate the interpretation of the statistical results when the outcomes were fairly noisy.

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

the five households into five different treatment statuses.

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

The average credit size among the borrowers was 16,095 BDT (approximately 196.4 USD). The smallest credit size was 5,500 BDT in the traditional credit and the crop credit, and 3,360 BDT in the sequential credit. The maximum credit size was 27,300 BDT. We have no data on the loanable amount that the GUK actually imposed, which we instead computed based on the land area under sharecropping contracts reported in the follow-up survey. While this can differ from the actual loanable amount due to reporting errors, comparing it with the actual credit size will reveal if the loanable amount ($\overline{M}$) constrained the borrower's choice of the credit size. In the following analysis, we excluded 2 observations with loanable amounts less than 3,000 BDT as computed from their self-reported plot areas, as this suggests that they did not report all the plot they cultivated and hence we would undervalue their total investment and output. Figure 5 depicts the scatter plot of the computed loanable amount (horizontal axis) and the actual loan size (vertical axis), with a 45 degree line. The actual credit size was less than the estimated loanable amount for most borrowers, implying that the constraint $M \leq \overline{M}$ would not bind in most cases.

Figure 5: The loanable amount and the actual loan size

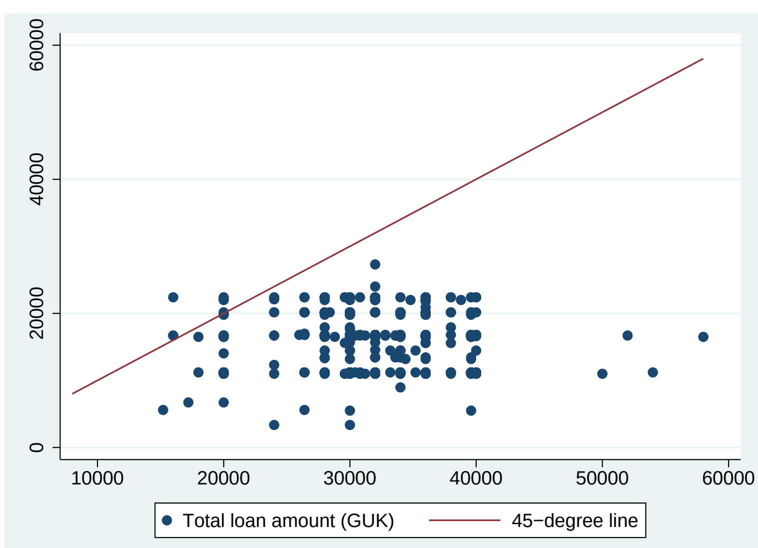


Table 3 reports the summary statistics of our sample. The average uptake rate was 56.1 percent based on the whole sample. Excluding the farmers in the control group who were not offered the credit, the average uptake rate was 70%, which is relatively high, which was due to the fact that our sample consists of the farmers in the self-formed borrowing groups who exhibit an interest in taking out loans.[22]

Table 3: Summary Statistics

	count	mean	sd	min	max
Uptake	998	0.561	0.496	0	1
Total loan amount (GUK)	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	560	0.076	0.235	0	.951
Cumulative savings	560	2320.920	495.466	300	3940
Owned land area (Baseline)	998	12.260	15.677	0	50
Tenanted land area (Baseline)	998	79.397	14.760	0	145
ln(household asset) (Baseline)	998	12.272	1.039	8.22	14.6
ln(productive asset) (Baseline)	998	7.689	1.101	5.52	13
ihs(Livestock asset)	998	10.460	2.361	0	12.9
Total other income (Baseline)	998	100626.011	45800.203	0	385650
Total borrowing (Baseline)	998	1298.698	5173.616	0	80000
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

While 57.2% of the sampled farmers were landless, nearly 30% owned land no less than 20 decimal (approximately $800m^2$), as shown in the upper panel of Appendix Figure 4. Most of them tenanted land no less than 50 decimal (see the lower panel of Appendix Figure 4. While some changed the areas of tenanted land, most farmers cultivated the same tenanted land (Appendix

[22] 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 an interest in taking out the loan was necessary to obtain the loan but still left the option of not doing so, 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.

Figure 5). At baseline, the loan access was fairly limited. About two-thirds of the sampled farmers had no borrowing in the past 12 months, and only 5% borrowed no less than 10,000 BDT (Appendix Figure 6).

We computed the first and second investment in a consistent way to our conceptual framework described in Table 1. Specifically, the first investment consists of expenses for seeds, basal fertilizers, wages and costs for hiring labors and machines for land preparation and transplanting, and irrigation fees. The second investment consists of expenses for topdressing fertilizers, herbicides, pesticides, and wages for hiring labors for weeding. Since our focus is on the impact of financial access on the investment, we excluded the imputed costs of family labors from computing the investment amounts, while we consider them in computing the profit.[23] Note that the average total income from sources other than agricultural production are substantially larger than the average profit from *Aman* season production, indicating that rice production is not a main source of income for most sampled farmers. Given that *Aman* season spans 6 months, we compute the ratio of profit from *Aman* season production to other total income over 6 months. But only 10% of the sampled farmers earned *Aman* season profit exceeding a quarter of the other total income over 6 months.

In the surveyed region, the harvest was considerably delayed due to weather conditions, and many borrowers did not finish harvesting on the loan due date, which affected their ability to repay the credit on time.[24] Given this abnormal weather, the GUK extended the due date by three weeks, but nearly half the borrowers (48.7%) could nevertheless not repay the loan on this due date. After the due date, the GUK expended 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.

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.[25] While we do not find significant differences across treatment groups in most baseline characteristics, there are significant differences in the land holdings and the first investment. The traditional credit groups had significantly smaller baseline land sizes than the sequential credit groups, and

[23] We also subtract the labor costs for harvesting in computing the profit.

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

[25] Specifically, the variable named `Sequential` takes the value of 1 if the borrower is in the sequential credit (T3) or sequential in-kind credit (T4), and 0 otherwise; and the variable named `In-kind` takes the value of 1 if the borrower is in the sequential in-kind credit (T4), and 0 otherwise.

the control group had significantly lower levels of first investment at baseline. However, these standardized differences never exceed 0.17 in these variables. In sum, 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.

Table 4: Balance tests

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	HH Asset	Prod asset	Land	Borrowing	1st invest	2nd invest	Other income	Output
Crop Credit	-0.022	-0.088	0.813	-91.542	405.317**	113.222	-2271.621	28.990
	(0.052)	(0.102)	(1.459)	(523.162)	(174.711)	(162.888)	(4417.361)	(758.307)
Sequential	0.061	0.006	1.636	174.891	401.893**	180.893	-6398.083	723.800
	(0.064)	(0.102)	(1.490)	(489.523)	(153.387)	(142.530)	(4214.086)	(656.175)
In-kind	-0.028	-0.030	0.345	-219.322	-63.139	0.434	-58.084	208.621
	(0.058)	(0.102)	(1.502)	(598.115)	(167.081)	(140.496)	(3523.518)	(873.406)
Traditional	-0.045	-0.071	-1.465	370.022	230.554	180.720	-4321.644	-285.834
	(0.059)	(0.107)	(1.394)	(701.650)	(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	1594.405	8213.550	4461.546	1.00e+05	31657.050
SD_Control	0.998	0.999	21.185	5614.285	2464.009	1889.687	45688.444	9798.711
Trad_vs_Crop	0.755	0.858	0.104	0.458	0.345	0.668	0.627	0.670
Trad_vs_SeqCash	0.155	0.540	0.033	0.743	0.253	0.999	0.597	0.171
Trad_vs_SeqKind	0.249	0.670	0.019	0.568	0.489	0.997	0.555	0.116
Crop_vs_SeqCash	0.169	0.448	0.542	0.572	0.984	0.665	0.331	0.413
Crop_vs_SeqKind	0.387	0.572	0.484	0.913	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 hypothesis that the coefficients of the corresponding treatment indicators are the same.

4 Results

To investigate the impact of different credit schemes on the outcome measures, we estimate the following regression:

$$y_{ij}^F = \gamma_0 + \gamma_1 y_{ij}^B + \mathbf{T}_{ij}\boldsymbol{\tau} + \mathbf{X}_{ij}\boldsymbol{\gamma}_x + \zeta_j + \epsilon_{ij} \tag{8}$$

where y_{ij}^F is the outcome variable at the follow-up survey of the household i in the borrowing group j, y_{ij}^B is the lagged dependent variable measured at the baseline survey, $\mathbf{X}_{ij}$ is the set of other control variables including the factor score used for the randomization and the baseline values of productive and non-productive assets (transformed into logarithms), livestock assets (transformed by the inverse-hyperbolic function), owned land area, tenanted land area, borrowing amount, saving amount, first and second investment, total output, 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 $(\gamma_0, \gamma_1, \boldsymbol{\tau}', \boldsymbol{\gamma}'_x)$. ζ_j refers to the fixed effects for the borrower group, and ϵ_{ij} represents the idiosyncratic errors that are allowed to be correlated within the same lending group.[26]

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

$$y^F_{ij} = \gamma_0 + \mathbf{T}^S_{ij}\boldsymbol{\tau} + \mathbf{X}_{ij}\boldsymbol{\gamma}_x + \epsilon_{ij} \tag{9}$$

where $\mathbf{T}^S_i$ 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 the regression equation.

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 uptake rate by 13.8 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. While we cannot detect any significant differences in the uptake rates between crop credit and sequential credit (either cash or in-kind), the results clearly suggest that weekly installment payments discouraged potential borrowers from taking up credit, as predicted by our theory.

The theory also implies that the lower uptake rate of the standard microcredit is evident among borrowers whose endowment or other income sources were limited. To examine this prediction, we

[26] One might be tempted to use the treatment variables as the instruments for credit uptake to estimate the local average treatment effects (LATE). The LATE evaluates the average treatment effects over the people who switched to using the credit due to the treatment assignment. However, the population of these switchers may not be comparable across our treatments. Suppose that farmers with greater treatment effects are more likely to uptake the loan, which is plausible. The regular repayment will discourage borrowers from taking up the product as it requires repayment when they need investment expenses, and hence, only those with quite large treatment effects will uptake the loan. Then even when the treatment effects are the same across the products, the LATE will be greatest for regular repayment credit. This implies that the LATE will not tell us which product was more desirable. Actually, one can increase the LATE by increasing the transaction costs for uptake. Given the differences in uptake behavior, we chose not to report the LATE.

Table 5: Uptake and loan size

	(1) Uptake	(2) Uptake (low other income)	(3) Uptake (high other income)	(4) Uptake	(5) Loan size	(6) Loan size	(7) Loan size	(8) Loan size
Crop Credit	0.138^{**}	0.202^{**}	0.058	0.129	120.732	0.480	-411.048	-493.670
	(0.059)	(0.096)	(0.086)	(0.089)	(548.097)	(613.748)	(735.589)	(711.023)
Sequential	0.107^{*}	0.064	0.048	0.098	-1144.070^{**}	-1120.328^{*}	-1847.793^{**}	-1699.469^{**}
	(0.056)	(0.098)	(0.088)	(0.079)	(566.545)	(596.738)	(750.395)	(807.884)
In-kind	0.075	0.202^{**}	0.064	0.042	-453.841	-646.504	243.644	-99.033
	(0.049)	(0.078)	(0.086)	(0.082)	(341.559)	(409.541)	(528.550)	(650.743)
PB=1				-0.037			-652.124	-541.689
				(0.060)			(825.215)	(913.467)
Crop Credit × PB=1				-0.001			898.021	800.177
				(0.096)			(1104.276)	(1210.332)
Sequential × PB=1				-0.006			1272.254	1019.695
				(0.080)			(1034.890)	(1178.120)
In-kind × PB=1				0.068			-1293.349^{*}	-1026.164
				(0.089)			(719.987)	(732.637)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	799	326	314	788	560	560	551	551
Mean_Control	0.595	0.570	0.616	0.595	16910.420		16910.420	
Crop_vs_SeqCash	0.441	0.040	0.898	0.694	0.006	0.015	0.016	0.058
Crop_vs_SeqKind	0.375	0.333	0.520	0.909	0.001	0.001	0.099	0.062
PB_Trad_vs_Crop				0.054			0.550	0.747
PB_Trad_vs_SeqC				0.152			0.460	0.426
PB_Trad_vs_SeqK				0.001			0.043	0.051
PB_Crop_vs_SeqC				0.421			0.048	0.065
PB_Crop_vs_SeqK				0.154			0.001	0.001

The table reports 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 values of asset, savings, land area, other income than agricultural production, and agricultural output, 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.

run the regression for the subsample with low total income from sources other than agricultural production at the baseline (lower than the 40 percentile) and the subsample whose other total income is high (higher than the 60 percentile).[27] The results reported in columns (2) and (3) show that discarding the weekly installment requirement substantially improved the uptake rates among the farmers who had low income from other sources, while it did not have significant effects for the farmers whose other income was high. Although we did not find significant impacts of the sequential cash credit on the uptake in either of these subsamples, the results seem to suggest that the requirement of the weekly installment limits the outreach of microcredit among agricultural households without sufficient steady income.

In column (4), we include the interaction terms of the treatment variables and the indicator for being PB.[28] The uptake behavior did not differ between time-consistent farmers and PB farmers in any credit schemes.[29] While the sequential credit could provide the commitment functions for PB borrowers, it did not significantly improve the uptake rates over the crop credit. This could be explained by a small difference in the total utility between the crop credit and sequential credit as presented in the numerical exercise in Section 2.2.

4.2 Loan size

Column (5) of Table 5 reports the impact on the loan size. Since we only observe the loan size for those who actually took up the credit, the analysis is based on the selected sample of the uptakers. To address the sample selection problem, we also report the results using the inverse probability weighting (Robins et al., 1995; Wooldridge, 2010) in column (6).[30] Correcting the sample selection

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

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

[29]The numbers in the lower panel are the p-values against the null hypothesis that the impacts are equal. For the PB 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 $H_0 : \tau_C + \delta_C = \tau_S + \delta_S$.

[30]We include as the predictors for the sample selection all the covariates of the regression and an indicator for savings in the previous year. We estimate a propensity score function for each treatment group (we used the union fixed effects instead of the group fixed effects because the size of the group is too small when we separate the sample into treatment groups), and we run the regression for equation (9) using the inverse of the estimated propensity score as the weight. By this procedure, the characteristics of the uptakers across the treatment arms will be well

only slightly changes the coefficient values.

We found no significant impact of removing the weekly repayment on the loan size, which is not in line with the prediction of our numerical exercises. However, the direction of $\frac{\partial M^*}{\partial \pi}$ is in general undetermined as stated in Section 2, and depends on the functional form of F and u.[31] So the result does not necessarily contradicts the model.

A striking finding is that the sequential credit substantially reduced the loan size by more than 1,100 BDT compared to the traditional credit or crop credit, that is, more than a 6.8 percent reduction (Columns (5) and (6)). When combined with the in-kind disbursement, it reduced the loan size by 9.4-10.4 percent and 10.1-10.5 percent compared to the traditional credit and the crop credit, respectively. This reduction in the credit size was driven by time-consistent borrowers, and we found no significant differences in the loan size among the PB borrowers between the sequential cash credit and the traditional credit (Columns (7) and (8)). However, disbursing the credit in kind (stronger commitment) led PB borrowers to borrow less.

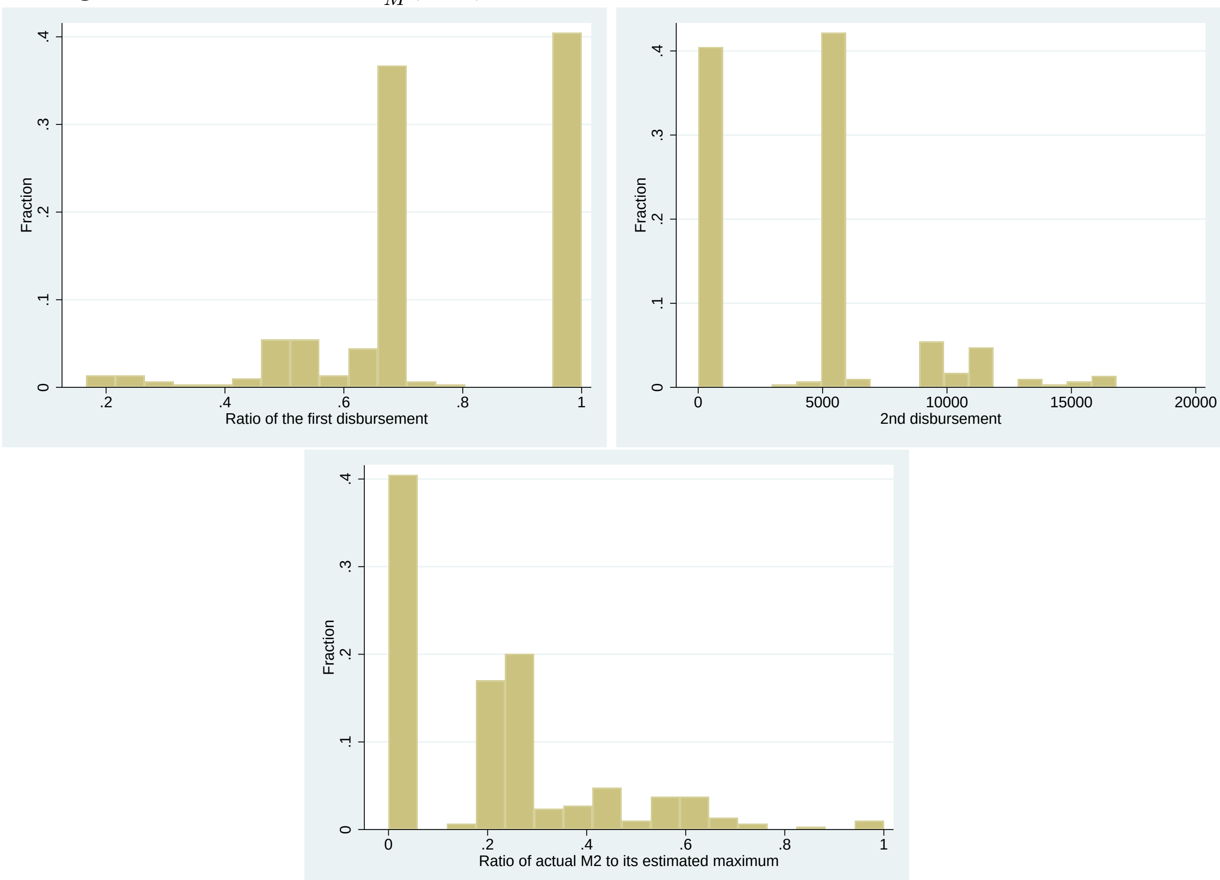
To explore the lower credit size under the sequential credit, we draw the distribution of $\frac{M_1}{M} = \frac{M_1}{M_1+M_2}$ in the top left of Figure 6. As explained in Section 3.2, the borrower could choose the first disbursement M_1 subject to $M_1 \leq 0.6\overline{M}$, and the second disbursement M_2 subject to $M_2 \leq \overline{M} - M_1$. The value of $\frac{M_1}{M}$ is greater than 0.6 when $M_2 < \overline{M} - M_1$, and equal to 1 when $M_2 = 0$. The figure shows that the majority of the borrowers chose $M_2 < \overline{M} - M_1$ and furthermore, 40% of the borrowers chose $M_2 = 0$. In contrast, some borrowers recorded quite a low value of M_1/M, which occurred only when M_1 was small and M_2 was large. The top right of Figure 6 depicts the distribution of M_2, showing a fraction of borrowers recorded a fairly large M_2.

We argue that these results—a smaller credit size under the sequential credit and the pattern of the second disbursement M_2 mentioned above—can be explained by the option value provided by the sequential credit. We defer the model with the option value to the next section, and briefly explain its essence here. Under the sequential credit, the total credit size is determined at later stages, after uncertainties such as productivity shocks and expenditure shocks were resolved. In the standard credit or crop credit that disburse the credit at the outset, borrowers have to decide the credit size at the application. This rigidity causes precautionary borrowing: they borrow a precautionary fund for potential shocks. The sequential credit allows borrowers to determine the total credit size after observing these shocks, which reduces the credit size and results in the optimal investment level. Borrowers concerning a potential large shock at $t = 1$ will choose large M_1 for

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 very meaningful. The identifying assumption is that conditional on these variables, the uptake decision is independent of the other factors than $\mathbf{X}_{ij}$ that determines the borrowing amount.

[31] Also see footnote 43 of Appendix A.1.1 for the expression of $\frac{\partial M^*}{\partial \pi}$.

Figure 6: Distribution of $\frac{M_1}{M}$, M_2, and the ratio of actual M_2 to its estimated maximum



some buffer, and then choose small M_2 after observing no shocks.[32] In contrast, borrowers who believe the shock at $t = 1$ is small, if any, choose small M_1 to keep enough room for adjustment at $t = 2$.

PB borrowers still face the overconsumption problem at $t = 2$ under the sequential disbursement: they could consume more by borrowing more at $t = 2$. Disbursing the credit in kind could alleviate this problem as the borrower could not increase the consumption by borrowing more unless she resells the in-kind disbursement. This commitment functions to keep the credit size of PB borrowers small under the sequential in-kind credit, which explains the results in Columns (7)-(8) in Table 5.

One may be concerned that the maturity for the second disbursement was shorter than the first disbursement, which makes the effective interest rate for the second disbursement greater and that this may explain the smaller credit size under the sequential credit. However, this cannot explain the behavior of borrowers who chose low M_1 and large M_2. Further, as many borrowers chose $M_2 = 0$, explaining the smaller credit size solely by the higher effective interest rate requires an

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

extremely large price elasticity that cannot be supported by existing empirical studies (Dehejia et al., 2012; Karlan and Zinman, 2019).

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

Appendix Table 1 shows the impacts on borrowing from other sources. The treatments did not significantly change 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.

4.3 Investment

Next, we examine 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 investments (Table 6, Column (1)), though the effect for the former was smaller and not statistically significant. When restricted to the time-consistent borrowers (Column (2)), we found that both the crop credit and sequential credit significantly increases the first investment compared to traditional credit. The theory implies that this increase in the first investment will make the investment decision close to the socially 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 focused on the PB borrowers (Column (4)), we found that the sequential cash credit significantly increases the second investment, compared with the control, traditional credit, or crop credit (p-values are 0.018, 0.089, 0.099, respectively), as our theory predicts. This implies that sequential credit can work as a commitment device. For the time-consistent borrowers, the sequential credit did not increase the second investment; however, this does not mean that the sequential credit did not benefit them, as it decreased the loan size for the time-consistent borrowers as shown above. The next section provides the framework to understand these results in a unified manner.

Note that no other credit schemes than the sequential credit significantly increased the investment in comparison with the control group. This makes us wonder how the farmers in the control group financed the investment. In Appendix Table 2, we run the regression for the subsample with

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	-63.676	-268.197*	-3.322	-140.230	53.061	-700.304	-89.129	51.808
	(78.851)	(158.941)	(81.143)	(147.601)	(447.769)	(685.002)	(350.133)	(492.590)
Crop Credit	129.904	74.290	42.624	-49.271	564.765	169.065	106.564	133.925
	(85.271)	(176.247)	(81.186)	(137.208)	(394.812)	(652.269)	(312.239)	(443.842)
Sequential	254.406***	156.999	115.986	-115.924	606.638	-99.102	-122.332	-13.429
	(83.632)	(182.520)	(84.389)	(145.818)	(415.467)	(677.482)	(328.684)	(437.078)
In-kind	-143.437	-71.203	13.476	85.139	-260.424	-481.355	19.899	-242.033
	(93.367)	(153.912)	(85.813)	(122.891)	(554.183)	(762.790)	(422.400)	(560.743)
PB=1		-142.373		-247.148*		-864.169		134.852
		(159.382)		(137.660)		(800.234)		(495.176)
Traditional × PB=1		325.005		225.875		1363.688		-107.455
		(211.706)		(190.444)		(1065.758)		(657.942)
Crop Credit × PB=1		96.894		142.825		833.270		120.602
		(229.070)		(155.517)		(943.305)		(596.543)
Sequential × PB=1		166.364		412.654**		1345.969		-67.571
		(263.086)		(197.299)		(1197.239)		(672.055)
In-kind × PB=1		-104.250		-124.685		335.359		400.715
		(186.565)		(177.713)		(744.304)		(617.876)
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	0.027	0.015	0.605	0.529	0.191	0.142	0.497	0.872
Trad_vs_SeqCash	0.003	0.006	0.146	0.851	0.159	0.291	0.917	0.900
Trad_vs_SeqKind	0.064	0.007	0.144	0.363	0.532	0.858	0.965	0.600
Crop_vs_SeqCash	0.181	0.588	0.450	0.596	0.911	0.616	0.453	0.723
Crop_vs_SeqKind	0.843	0.917	0.389	0.891	0.672	0.302	0.576	0.459
PB_Trad_vs_Crop		0.285		0.944		0.517		0.467
PB_Trad_vs_SeqC		0.078		0.089		0.372		0.952
PB_Trad_vs_SeqK		0.524		0.188		0.505		0.734
PB_Crop_vs_SeqCash		0.276		0.099		0.690		0.424
PB_Crop_vs_SeqKind		0.861		0.188		0.871		0.670

The table shows 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 outcome variable, the baseline values of asset, savings, land area, other income than agricultural production, and agricultural output, and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

low total income from sources other than agricultural production at the baseline (lower than the 40 percentile) and the subsample whose other total income is high (higher than the 60 percentile). We found positive impacts of the sequential credit on the first and second investment for the borrowers with low total other income, but other product had no significant positive impact. Appendix Table 1 shows that borrowing from other sources were not significantly affected by our interventions. Further, columns (1) and (2) in Appendix Table 3 investigate the total income flow — borrowings from other sources plus wage income, subtracting savings, showing no significant differences across experimental groups. These may suggest that many farmers were not severely credit constrained in the agricultural production as most of them have additional income sources to finance them.[33]

Columns (5) to (8) show the impacts on the output and profit. The estimates are quite noisy, 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 a 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.[34]

4.4 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. Present bias did not significantly influence the pattern of the savings as reported in Column (2). Given the result that credit did not significantly increase the output, we attribute the positive impact on the savings to the GUK's encouragement of savings. Columns (3) and (4) in Appendix Table 3 show the impacts on savings at NGOs. The coefficients are quite close to those in Columns (1) and (2) in Table 7, suggesting that the increased

[33]After the follow-up survey, we conducted interview with farmers in the control group to understand how they financed the investment. Their typical answers were that they had somehow managed to finance the investment, without identifying any specific means. Since they had been engaged in crop production for many years without formal financial access, they could find ways to finance the investment without our products, which they did not disclose to us in the survey. Actually, most of the recorded financial transactions were transactions with MFIs, and only 2.3% of the respondents reported borrowing from relatives or friends, and only 1.2% reported borrowing from a moneylender. Savings at home were also likely under-reported, especially in the follow-up data: 6.5% of the household reported savings at home at baseline, but none of the household reported savings at home at follow-up. Given the extensive utilization of available financial services by the poor as reported in (Collins et al., 2009), there would be many financial transactions missing in our survey data.

[34]If we were to implement 3 treatments instead of 4 (by removing the sequential in-kind as discussed in footnote 20), then the MDE would be 840, which is still large.

savings are mainly driven by the savings at NGOs, especially at GUK.

We have argued that the option value of the sequential credit — the ability of borrowers to adjust the loan size after observing shocks — can explain the reduction in the loan size. This argument also implies that 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 to see if the borrowers of the traditional credit and crop credit made a greater savings, with the traditional credit group set as the reference category. In this selected sample, we found exactly this pattern. Borrowers in the sequential credit made significantly less savings than those in traditional or crop credit.[35]

In column (4), we utilize the administrative record of the GUK on the monthly savings deposited to it. The data show that the savings accumulation is concentrated in July and August. 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 July and August implies that borrowers deposited part of the disbursed credit into their savings account. To capture the savings funded by the disbursed credit, we aggregate the savings deposited at the GUK in July to September. The regression results shows that sequential credit resulted in significantly smaller savings in these months compared to the traditional credit and crop credit, indicating that borrowers of the traditional credit and crop credit made additional savings as a buffer to cope with the potential shocks. 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 follow-up survey. The sequential credit still resulted in lower net savings than the traditional and crop credits. The results are robust to sample selection correction by the IPW.[36]

4.5 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 crop credit and sequential credit did not worsen the default rate.

[35]Correcting the sample selection bias by the IPW does not change the results. These results are available upon request.

[36]See Columns (5)-(8) in Appendix Table 3.

Table 7: Savings

	(1) Saving	(2) Saving	(3) Saving	(4) Savings at MFI in Jul-Sept	(5) Savings at MFI in Jul-Sept	(6) Net savings at MFI	(7) Net savings at MFI
Traditional	1476.155***	1370.580***					
	(175.336)	(231.723)					
Crop Credit	1616.107***	1711.882***	-208.983	34.744	54.565	60.276	17.463
	(128.093)	(173.461)	(227.006)	(76.856)	(104.589)	(72.698)	(104.025)
Sequential	1331.864***	1403.233***	-476.292*	-363.182***	-363.992***	-236.495***	-303.796***
	(143.189)	(183.623)	(245.325)	(88.971)	(105.065)	(71.887)	(89.240)
In-kind	52.851	-75.649	-38.384	-170.393**	-193.430**	-12.694	11.598
	(129.559)	(208.869)	(116.962)	(64.878)	(78.656)	(41.787)	(58.415)
PB=1		-9.027			4.781		-72.507
		(109.780)			(96.275)		(93.582)
Traditional × PB=1		181.339					
		(326.659)					
Crop Credit × PB=1		-172.520			-14.904		79.600
		(213.596)			(139.904)		(137.858)
Sequential × PB=1		-161.002			19.364		113.240
		(201.819)			(118.150)		(120.496)
In-kind × PB=1		233.272			33.119		-47.672
		(214.886)			(102.334)		(92.321)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	998	986	560	560	551	560	551
Mean_Control	266.884	266.884	2853.445	1749.202	1749.202	2432.437	2432.437
Trad_vs_Crop	0.536	0.169					
Trad_vs_SeqCash	0.532	0.875					
Trad_vs_SeqKind	0.678	0.839					
Crop_vs_SeqCash	0.009	0.112	0.006	0.000	0.001	0.000	0.004
Crop_vs_SeqKind	0.067	0.096	0.009	0.000	0.000	0.000	0.002
PB_Trad_vs_Crop		0.970			0.703		0.328
PB_Trad_vs_SeqC		0.356			0.003		0.060
PB_Trad_vs_SeqK		0.627			0.000		0.023
PB_Crop_vs_SeqCash		0.026					
PB_Crop_vs_SeqKind		0.291					

The table shows 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 outcome variable, the baseline values of asset, savings, land area, other income than agricultural production, and agricultural output, and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

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	-0.075	-0.072	-0.017	-0.020	-0.067	-0.018
	(0.050)	(0.053)	(0.047)	(0.048)	(0.225)	(0.231)
Sequential	-0.075	-0.070	-0.026	-0.017	-0.224	-0.137
	(0.060)	(0.062)	(0.049)	(0.057)	(0.212)	(0.264)
In-kind	-0.048	-0.072	-0.017	-0.040	0.062	-0.082
	(0.051)	(0.055)	(0.045)	(0.051)	(0.258)	(0.299)
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	0.997	0.972	0.815	0.951	0.470	0.655
Crop_vs_SeqKind	0.418	0.236	0.517	0.358	0.659	0.380

The table shows 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 values of asset, savings, land area, other income than agricultural production, and agricultural output, and group dummies. Columns (5) and (6) report the average partial effects in the Tobit models. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

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

$$\%\text{ of amount not repaid } = 1 - \frac{\text{Amount repaid} + \text{Net savings at MFI}}{\text{Total amount to be repaid}}.$$

Given that there are many observations whose percent of amount not repaid was zero, we use the Tobit regression and once again find no significant differences across the treatment groups.[37]

Including the interaction terms of the treatment variables and the present bias indicator does not change the results except that PB borrowers achieved lower default under the crop credit compared to the traditional credit (Appendix Table 4).

These results indicate that the crop credit and sequential credit achieved more financial inclusion among farmers with lower steady income flows without deteriorating its financial sustainablity. While proponents of the weekly installment model argue that it is required to keep the repayment rate high, our point estimates consistently suggesst that our 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 harvest, requiring one-time repayment after

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

the harvest does not worsen the repayment performance. Combined with the theoretical prediction that the regular installment would reduce the investment, there would be no rationale for requiring the regular installment for farming households.

4.6 Uptake in the second round

Finally, we investigate the satisfaction with the credit scheme. Columns (1) and (2) in Table 9 show the demand for the loans in the second round when the farmers were offered the same product as the first rounds. The greater uptake will indicate that the borrowers highly evaluated the product. 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. Further, we find no systematic differences in the second season uptake rate between the time-consistent borrowers and PB borrowers, although PB borrowers are more likely to uptake the credit if it is crop credit or disbursed in kind.

Columns (3) to (6) report 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 the GUK that found that many farmers requested credit access, particularly seasonal credit in the following season.

5 Option value

5.1 Model

We have argued that the option value could explain the pattern of the empirical results relating to the actual sequential credit product. In this section, we provide a sketch of the model incorporating the option value, followed by the discussion on its empirical relevance and numerical exercises. The complete characterization of the solution is provided in Appendix A.2.

We modify the model to incorporate productivity shocks and expenditure or income shocks. 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 2, respectively. We can interpret $\theta_t > 1$, $t = 1, 2$ as the positive shocks and $\theta_t < 1$ as the negative shock. We also consider expenditure/income shocks ξ_1 and ξ_2 realized at period 1 and 2,

Table 9: Uptake in the second round

	(1)	(2)	(3)	(4)	(5)	(6)
	Uptake:2nd	Uptake:2nd	Satisfaction	Satisfaction	Satisfaction	Satisfaction
Crop Credit	0.155^{***}	0.150^{*}	1.883^{***}	1.740^{***}	1.879^{***}	1.772^{***}
	(0.055)	(0.082)	(0.163)	(0.221)	(0.171)	(0.210)
Sequential	0.122^{**}	0.144^{*}	1.077^{***}	0.887^{***}	1.112^{***}	0.946^{***}
	(0.052)	(0.081)	(0.118)	(0.224)	(0.127)	(0.224)
In-kind	0.050	0.042	-0.296^{***}	-0.218	-0.333^{***}	-0.255
	(0.049)	(0.080)	(0.098)	(0.148)	(0.106)	(0.163)
PB=1		-0.015		-0.259		-0.277
		(0.057)		(0.242)		(0.233)
Crop Credit × PB=1		0.004		0.244		0.197
		(0.089)		(0.317)		(0.311)
Sequential × PB=1		-0.063		0.310		0.283
		(0.090)		(0.260)		(0.255)
In-kind × PB=1		0.035		-0.126		-0.123
		(0.099)		(0.189)		(0.199)
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	0.463	0.940	0.000	0.000	0.000	0.000
Crop_vs_SeqKind	0.761	0.640	0.000	0.000	0.000	0.000
PB_Trad_vs_Crop		0.015		0.000		0.000
PB_Trad_vs_SeqC		0.163		0.000		0.000
PB_Trad_vs_SeqK		0.008		0.000		0.000
PB_Crop_vs_SeqC		0.194		0.000		0.000
PB_Crop_vs_SeqK		0.951		0.000		0.000

The table reports 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 values of asset, savings, land area, other income than agricultural production, and agricultural output, and group dummies. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

respectively. These shocks reduce the resource available for consumption and investment at each period by ξ_t. That is, the budget constraints at each period become

$$\begin{aligned} c_1 + K_1 &\le A_1 - \xi_1, \\ c_2 + K_2 &\le A_2 - \xi_2. \end{aligned} \tag{10}$$

First, we consider the choice under the crop credit. The timing of the decision making is summarized in the upper part of Table 10. We can solve the problem backwardly.

Table 10: Timing of the decision making under uncertainties

	$t = 0$	$t = 1$ Observe θ_1, ξ_1	$t = 2$ Observe θ_2, ξ_2	$t = 3$
Crop	* Decide M	Disburse M * 1st investment K_1 * Consume c_1	* 2nd investment K_2 * Consume c_2	Harvest $Y = \theta_1\theta_2 F(K_1, K_2)$ Repay $(1+r)M$ Consume c_3
Sequential	* Decide M_1	Disburse M_1 * 1st investment K_1 * Consume c_1	* Receive $M_2 \le \bar{M} - M_1$ * 2nd investment K_2 * Consume c_2	Harvest $Y = \theta_1\theta_2 F(K_1, K_2)$ Repay $(1+r)(M_1 + M_2)$ Consume c_3
Sequential with self-set limit	* Decide M, M_1	Disburse M_1 * 1st investment K_1 * Consume c_1	* Receive $M_2 \le M - M_1$ * 2nd investment K_2 * Consume c_2	Harvest $Y = \theta_1\theta_2 F(K_1, K_2)$ Repay $(1+r)(M_1 + M_2)$ Consume c_3

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

At $t = 2$, a borrower decides K_2 and c_2 after observing the productivity shock θ_2 and expenditure/income shock ξ_t. She will choose the second investment K_2^* such that

$$\theta_1\theta_2 F_2'(K_1, K_2^*) = 1 \qquad \text{if the constraint (10) does not bind,} \tag{11}$$

$$u'(c_2^*) = \theta_1\theta_2 F_2'(K_1, K_2^*) u'(c_3^*) \qquad \text{if the constraint (10) binds.} \tag{12}$$

The constraint (10) will not bind if she has set A_2 sufficiently high as a precaution for expenditure shocks and positive productivity shocks but finally finds no such shocks occur. If the constraint (10) does not bind (i.e. make savings at $t = 2$), then reducing K_2 by 1 unit will increase the savings carried over to $t = 3$ by 1 while reduce the output at $t = 3$ by $\theta_1\theta_2 F_2'(K_1, K_2^*)$. Then an optimizing borrower will invest until the marginal product equals to 1, as expressed in equation (11). We can also show that she will choose the credit size M at $t = 0$ to satisfy

$$E[u'(c_2^*)] = (1 + r)E[u'(c_3^*)]. \tag{13}$$

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

$$M_2 \leq \overline{M} - M_1. \tag{14}$$

$$M_2 \geq 0. \tag{15}$$

conditional on $(\theta_1, \theta_2, \xi_1, \xi_2)$. The repayment amount at $t = 3$ is $(1 + r)(M_1 + M_2)$. Note that this sequential credit modifies not only the timing of the repayment and disbursement, but also the timing of deciding the total credit size to a point in time after the shock was observed. The first-order conditions at $t = 2$ are written as

$$u'(c_2^*) = (1 + r)u'(c_3^*) + \mu - \nu,$$
$$[\theta_1\theta_2 F_2'(K_1, K_2^*) - (1 + r)]u'(c_3^*) - \mu + \nu = 0,$$

where μ and ν are the Lagrange multipliers associated with the constraints (14) and (15), respectively. If these constraints do not bind, we obtain

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

which states that the second investment is made optimally ex post, which is lower than the case under the crop credit (11). By reducing K_2 by 1 unit, she can reduce her repayment at $t = 3$ by $(1 + r)$ while the output reduces by $\theta_1\theta_2 F_2'(K_1, K_2^*)$. Thus, she will eventually choose K_2 so that its marginal product equals $1 + r$. Under crop credit, reducing K_2 by 1 unit will not reduce the repayment at $t = 3$, and only can use that 1 unit to make the repayment, which induces her to choose K_2 so that its marginal product equals to 1.

Based on this decision rule, she chooses (c_1, K_1) at $t = 1$ subject to the budget constraint

$$c_1 + K_1 \leq A_0 + M_1 - \xi_1. \tag{17}$$

Let the Lagrange multipliers associated with the constraints (17) be λ. Assuming the inner solution, the choice of M_1 at period 0 satisfies

$$E(\lambda) = E(\nu). \tag{18}$$

Suppose she chooses M_1 low. Then if she found θ_1 or ξ_1 large, the budget constraint (17) is likely to bind, resulting in too low c_1 and K_1. If on the contrary she chooses M_1 high, then the budget constraint (17) will not bind, but she cannot reduce the credit size due to the constraint (15) even when θ_t and ξ_t low. The condition (18) states that she set M_1 to balance these two possibilities.

Under the crop credit, the loan size is determined at period 0 by condition (13): 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 when she chooses M_2 to equalize the marginal product of the second investment to the cost of the loan as stated in equation (16) if $\nu = 0$, which is optimal ex post.

Under the sequential credit, a borrower does not have to borrow for precaution, which may explain the smaller credit size under this credit scheme. However, the impact on the credit size is a bit more complicated. Suppose $\nu = 0$ at $t = 2$. Then given K_2^* determined by equation (16), she will decide M_2 according to the equation (16), or

$$u'(\tilde{A}_2 + M_2^* - K_2^* - \xi_2) = (1+r)u'(\theta_1\theta_2 F(K_1^*, K_2^*) - (1+r)(M_1^* + M_2^*)). \quad (19)$$

which also determines $c_2^* = \tilde{A}_2 + M_2^* - K_2^* - \xi_2$, where $\tilde{A}_2 = A_1 - \xi_1 - c_1 - K_1$ is the resource available at $t = 2$ excluding M_2. Under the crop credit, the credit size is determined by equation (13). Without uncertainties in productivity, the Jensen's inequality implies that the credit size is lower under the sequential credit as in the standard precautionary savings argument. However, if the productivity uncertainty is serious, it is possible that the crop credit results in a lower credit size, because borrowers refrain from borrowing a large amount in fear of having a large repayment burden with low harvest.

Unfortunately, the data do not contain information on production, nor expenditure shocks. Note that the second disbursement is determined as $M_2^* = K_2^* + \tilde{A}_2 - \xi_2$, and K_2^* is the function of the productivity shocks (θ_1, θ_2). Hence, if productivity shocks are important, the second disbursement M_2 will be significantly affected by the second investment K_2. Columns (1)-(2) in Table 11 show that this is not the case. Here we only use the sample of time-consistent borrowers under the sequential credit, and control the demographic variables that we have included in the previous regressions. We do not control for group dummies or village dummies given the possible existence of village-level productivity shocks. We found no statistically significant correlation between K_2 and M_2. Including K_1 and the output, which will be also affected by the productivity shocks, does not change the results. The pattern is the same for the first disbursement, which would be set before observing the productivity shocks. This similar results imply that productivity shocks are not important in the determination of the credit size.

Further, if we assume the standard utility function such as CRRA and CARA,[38] we can derive:

$$M_1^* + M_2^* = R[K_2^* + K_1^* + \xi_2 + c_1^* + \theta_1\theta_2 F(K_1^*, K_2^*) - A_0] \quad (20)$$

where $R \equiv \frac{1}{1+(1+r)u'^{-1}(1+r)} > 0$. If the variation in the final loan size $(M_1 + M_2)$ is driven by productivity shocks, then we should find that K_2 and K_1 are positively correlated with the final loan size. Columns (5) of Table 11 reports the result of this regression, where we approximate A_0 by

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

Table 11: M_2 and M_1

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	M2	M2	M1	M1	M:Seq	M:Seq	M:Crop& Seq	M:Crop& Seq
K_2	-0.637	-0.407	-0.097	-0.099	-0.506	-0.504	-1.230	-1.226
	(0.401)	(0.435)	(0.318)	(0.327)	(0.448)	(0.445)	(0.774)	(0.770)
K_1		-0.435		0.000	-0.435	-0.451	0.749	0.738
		(0.519)		(0.320)	(0.450)	(0.445)	(0.509)	(0.510)
Output (Followup)		0.041		-0.010	0.031		0.033	
		(0.134)		(0.134)	(0.125)		(0.098)	
Seq $\times K_2$							0.681	0.679
							(0.928)	(0.925)
Seq $\times K_1$							-0.492	-0.489
							(0.474)	(0.471)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	63	63	63	63	63	63	121	121

The table shows 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 values of asset, savings, land area, other income than agricultural production, and agricultural output. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

the baseline assets, land areas, other income flows, savings, and production, finding no significant correlation. In columns (6), we exclude the output $\theta_1\theta_2F(K_1^*, K_2^*)$ as it is a function of K_1 and K_2, which could make the terms K_2^* and K_1^* in equation (20) subsumed in $\theta_1\theta_2F(K_1^*, K_2^*)$ and mask the correlation with K_2 and K_1. We again found no significant correlation.[39].

Note that the sign of the coefficients on K_1 and K_2 are negative and large in columns (5) and (6) in Table 11. One may be concerned that there would be some unobservables that are correlated with K_1 and K_2. To address this issue, we use the crop credit as the benchmark. If there are unobservable factors that affect the credit demand and are correlated with K_1 and K_2, they will also influence the credit size under the crop credit. Hence, we regress the credit size on K_1 and K_2 and other control variables, with including the interaction terms of an indicator for the sequential credit and K_1 and K_2. Then the coefficients on these interaction terms will capture the correlation between the credit size and K_1 and K_2 after controlling those unobservables. The coefficients are now positive but insignificant, lending support to the argument that the productivity shocks were not important determinants of the credit size.

The model implies that under the actual sequential credit, a PB borrower will set M_1 low to

[39] Adding the second-order terms of K_2 and K_1 to capture nonlinearity of the production function does not change the results

limit the overconsumption of her period-1 self, while a time-consistent borrower will set M_1 to balance the probability of the budget constraints being bound at $t = 1$ and $t = 2$. Hence, a PB borrower will choose M_1 lower and M_2 larger compared to a time-consistent borrower. Further, as a PB borrower choosing M_2 at $t = 2$ will be subject to the present bias, which further increases M_2. This pattern is actually found in the data, as reported in Table 12. Column (1) shows that the second disbursement of PB borrowers were greater than time-consistent borrowers by 1,586 BDT, which corresponds to 10% of the average credit size of the sequential credit. However, the sequential in-kind credit did not show such a pattern (Column (2)), suggesting that the present bias at $t = 2$ will be the main driver of the larger second disbursement. As predicted, the first disbursement was smaller for PB borrowers, though it is not significant. The ratio of M_2 over the final credit size is 8.7 percentage point larger for PB borrowers (Column (4)). The fraction of borrowers who chose zero second disbursement was greater among time-consistent borrowers (Column (5)).

Table 12: M_2, $M_2/(M_1 + M_2)$, and $M_2 = 0$

	(1) M2:Seq cash	(2) M2:Seq kind	(3) M1:Seq cash	(4) M2ratio:Seq cash	(5) M2=0:Seq cash	(6) M2=0:Seq kind
PB=1	1586.518**	-324.508	-546.773	0.087***	-0.138**	-0.081**
	(609.690)	(899.549)	(498.343)	(0.030)	(0.060)	(0.040)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Observations	139	153	137	137	196	395

The table shows 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 values of asset, savings, land area, other income than agricultural production, and agricultural output. Asterisks indicate statistical significance: * $p < .10$, ** $p < .05$, *** $p < .01$.

These results implies a potential for another product. To mitigate the present bias problem at $t = 2$, the MFI can let a borrower choose the maximum total credit size at $t = 0$. We call this product a sequential credit with self-set limit. The timing of the decision making is summarized in the bottom part of Table 10. This product only differs from the sequential credit in the ability of choosing M at $t = 0$. For a time-consistent borrower, it is optimal to set M large enough so that the period-2 constraint $M_2 \leq M - M_1$ never binds ($E(\mu) = 0$). The full characterization of the model is provided in Appendix A.2.2 and A.2.3. The choice on M at $t = 0$ will provide the commitment for the $t = 2$ decision as it can constrain the consumption and investment amount at $t = 2$. We evaluate this hypothetical product using numerical exercise described below.

5.2 Numerical examples

Thus far, we have argued that the model incorporating the option value can explain our empirical results. Now we examine the numerical examples that incorporate the uncertainty in the productivity and the expenditure shocks to see (1) how the decisions on the credit size and investment decisions are affected, and (2) the impact of an alternative credit scheme. To reduce the computational burden, we consider the cases where θ_t, ξ_t, $t = 1, 2$, are discrete and i.i.d. In particular, 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):

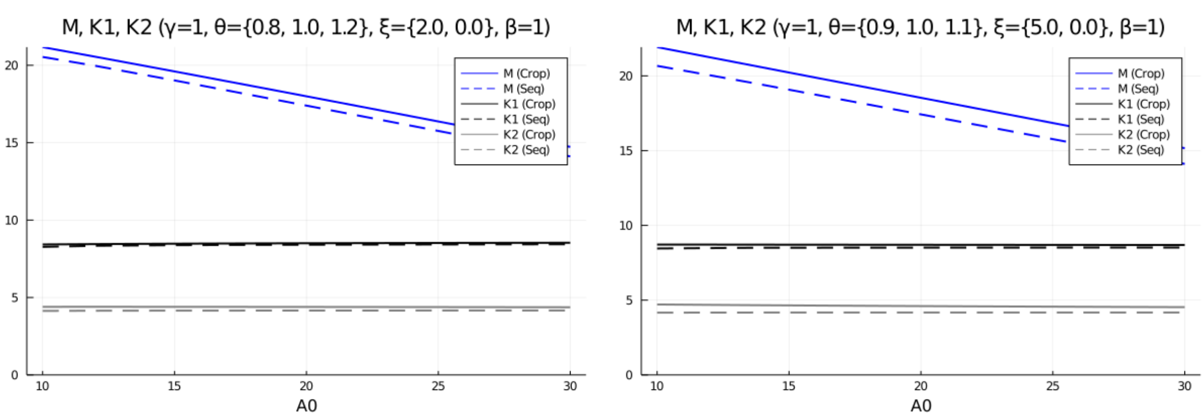
$\theta_t \in \{0.9, 1.0, 1.1\}$, with $\Pr(\theta_t = 0.9) = \Pr(\theta_t = 1.1) = 0.1$, $\Pr(\theta_t = 1.0) = 0.8$.

$\xi_t \in \{0, 5.0\}$, 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, in case 2. The computation details are provided in Appendix A.3.

Figure 7 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 $\gamma = 1$.[40] The optimal values of K_t, $t = 1, 2$ are computed when the productivity is at the 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, under Case 2.

Figure 7: Choice of (M, K_1, K_2) under crop credit and sequential credit when $\gamma = 1$



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

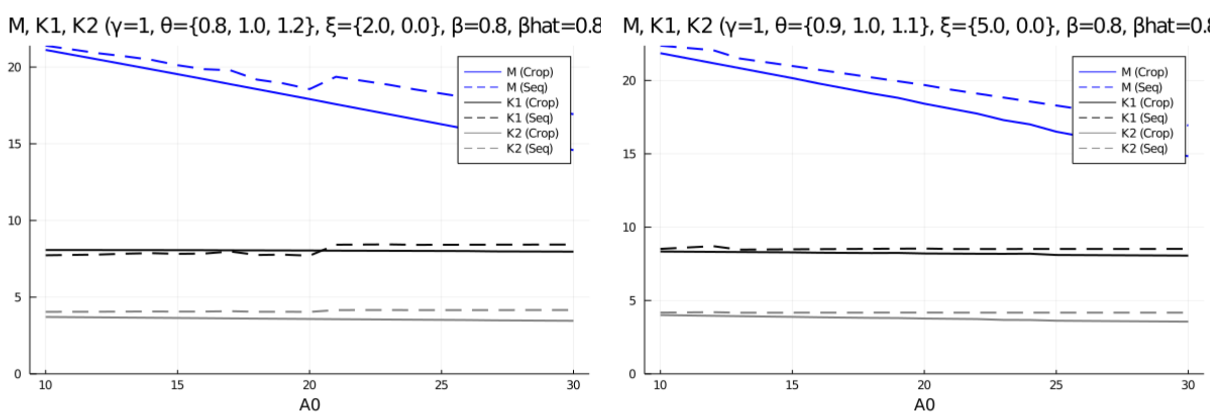
[40]The analogous figures when $\gamma = 2$ are reported in the Appendix Figure 7.

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.

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 (11). 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 8, even though the latter resulted in higher output values at period 3 due to overinvestment at $t = 2$.

Figure 8 depicts the final credit size M and the investment amounts, K_1 and K_2 for PB borrowers ($\beta = \hat{\beta} = 0.8$). Unlike the case of the time-consistent borrowers, the sequential credit resulted in higher credit sizes. At period 0, PB borrowers expect that their future selves will overconsume, and hence have incentives to reduce credit size to prevent overconsumption under crop credit. However, under sequential credit, she can constrain her consumption at period 1 by choosing M_1 at an appropriate level, and can ensure that the period-2 self finances the second investment by the sequential disbursement $M_2 \leq \overline{M} - M_1$. This commitment function of the sequential credit results in a larger investment at period 2. Further, expecting the larger K_2 and the resultant increase in the marginal product of the first investment, $F_1'(K_1, K_2)$, the borrower will also make a larger investment at period 1 than under crop credit. This may explain the larger first investment amount in Table 6.

Figure 8: Choice of (M, K_1, K_2) for PB borrowers under Crop credit and Sequential credit



Finally, Figure 9 shows the potential of the sequential credit with self-set limit. Note that if the present bias is not serious ($\beta = \hat{\beta} = 0.8$), then the numerical exercise shows that this new product is quite similar to the current sequential credit. However, if the present bias is more serious ($\beta = \hat{\beta} = 0.6$), there are some gain in the expected value at $t = 0$ as shown in Figure 9.

However, partially naive PB borrowers may be worse off when they can determine the credit limit by themselves as shown in Figure 10 for the case of $(\beta, \hat{\beta}) = (0.6, 0.8)$, as they set the limit too low by believing that their period 1 self will not overconsume so much. For partially naive PB farmers, the sequential in-kind credit could be a better option.

6 Conclusion

The timing mismatch between cash flows and credit flows caused by the standard microcredit for crop farmers would cause underinvestment and low uptake. We evaluated two modified microcredit programs, crop credit and sequential credit, in which the repayment schedule and disbursement schedule were changed to match the cash flow of rice farmers. Our results indicate these products increased the uptake rate without worsening the default rate. Further, 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 by eliminating the need for precautionary borrowing: under sequential credit, borrowers could determine the total loan size after observing productivity and expenditure shocks. Allowing for such uncertainty can also explain the increased first investment under the sequential credit.

The argument of the option value is related to the emergency loans and credit lines, as these products would also allow borrowers to adjust the final loan size after observing shocks. This implies that the availability of emergency loans might increase the uptake rate of the original microcredit product, and also reduce the total loan size. However, these loans might exacerbate the problem of overborrowing among present-biased borrowers as in our sequential credit. Our numerical analysis shows that a sequential credit with self-set limit, which allows borrowers to set the maximum credit size and disbursement schedule at the initial stage, will outperform the emergency loans and credit lines, as it can offer a commitment on the total borrowing amount. However, the sequential in-kind credit could be better for paritally naive farmers. Understanding the borrowers' economic environment and their decision-making process is key to improving 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. Rather, our point estimates suggest the possibility that modifying the repayment and disbursement scheme can improve the repayment rate. This result is interesting as these modified schemes attracted borrowers with less steady income flows, who are usually regarded as riskier borrowers. Further investigation on the repayment performance with larger sample size and better understanding of borrower's selection and repayment performance are left to future research.

Figure 9: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = \hat{\beta} = 0.6$)

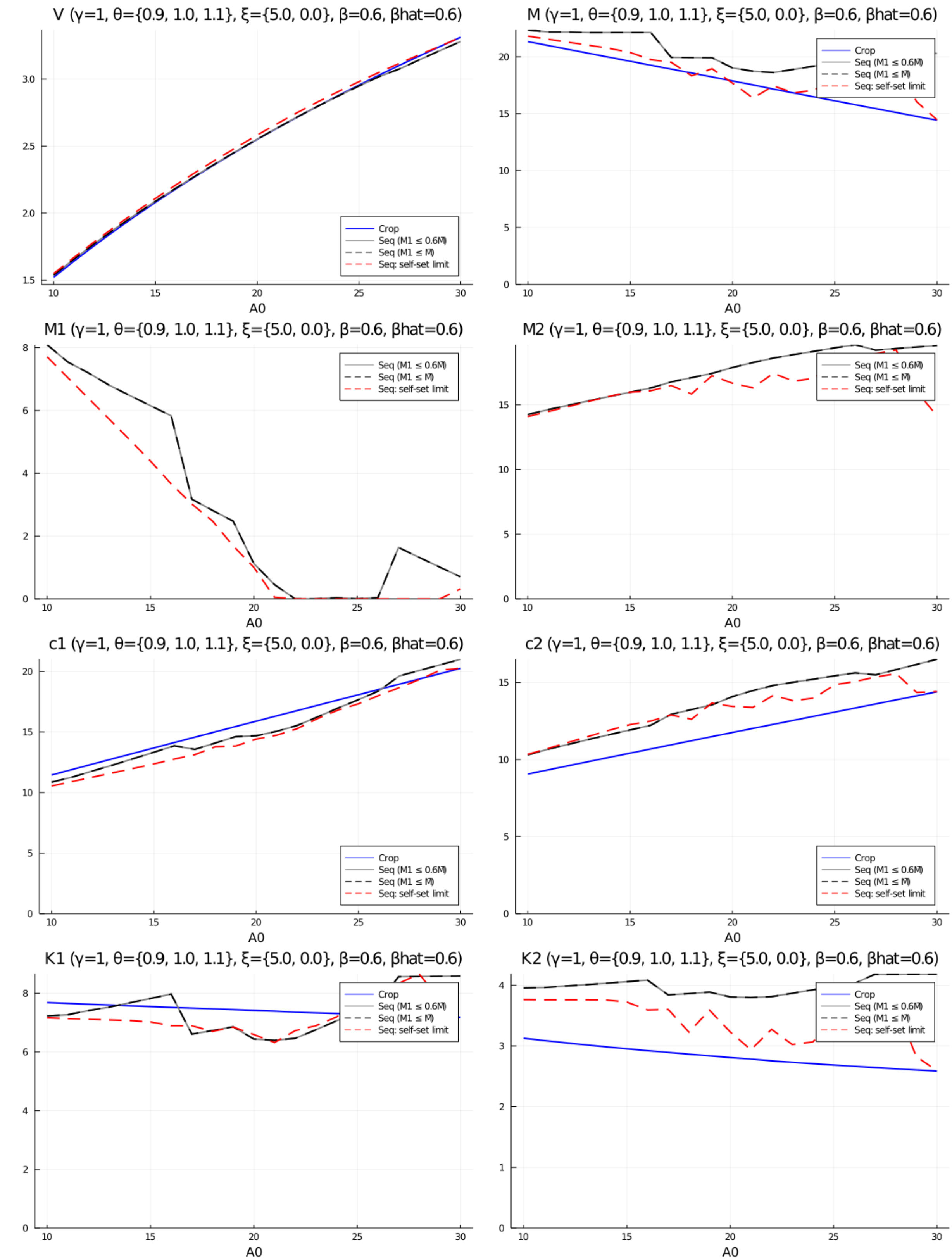
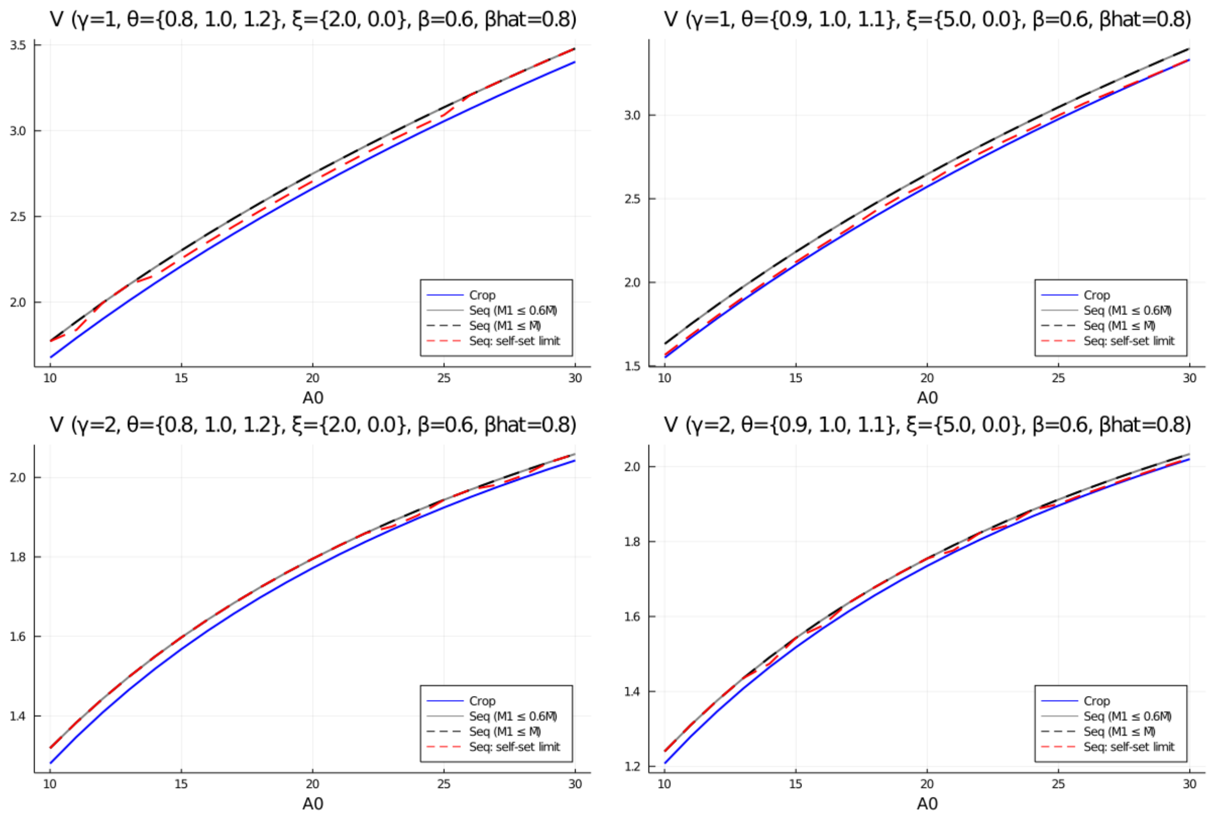


Figure 10: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = 0.6, \hat{\beta} = 0.8$)



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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

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

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

$$A_1 = A_0 + M_1 - \frac{\pi}{3}(1+r)M, \tag{A.3}$$

$$A_2 = A_1 - c_1 - K_1 + M - M_1 - \frac{\pi}{3}(1+r)M. \tag{A.4}$$

Note that the disbursement schedule, captured by M_1, will not affect the borrower's decision unless M_1 is sufficiently small that the period-1 budget constraint binds. The borrower will not benefit from such a low level of M_1 since it only imposes the additional binding constraint. Hence, we can ignore the decision on M_1 in the analysis below.

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, we start with the problem at $t=2$, where the borrower chooses (c_2,K_2). 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) constitutes the state variables for the decision problem at $t=2$. The first-order condition (FOC) is

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

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

$$\frac{\partial V_2}{\partial A_2} = u'(c_2^*) \tag{A.7}$$
$$\frac{\partial V_2}{\partial K_1} = F_1'(K_1, K_2^*)u'(c_3^*) \tag{A.8}$$
$$\frac{\partial V_2}{\partial M} = -\left(1 - \frac{2\pi}{3}\right)(1+r)u'(c_3^*).$$

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

$$\begin{aligned} \max_{c_1, K_1} \quad & u(c_1) + V_2(A_2, K_1, M) \\ \text{s.t.} \quad & c_1 + K_1 \leq A_1 \\ & A_2 = A_1 - c_1 - K_1 + M - M_1 - \frac{\pi}{3}(1+r)M \end{aligned} \tag{A.9}$$

Note that the constraint (A.9) will not bind if M_1 is close to M.[41] Then, we can write the value function as

$$V_1(A_1, M) = \max_{c_1, K_1} \; u(c_1) + V_2\left(A_1 - c_1 - K_1 + M - M_1 - \frac{\pi}{3}(1+r)M, K_1, M\right)$$

The FOCs are

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

Using equations (A.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

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

Combined with equations (A.6) and (A.10), equation (A.11) implies

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

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

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

If M_1 is close to M, then $c_2 < 0$, which contradicts the borrower's optimization.

The partial derivatives of the value function are:

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

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

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

$$\begin{aligned} \max_{M} \quad & V_1(A_1, M) \\ \text{s.t.} \quad & M \leq \overline{M}. \\ & A_1 = A_0 + M_1 - \frac{\pi}{3}(1+r)M. \end{aligned} \tag{A.16}$$

If the constraint (A.16) does not bind, the FOC is

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

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 borrower chooses the credit size M so that

$$F_1'(K_1^*, K_2^*) = F_2'(K_1^*, K_2^*) = 1 + \frac{r}{Q}. \tag{A.17}$$

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 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 π, we can apply the comparative statics to the FOCs (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 the installment before the harvest (an increase in π) 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.[42] Specifically, the effect of π on M can be written as

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

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

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

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 42.[43] 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 M_1 does not affect the decisions as long as the budget constraint at $t = 1$, (A.9), does not bind. Further reduction in M_1 will tighten the budget constraint at period 1 and hence will reduce the borrower's welfare.

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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 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 $M^* = \overline{M}$,

$$\frac{\partial K_j^*}{\partial \pi} = -\frac{1}{3} \frac{(F_{12}'' - F_{jj}'')(1+r)\overline{M}[u''(c_1^*) + 2F_1'u''(c_3^*)]}{[(F_{12}'')^2 - F_{11}''F_{22}'']u'(c_3^*) + (2F_{12}'' - F_{11}'' - F_{22}'')[u''(c_1^*) + (F_1')^2u''(c_3^*)]} < 0 \qquad \text{for } j = 1, 2,$$

$$\frac{\partial c_1^*}{\partial \pi} = \frac{\partial c_2^*}{\partial \pi} = -\frac{(1+r)\overline{M}}{6} \frac{(2F_{12}'' - F_{11}'' - F_{22}'')[u''(c_1^*) + 2F_1'(F_1' - 1)u''(c_3^*)] - [(F_{12}'')^2 - F_{11}''F_{22}'']u'(c_3^*)}{[(F_{12}'')^2 - F_{11}''F_{22}'']u'(c_3^*) + (2F_{12}'' - F_{11}'' - F_{22}'')[u''(c_1^*) + (F_1')^2u''(c_3^*)]} < 0.$$

[43] 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 π 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 π, 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 the terms gives the expression (A.18).

A.1.2 A present-biased borrower

Consider a quasi-hyperbolic discounter who discounts the future by β. At $t = 0$, she decides the total credit size M and the amount of the credit disbursed at $t = 1$, M_1. She believes that her future selves will discount the future by $\hat{\beta} \in [\beta, 1]$. If $\hat{\beta} = \beta$, she correctly predicts her present biasedness (sophisticated). If $\hat{\beta} = 1$, she is unaware of her present bias (naive).

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

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

Period-2 problem

Write the discounted value function that 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 β along with the state variables (A_2, K_1, M). The FOC is

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

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

The partial derivatives of the discounted continuation value are

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

Period-1 problem

At $t = 1$, 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 (A_1, M), which makes the analysis simpler.

The discounted value function that her period-1 self maximizes is

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

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 $\hat{\beta}$.

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

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

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

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

or

$$\hat{V}_2(A_2, K_1, M; \hat{\beta}) = \frac{1}{\hat{\beta}}\left[W_2(A_2, K_1, M; \hat{\beta}) - (1-\hat{\beta}) u(c_2^{*(\hat{\beta})})\right]. \tag{A.21}$$

Then, we can derive[44]:

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

$$= F_2'(K_1, K_2^{*(\hat{\beta})})u'(c_3^{*(\hat{\beta})})\left[1 - (1-\hat{\beta})\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}\right] \tag{A.22}$$

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

$$= u'(c_3^{*(\hat{\beta})})\left[F_1'(K_1, K_2^{*(\hat{\beta})}) + (1-\hat{\beta})F_2'(K_1, K_2^{*(\hat{\beta})})\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}\right], \tag{A.23}$$

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

$$= -u'(c_3^{*(\hat{\beta})})\left[1 + r + (1-\hat{\beta})F_2'(K_1, K_2^{*(\hat{\beta})})\frac{\partial c_2^{*(\hat{\beta})}}{\partial M}\right]. \tag{A.24}$$

Decision rules at $t = 1$ We denote the decision rules of the borrower's period-1 self by $c_1^{*(\beta,\hat{\beta})} \equiv c_1(A_0, M, M_1; \beta, \hat{\beta})$ and $K_1^{*(\beta,\hat{\beta})} \equiv K_1(A_0, M, M_1; \beta, \hat{\beta})$ to make explicit their dependence on the true β and her belief $\hat{\beta}$. We separately consider the decision rules when the constraint (A.20) does not bind and when it does.

[44]By differentiating equation (A.19), we can derive the partial derivatives $\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}$ and $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1}$ as follows:

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

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

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

Case (a): the constraint (A.20) does not bind. The FOCs are

$$u'(c_1^{*(\beta,\hat{\beta})}) - \beta \frac{\partial \hat{V}_2(A_2^*, K_1^{*(\beta,\hat{\beta})}, M; \hat{\beta})}{\partial A_2} = 0 \tag{A.25}$$

$$-\beta \frac{\partial \hat{V}_2(A_2^*, K_1^{*(\beta,\hat{\beta})}, M; \hat{\beta})}{\partial A_2} + \beta \frac{\partial \hat{V}_2(A_2^*, K_1^{*(\beta,\hat{\beta})}, M; \hat{\beta})}{\partial K_1} = 0, \tag{A.26}$$

where $A_2^* = A_0 + M - c_1^{*(\beta,\hat{\beta})} - K_1^{*(\beta,\hat{\beta})}$ is the value of A_2 on the optimal path. Using expression (A.22), the FOC (A.25) is rewritten as

$$u'(c_1^{*(\beta,\hat{\beta})}) = \beta F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) u'(c_3^{*(\hat{\beta})}) \left[1 - (1-\hat{\beta}) \frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} \right], \tag{A.27}$$

where $\frac{c_2^{*(\hat{\beta})}}{\partial A_2} > 0$ (footnote 44). Comparison with the FOC at $t = 2$, (A.19), implies $c_1^{*(\beta,\hat{\beta})} \geq c_2^{*(\hat{\beta})}$ where the strict inequality holds if $\hat{\beta} < 1$. The term $(1-\hat{\beta}) \frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2}$ reflects the fact that the borrower who understands her present bias ($\hat{\beta} < 1$) makes her consumption decision considering that the current increase in the consumption and thus the reduction in A_2 will constrain her period-2 consumption, alleviating the present bias problem at $t = 2$. Hence, being aware of own present bias will further exacerbate the overconsumption at $t = 1$, as she expects that her future self will consume more if she chooses lower consumption to leave more asset for her future self.

We can also rewrite the FOC (A.26) as

$$F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) - F_1'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) = (1-\hat{\beta})\hat{\beta} F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) \left[\frac{\partial c_2^{*(\hat{\beta})}}{\partial A_2} + \frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1} \right]. \tag{A.28}$$

The marginal product of the investment will be equalize if she is unaware of her present bias ($\hat{\beta} = 1$). If $\beta < 1$, then $F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) > F_1'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})})$.[45]

Note that given A_0 and M, the value of M_1 will not affect the state variable at $t = 2$, (A_2, K_1, M), when the constraint (A.20) does not bind. Hence, the FOCs (A.25) and (A.26) imply that:

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

which also implies that:

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

[45] Using the expression for the partial derivatives derived in footnote 44, equation (A.28) becomes

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

which can be rewritten as

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

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

Case (b): the constraint (A.20) binds. With the constraint (A.20) binding, the borrower maximizes $u(A_1 - K_1) + \beta \hat{V}_2(M - M_1, K_1, M; \hat{\beta})$, which gives the FOC

$$-u'(c_1^{*(\beta,\hat{\beta})}) + \beta \frac{\partial \hat{V}_2(M - M_1, K_1^{*(\beta,\hat{\beta})}, M; \hat{\beta})}{\partial K_1} = 0 \tag{A.29}$$

which balances the current cost of reducing c_1 and the future benefit of increasing K_1. By substituting expression (A.26), this condition becomes

$$u'(c_1^{*(\beta,\hat{\beta})}) = \beta u'(c_3^{*(\hat{\beta})}) \left[F_1'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) + (1 - \hat{\beta}) F_2'(K_1^{*(\beta,\hat{\beta})}, K_2^{*(\hat{\beta})}) \frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1} \right]. \tag{A.30}$$

If $\frac{\partial K_2^{*(\hat{\beta})}}{\partial K_1} < 0$, which is the plausible case as stated in footnote 44, being aware of own present bias will further exacerbate the overconsumption at $t = 1$, as she expects that her future self will compensate the reduction of the output loss due to the smaller first investment by increasing the second investment.

Period-0 problem

Now consider the problem at $t = 0$ and examine if she prefers to make this constraint binding. Taking into account the decision rules of her future selves, she maximizes her utility

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

by setting M and M appropriately.

Let $c_1^{+(\hat{\beta},\hat{\beta})}$ and $K_1^{+(\hat{\beta},\hat{\beta})}$ be the level of c_1 and K_1 that would be chosen when the constraint (A.20) does not bind and the present bias parameter is $\hat{\beta}$. Define $M_1^{+(\hat{\beta},\hat{\beta})}$ as the level of the first disbursement that just covers the expenditure at $t = 1$, net of the endowment A_0, that is, $c_1^{+(\hat{\beta},\hat{\beta})} + K_1^{+(\hat{\beta},\hat{\beta})} = A_0 + M_1^{+(\hat{\beta},\hat{\beta})}$. With this $M_1^{+(\hat{\beta},\hat{\beta})}$, $A_2 = M - M_1^{+(\hat{\beta},\hat{\beta})}$. Hence, her utility when $M_1 = M_1^{+(\hat{\beta},\hat{\beta})}$ is expressed as

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

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

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

Note that we are evaluating this expression at $(c_1, K_1, M_1) = (c_1^{+(\hat{\beta},\hat{\beta})}, K_1^{+(\hat{\beta},\hat{\beta})}, M_1^{+(\hat{\beta},\hat{\beta})})$, and we can substitute the equations (A.25) and (A.26). By substituting these and arranging terms, we can rewrite the above expression as

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

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

By setting M_1 small to bind the period-1 budget constraint, she can increase A_2. Since $\frac{\partial K_2^{*(\hat{\beta})}}{\partial A_2} > 0$ as shown in footnote 44, it is straightforward to show that the sequential credit that allows borrowers to choose the amount of the first disbursement will increase the second investment.[46]

A.2 Uncertainty and option values

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

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

where $\theta_t > 0$ are the productivity shocks revealed at the beginning of period $t = 1, 2$. Expenditure shocks $\xi_t \geq 0$ revealed at the beginning of period $t = 1, 2$ reduce the resource available for consumption and investment at each period. That is, the budget constraints at each period become

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

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

$$\begin{aligned} A_1 &= A_0 + M \\ A_2 &= A_1 - \xi_1 - c_1 - K_1. \end{aligned} \tag{A.31}$$

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

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

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

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

which follows from the equations (A.19) and (A.27). Clearly, the consumption path will be smoother under the sequential credit than under the crop credit.

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

$$V_2^C(A_2, K_1, M, \theta_1, \theta_2, \xi_2) = \max_{c_2, K_2} u(c_2) + u(\theta_1\theta_2 F(K_1, K_2) - (1+r)M + A_2 - \xi_2 - c_2 - K_2)$$
$$\text{s.t. } c_2 + K_2 \leq A_2 - \xi_2. \tag{A.32}$$

Denoting the Lagrange multiplier associated with the constraint (A.32) by η, the FOCs are written as

$$u'(c_2^*) - u'(c_3^*) - \eta = 0, \tag{A.33}$$
$$[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1] u'(c_3^*) - \eta = 0.$$

If the constraint (A.32) 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[47]:

$$\frac{\partial V_2^C}{\partial A_2} = u'(c_2^*) \tag{A.34}$$
$$\frac{\partial V_2^C}{\partial K_1} = \theta_1\theta_2 F_1'(K_1, K_2^*) u'(c_3^*) \tag{A.35}$$
$$\frac{\partial V_2^C}{\partial M} = -(1+r)u'(c_3^*).$$

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

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

The FOCs and equations (A.31), (A.34), and (A.35) imply that:

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

The partial derivatives of the value function are

$$\frac{\partial V_1^C}{\partial A_1} = E\left[\left.\frac{\partial V_2}{\partial A_2}\right|\theta_1, \xi_1\right] = E[u'(c_2^*)|\theta_1, \xi_1] \tag{A.36}$$
$$\frac{\partial V_1^C}{\partial M} = E\left[\left.\frac{\partial V_2}{\partial M}\right|\theta_1, \xi_1\right] = -(1+r)E[u'(c_3^*)|\theta_1, \xi_1]. \tag{A.37}$$

[47]Note that whether the constraint (A.32) binds does not matter for the partial derivatives of the value function. When the constraint (A.32) binds, then

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

Then we obtain $\frac{\partial V_2^C}{\partial A_2} = u'(c_2^*)$. When the constraint (A.32) does not bind, then $\frac{\partial V_2^C}{\partial A_2} = u'(c_3^*)$. However, in this case $\eta = 0$ and the FOC A.33 implies $u'(c_2^*) = u'(c_3^*)$, resulting in $\frac{\partial V_2^C}{\partial A_2} = u'(c_3^*)$.

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

$$\begin{aligned} \max_{M} \quad & E[V_1(A_1, M, \theta_1, \xi_1)] \\ \text{s.t.} \quad & M \le \overline{M}. \\ & A_1 = A_0 + M. \end{aligned} \tag{A.38}$$

If the constraint (A.38) does not bind, the FOC 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.36) and (A.37) as

$$E[u'(c_2^*)] = (1+r)E[u'(c_3^*)]. \tag{A.39}$$

A.2.2 Sequential credit

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

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

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

$$V_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2) = \max_{c_2, K_2, M_2} u(c_2) + u(c_3)$$

$$\text{s.t. } c_2 + K_2 \le \tilde{A}_2 - \xi_2 + M_2 \tag{A.40}$$

$$M_2 \le M - M_1 \tag{A.41}$$

$$M_2 \ge 0 \tag{A.42}$$

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

Note that M_1 enter as the state variable as it affects the upper limit of M_2. The FOCs are:

$$u'(c_2^*) - u'(c_3^*) - \eta = 0, \tag{A.43}$$

$$[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1]u'(c_3^*) - \eta = 0, \tag{A.44}$$

$$- ru'(c_3^*) + \eta - \mu + \nu = 0, \tag{A.45}$$

where η, μ, and ν are the Lagrange multipliers associated with the constraints (A.40), (A.41), and (A.42), respectively. Note that μ and ν cannot take a value of 0 simultaneously. Further, equation (A.45) implies that $\eta = ru'(c_3^*) + \mu - \nu$, implying that $\eta > 0$ if $\nu = 0$. Hence there are four possible cases: (i) $\mu = \nu = 0, \eta > 0$, (ii) $\mu > 0, \nu = 0, \eta > 0$, (iii) $\mu = 0, \nu > 0, \eta = 0$, and (iv) $\mu = 0, \nu > 0, \eta > 0$. By substituting (A.45) into equations (A.43) and (A.44), we obtain

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

The partial derivatives of the value function are

$$
\frac{\partial V_2^S}{\partial \tilde{A}_2} = u'(c_2^*) \tag{A.46}
$$

$$
\frac{\partial V_2^S}{\partial K_1} = \theta_1\theta_2 F_1'(K_1, K_2^*)u'(c_3^*) \tag{A.47}
$$

$$
\frac{\partial V_2^S}{\partial M} = \begin{cases} 0 & \text{if } \mu = 0 \\ u'(c_2^*) - (1+r)u'(c_3^*) & \text{if } \mu > 0 \end{cases} \tag{A.48}
$$

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

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

$$
\begin{aligned}
V_1^S(A_1, M, M_1, \theta_1, \xi_1) = \max_{c_1, K_1} \; & u(c_1) + E\left[V_2^S(A_1 - \xi_1 - c_1 - K_1, K_1, M, M_1, \theta_1, \theta_2, \xi_2)\middle|\, \theta_1, \xi_1\right] \\
\text{s.t. } \; & c_1 + K_1 \leq A_1 - \xi_1
\end{aligned} \tag{A.49}
$$

The FOCs are

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

where λ is the Lagrange multipliers associated with the constraint (A.49). Using equations (A.46) and (A.47), these conditions reduce to

$$
\begin{aligned}
&u'(c_1^*) = E\left[u'(c_2^*)|\theta_1, \xi_1\right] + \lambda. \\
&\theta_1 E\left[\theta_2 F_1'(K_1^*, K_2^*)u'(c_3^*)|\theta_1, \xi_1\right] = E\left[u'(c_2^*)|\theta_1, \xi_1\right] + \lambda.
\end{aligned}
$$

The partial derivatives of the value function are:[48]

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

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

$$\frac{\partial V_1^S}{\partial M_1} = -E\left[u'(c_2^*)|\theta_1,\xi_1\right] - E[\nu|\theta_1,\xi_1].$$

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

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

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

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

$$E[\mu] = 0. \tag{A.50}$$

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

[48]Here we provide the derivation of $\frac{\partial V_1^S}{\partial M}$. An analogous procedure gives $\frac{\partial V_1^S}{\partial M_1}$. From the definition of the value function $V_1^S(A_1, M, M_1, \theta_1, \xi_1)$ and equation (A.48),

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

where the last equation follows from equations (A.43) and (A.45). Using the fact that $\nu = 0$ if $\mu > 0$ and that $E[\mu|\theta_1,\xi_1] = \Pr(\mu > 0|\theta_1,\xi_1)E[\mu|\theta_1,\xi_1,\mu > 0]$ if $\mu \geq 0$, we obtain

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

A.2.3 Present-biased borrowers under the sequential credit

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

$$
\begin{aligned}
W_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \beta) = \max_{c_2, K_2, M_2} \; & u(c_2) + \beta u(c_3) \\
\text{s.t. } & c_2 + K_2 \leq \tilde{A}_2 - \xi_2 + M_2 && \text{(A.51)} \\
& M_2 \leq M - M_1 && \text{(A.52)} \\
& M_2 \geq 0 && \text{(A.53)} \\
& c_3 = \theta_1\theta_2 F(K_1, K_2) - (1+r)(M_1 + M_2) + \tilde{A}_2 - \xi_2 + M_2 - c_2 + K_2
\end{aligned}
$$

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

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

which gives us the decision rules $c_2^* = c_2(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \beta)$, $K_2^* = K_2(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \beta)$, and $M_2^* = M_2(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \beta)$. Hereafter, we write them as $c_2^{*(\beta)}$, $K_2^{*(\beta)}$, and $M_2^{*(\beta)}$ for brevity. If the constraints (A.52) and (A.53) do not bind, then the second investment will be made optimally. The partial derivatives of the value function are

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

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

$$
\begin{aligned}
W_1^S(A_1, M, M_1, \theta_1, \xi_1; \beta, \hat{\beta}) = \max_{c_1, K_1} \; & u(c_1) + \beta E\left[\hat{V}_2^S(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2; \hat{\beta}) \middle| \theta_1, \xi_1\right] \\
\text{s.t. } & c_1 + K_1 \leq A_1 - \xi_1 && \text{(A.54)} \\
& \tilde{A}_2 = A_1 - \xi_1 - c_1 - K_1
\end{aligned}
$$

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:

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

The FOCs are:

$$u'(c_1^*1) - \beta E\left[\left.\frac{\partial \hat{V}_2^S(\cdot;\hat{\beta})}{\partial \tilde{A}_2}\right| \theta_1, \xi_1\right] - \lambda = 0, \tag{A.55}$$

$$\beta E\left[\left.-\frac{\partial \hat{V}_2^S(\cdot;\hat{\beta})}{\partial \tilde{A}_2} + \frac{\partial \hat{V}_2^S(\cdot;\hat{\beta})}{\partial K_1}\right| \theta_1, \xi_1\right] - \lambda = 0, \tag{A.56}$$

where λ is the Lagrange multiplier associated with the constraint (A.54). These conditions give

$$u'(c_1^*) = \beta E\left[\left.\frac{\partial \hat{V}_2^S(\cdot;\hat{\beta})}{\partial K_1}\right| \theta_1, \xi_1\right]. \tag{A.57}$$

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

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

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

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

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

Then, the FOCs (A.55) and (A.56) can be written as:

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

$$\beta E\left[\theta_1\theta_2 F_1'(K_1^*, K_2^{*(\hat{\beta})})u'(c_3^{*(\hat{\beta})})\Big|\theta_1, \xi_1\right] = \frac{\beta}{\hat{\beta}}E\left[\left.\left\{1 - (1-\hat{\beta})\left(\frac{\partial c_2^{*(\hat{\beta})}}{\partial \tilde{A}_2} - \frac{\partial c_2^{*(\hat{\beta})}}{\partial K_1}\right)\right\}u'(c_2^{*(\hat{\beta})})\right|\theta_1, \xi_1\right] + \lambda.$$

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

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

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

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

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

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

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

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

and

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

The right-hand sides of these equations are positive. Remember that for the time-consistent borrowers, the right-hand sides are zero. This implies that the PB borrower will choose M and M_1 so that the probability of the resource constraints at $t = 1, 2$ 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 avoid the curse of dimensionality.

A.3.1 Benchmark model

First consider the benchmark model without uncertainty. As stated in equations (A.6), (A.12), (A.13), and (A.17), the FOCs are given by

$$
\begin{aligned}
c_1^* &= c_2^* && \text{(A.58)}\\
F_1'(K_1^*, K_2^*) &= F_2'(K_1^*, K_2^*) && \text{(A.59)}\\
u'(c_2^*) &= F_2'(K_1^*, K_2^*)u'(c_3^*) \\
F_1'(K_1^*, K_2^*) &= 1 + \frac{r}{Q}. && \text{(A.60)}
\end{aligned}
$$

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

First, with the Cobb–Douglass production function $F(K_1, K_2) = \theta K_1^{\psi_1} K_2^{\psi_2}$, the equation (A.59) implies that K_2^* can be written as a function of K_1:

$$K_2^*(K_1) = \frac{\psi_2}{\psi_1} K_1. \tag{A.61}$$

Then from equation (A.58) combined with equations (6) and (4), 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:

$$c_3^*(K_1, M) = F(K_1, K_2^*(K_1)) - (Q + r)M. \tag{A.62}$$

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

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

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

To calibrate the parameter values, we use the equations (A.61) and (A.60). These imply

$$
\begin{aligned}
\frac{\psi_1}{\psi_2} &= \frac{K_1^*}{K_2^*},\\
\psi_2 \theta K_1^{*\psi_1} K_2^{*\psi_2 - 1} &= 1 + \frac{r}{Q}. && \text{(A.63)}
\end{aligned}
$$

which pin down the optimal inputs (K_1^*, K_2^*). We set $r = 0.12$ to mimic our intervention described in the next section. The crop credit corresponds to the case of $Q = 1$, and the sample averages of K_1 and K_2 for the crop credit borrowers were 8,547 BDT and 4,179 BDT, respectively. These give us the calibrated parameter values as $(\psi_1, \psi_2) = (0.283, 0.139)$. With these inputs, the output will be

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

With the sample averages of Y for the crop credit borrowers (33,767 BDT), we calibrated as $\theta = 15.075$.[49]

A.3.2 Crop credit under uncertainty

The model with uncertainty can be solved backwardly. For generality, we consider the case of the PB 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

$$\begin{aligned} u'(c_2^*) &= \beta u'(c_3^*) + \eta \\ \left[\theta_1 \theta_2 F_2'(K_1, K_2^*) - 1\right] \beta u'(c_3^*) &= \eta \end{aligned} \tag{A.64}$$

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

Suppose the constraint does not bind ($\eta = 0$). With the Cobb–Douglass production function, equation (A.64) implies that the optimal second investment K_2^* satisfies

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

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

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

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

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

Then, the optimal consumption levels are derived as $c_2^* = A_2 - K_2^* - \xi_2$ and $c_3^* = \theta_1 \theta_2 F_2(K_1, K_2^*) - (1+r)M$.

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

[49] This calibration only uses the information on the average input and output amount. 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 θ, and without valid exogenous instruments, we cannot obtain the consistent estimates on the production function parameters.

(undiscounted) value of being at state $(A_2, K_1, M, \theta_1, \theta_2, \xi_2)$ under the present bias parameter β as

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

The borrower who perceives 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

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

subject to $c_1 + K_1 \leq A_1 - \xi_1$, where $A_2 = A_1 - \xi_1 - c_1 - K_1$ and the expectation is taken over (θ_2, ξ_2). This can be solved by nonlinear optimization routines, which gives us the decision rules c_1 and K_1 as functions of $(A_1, M, \theta_1, \xi_1)$. We denote them by $c_1(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta})$, and $K_1(A_1, M, \theta_1, \xi_1; \beta, \hat{\beta})$ as they will also depend on the actual present bias parameter β and her belief in it, $\hat{\beta}$. We denote the value of being the state $(A_1, M, \theta_1, \xi_1)$ for this borrower as:

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

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

Remember that $A_1 = A_0 + M$. Therefore, the borrower will choose the optimal 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 (θ_1, ξ_1). Once M^* is obtained, the optimal level of c_1, c_2, c_3, K_1, K_2 for possible values of $(\theta_1, \theta_2, \xi_1, \xi_2)$ can be computed accordingly. By searching M^* first, we only need to compute the value function in the states that are visited through the optimization search routine.

A.3.3 Sequential credit under uncertainty

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

$$u'(c_2^*) = \beta u'(c_3^*) + \eta \tag{A.65}$$

$$\left[\theta_1\theta_2 F_2'(K_1, K_2^*) - 1\right] \beta u'(c_3^*) = \eta \tag{A.66}$$

$$- r\beta u'(c_3^*) + \eta - \mu + \nu = 0, \tag{A.67}$$

where η, μ, and ν are the Lagrange multipliers associated with the constraints $c_2 + K_2 \leq \tilde{A}_2 - \xi_2 + M_2$, $M_2 \leq M - M_1$, 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 $c_2^* + K_2^* = \tilde{A}_2 - \xi_2 + M_2^*$ and $0 < M_2^* < M - M_1$. Case (ii) corresponds to the case where $c_2^* + K_2^* = \tilde{A}_2 + M_2^*$ and $M_2^* = M - M_1$. Case (iii) is the case where $c_2^* + K_2^* < \tilde{A}_2 - \xi_2$ and $M_2^* = 0$. In case (iv), $c_2^* + K_2^* = \tilde{A}_2 - \xi_2$ and $M_2^* = 0$.

By using (A.67), the conditions (A.65) and (A.66) reduce to

$$u'(c_2^*) = (1+r)\beta u'(c_3^*) + \mu - \nu, \tag{A.68}$$

$$\left[\theta_1\theta_2 F_2'(K_1, K_2^*) - (1+r)\right] \beta u'(c_3^*) = \mu - \nu, \tag{A.69}$$

First consider case (i). With the Cobb–Douglass production function, equation (A.69) implies

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

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

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

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

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

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

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

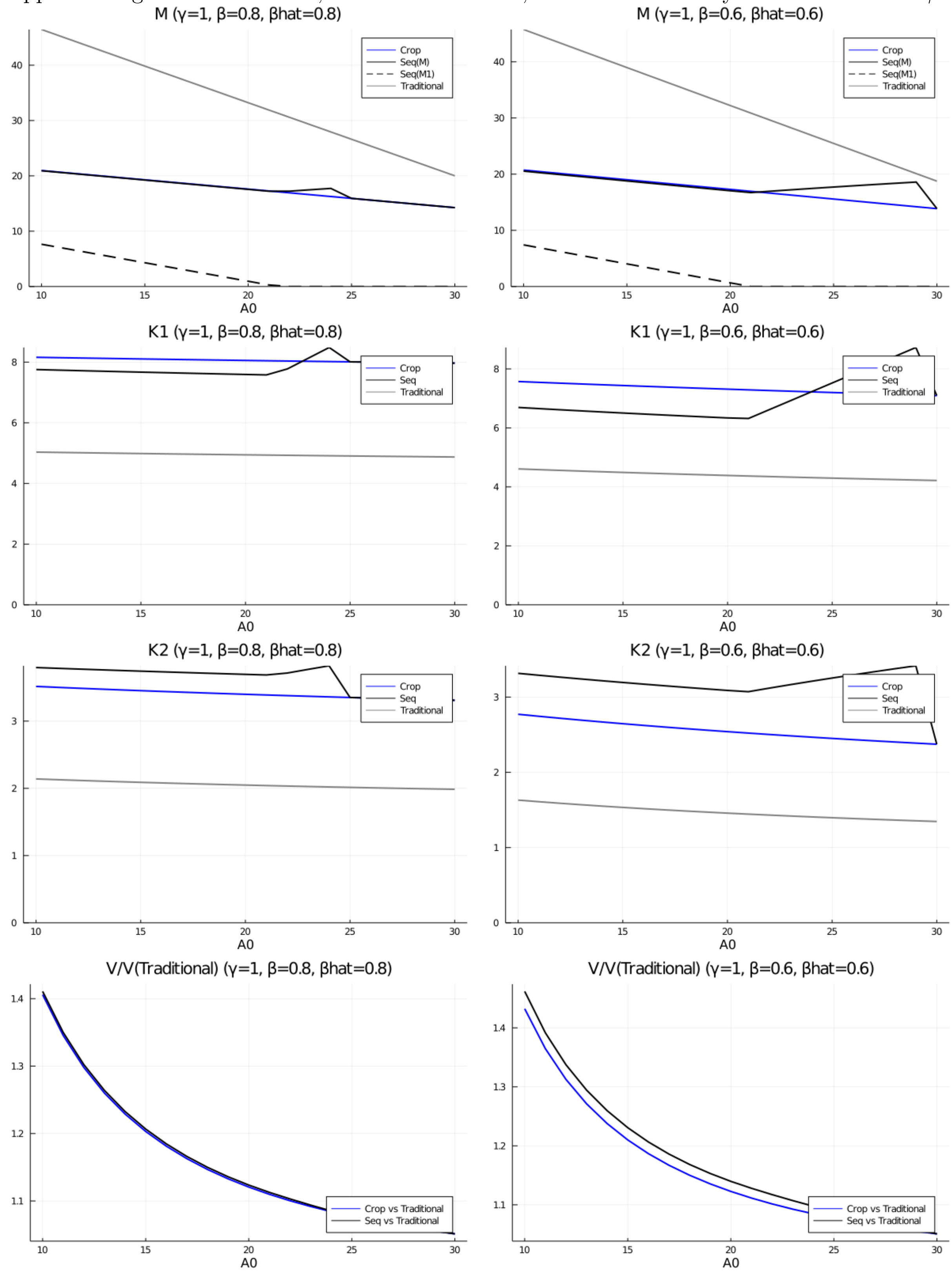
Once K_2^* is determined, we can compute $c_3^* = \theta_1\theta_2 F_2(K_1, K_2^*) - (1+r)M$.

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

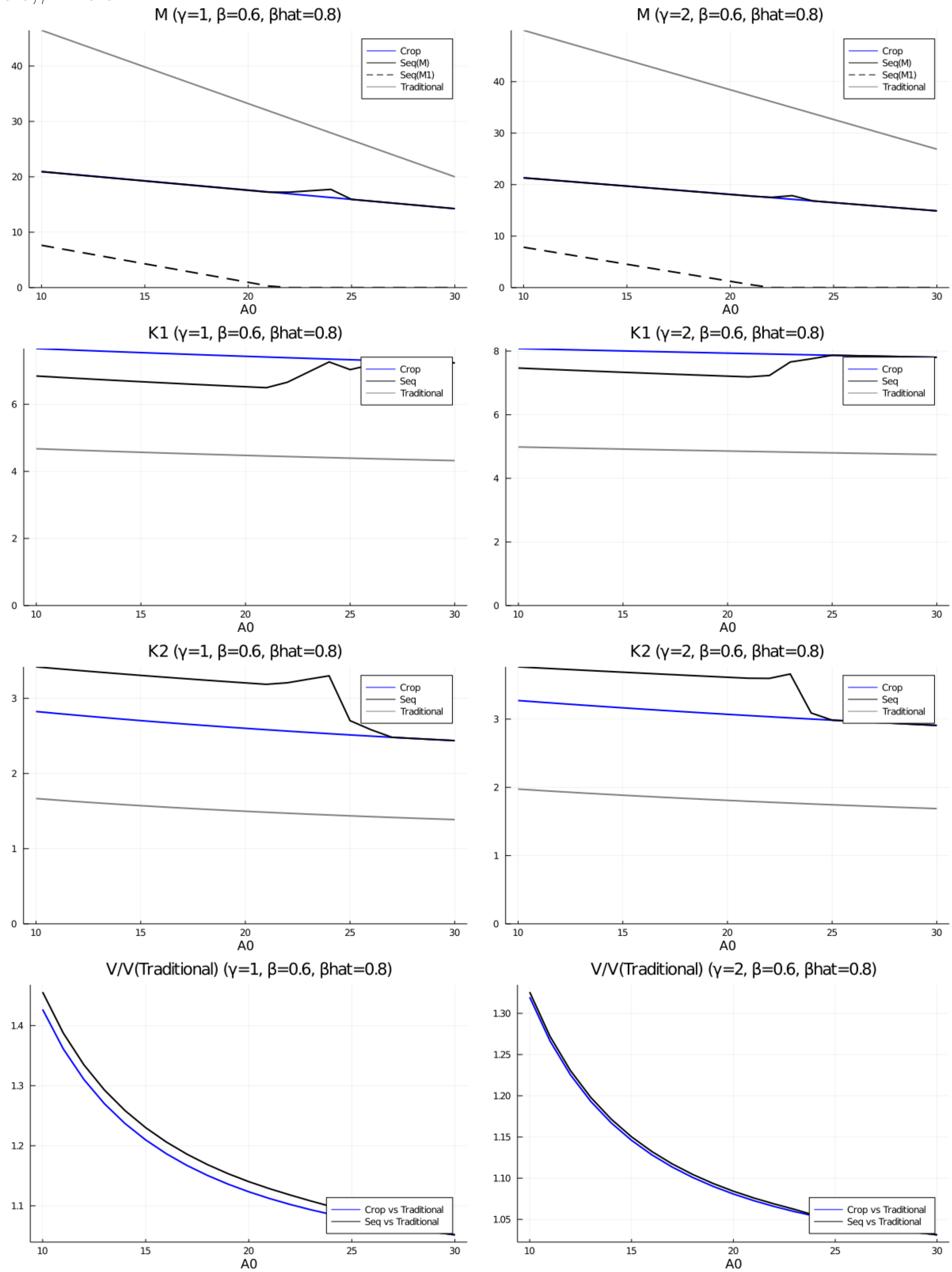
Once we obtain the decision rules for K_2, M_2, c_2, and c_3 as functions on the state variables $(\tilde{A}_2, K_1, M, M_1, \theta_1, \theta_2, \xi_2)$, the computation procedures are similar to the case of the crop credit described above, except that the borrower chooses the amount of the first disbursement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

A.4 Appendix Figures and Tables

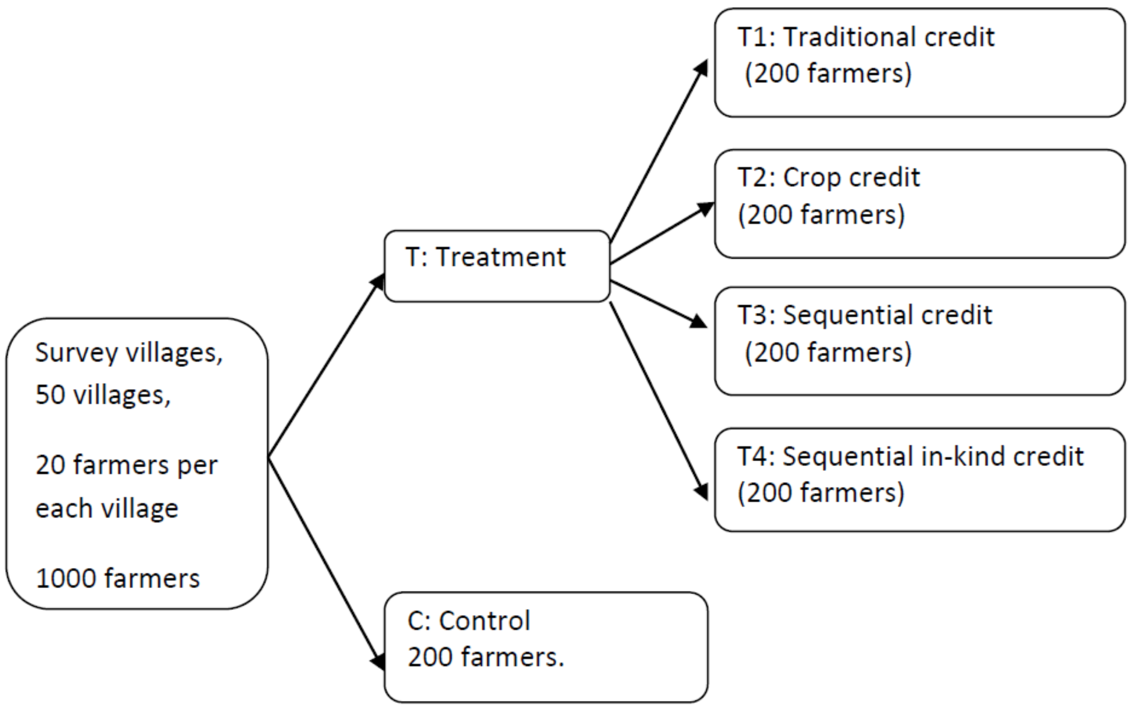
Appendix Figure 1: Credit size, investment amount, and the total utility of PB borrowers: $\gamma = 1$



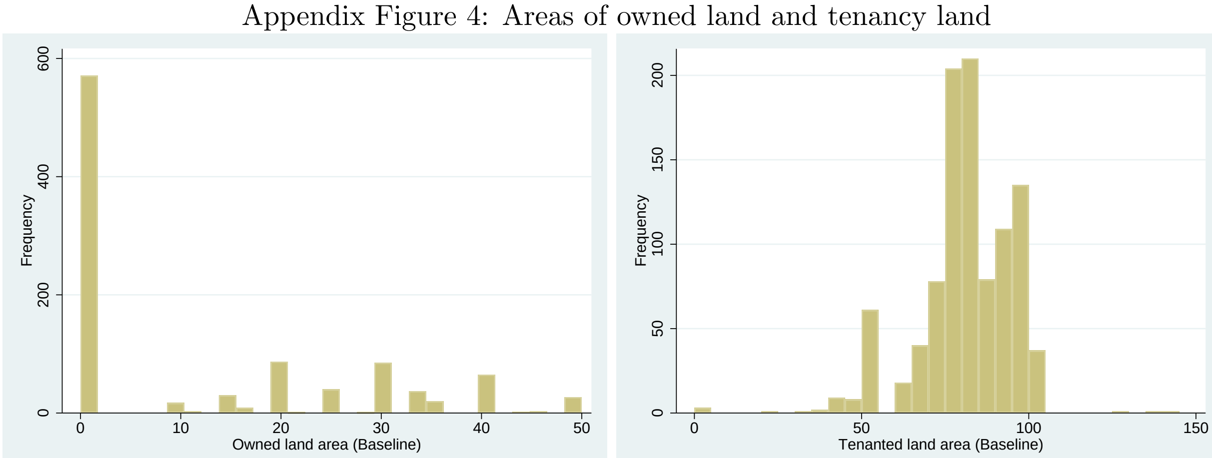
Appendix Figure 2: Credit size, investment amount, and the total utility of PB borrowers: $\beta = 0.6, \hat{\beta} = 0.8$



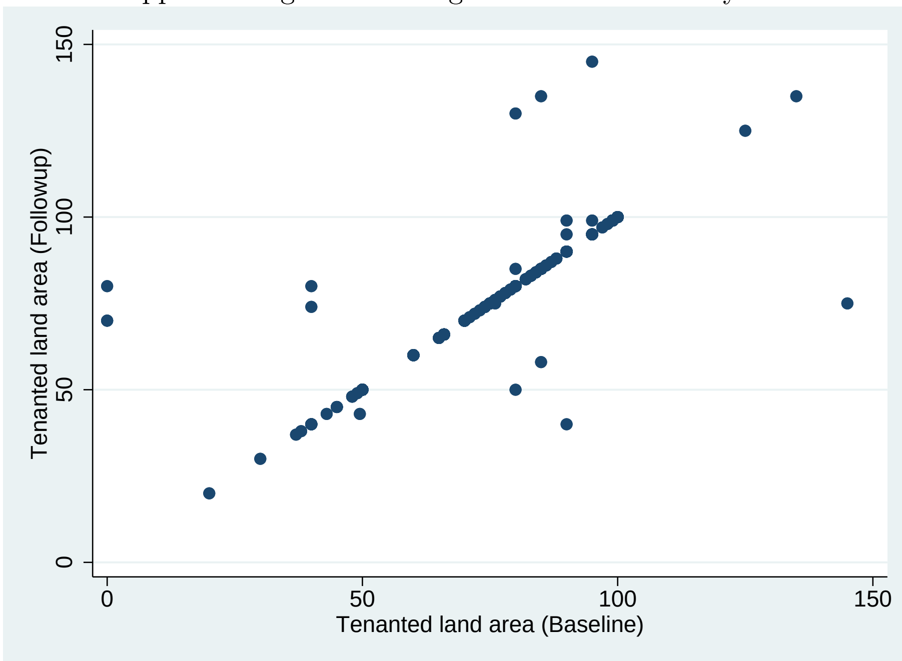
Appendix Figure 3: Experimental design



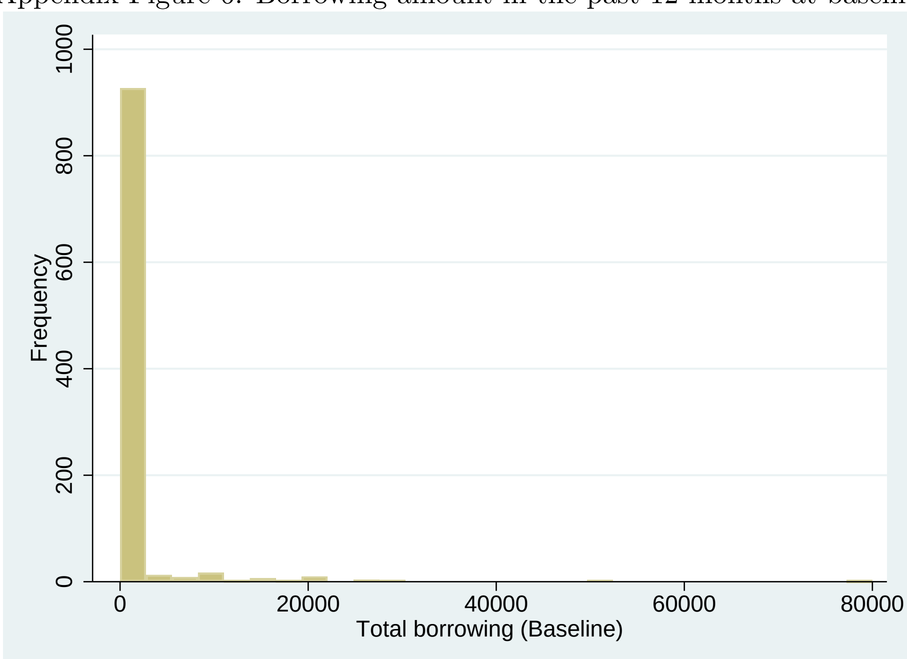
Appendix Figure 4: Areas of owned land and tenancy land



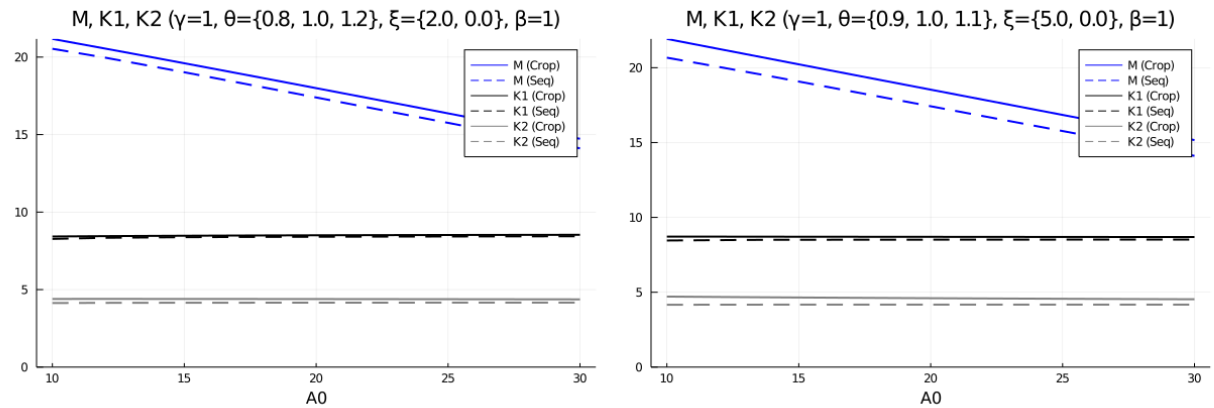
Appendix Figure 5: Changes in areas of tenancy land



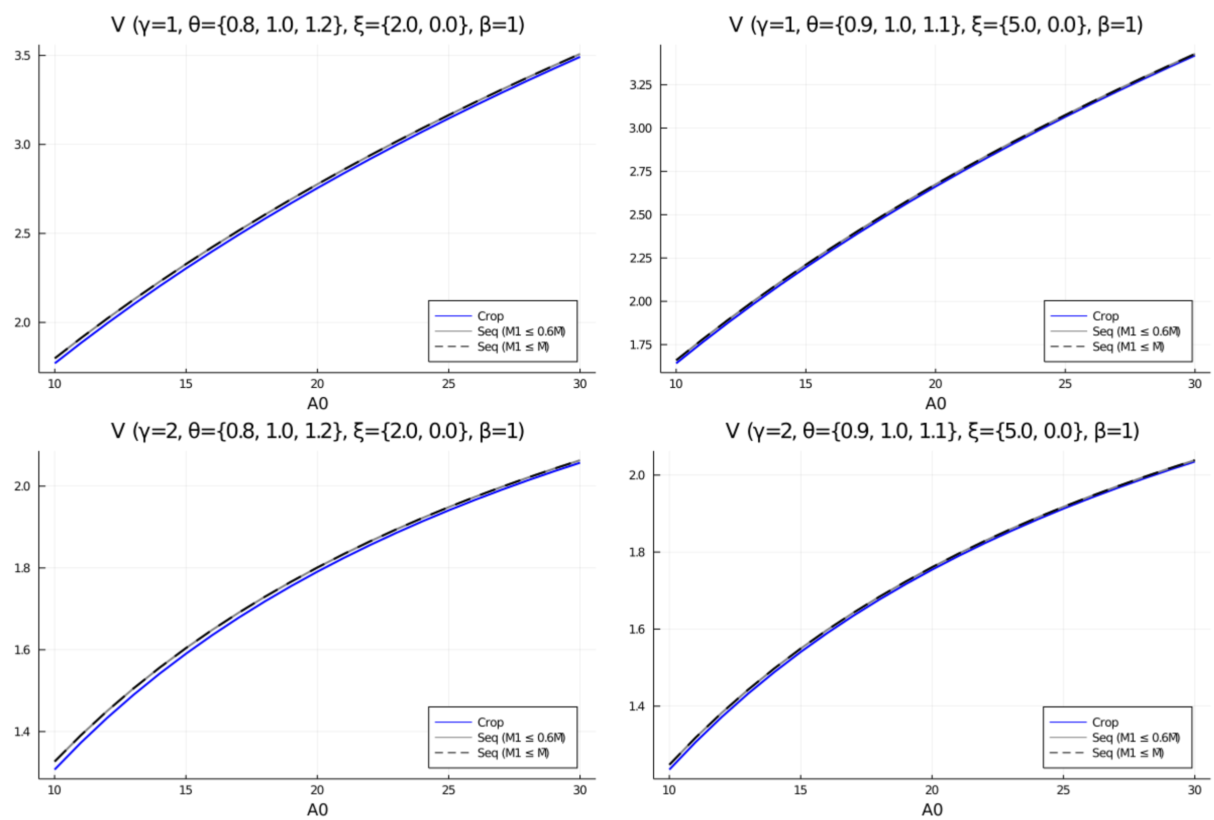
Appendix Figure 6: Borrowing amount in the past 12 months at baseline



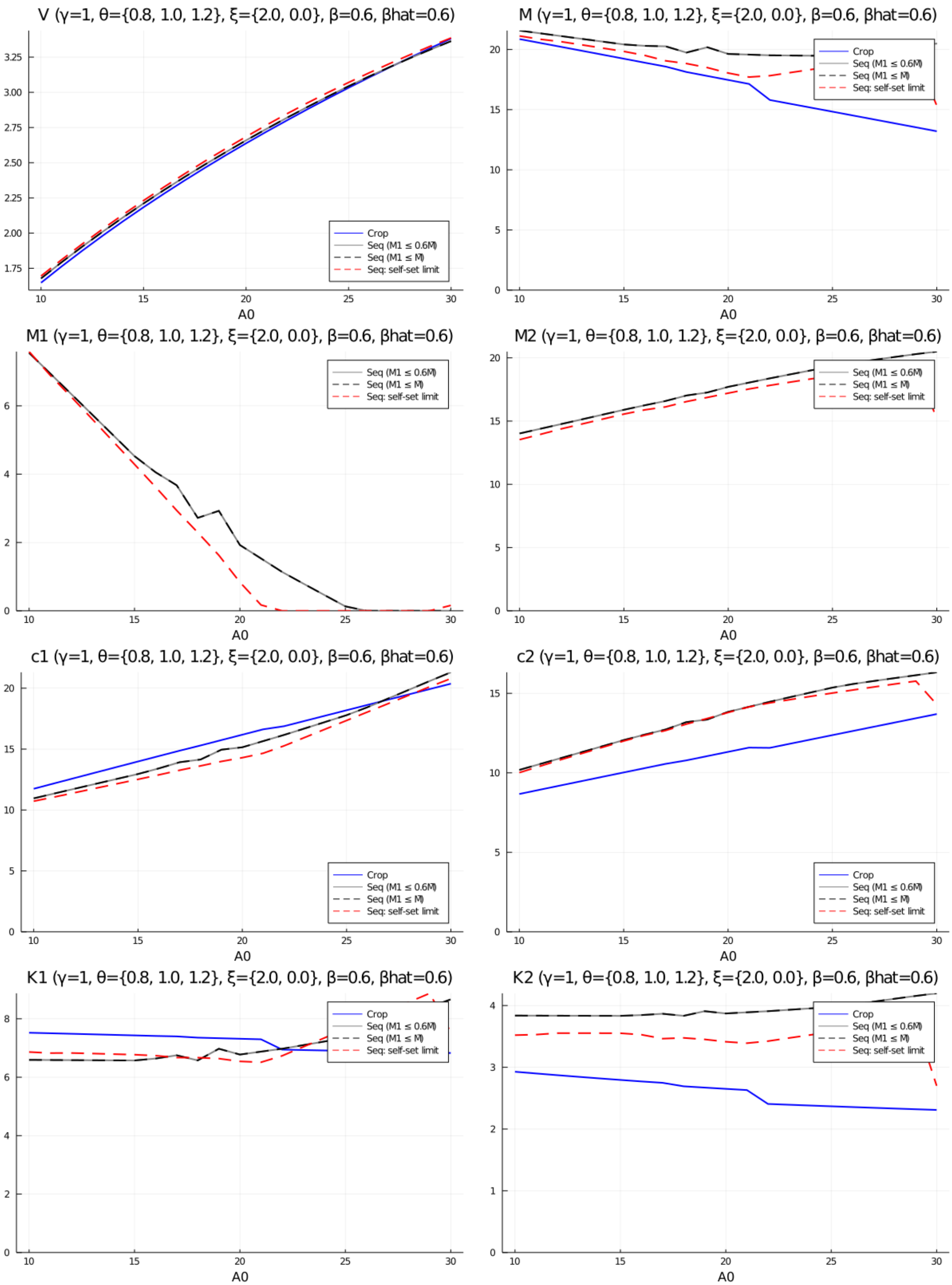
Appendix Figure 7: Choice of (M, K_1, K_2) under crop credit and sequential credit when $\gamma = 2$ (with uncertainty)



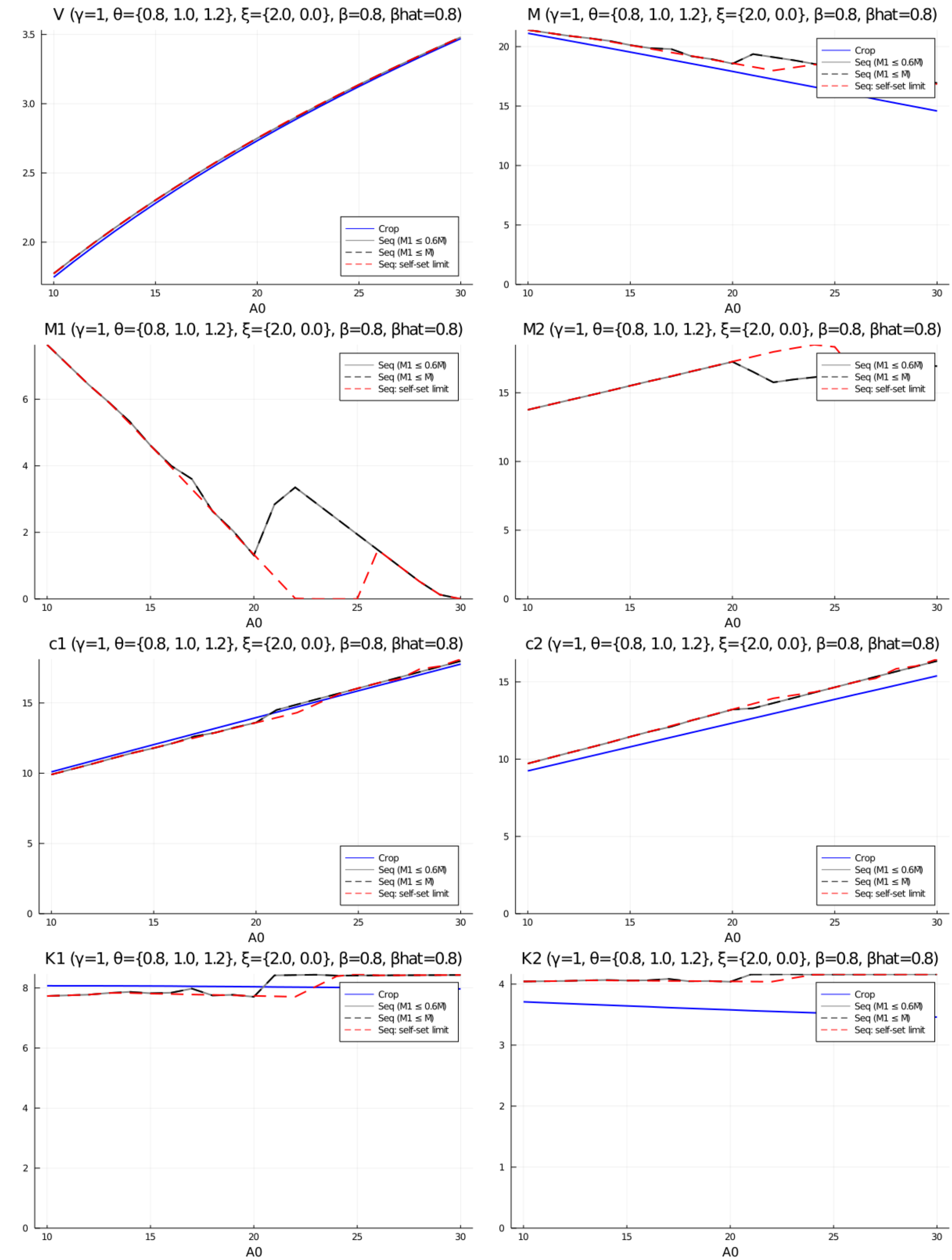
Appendix Figure 8: Ex ante expected utility under crop credit and sequential credit (with uncertainty)



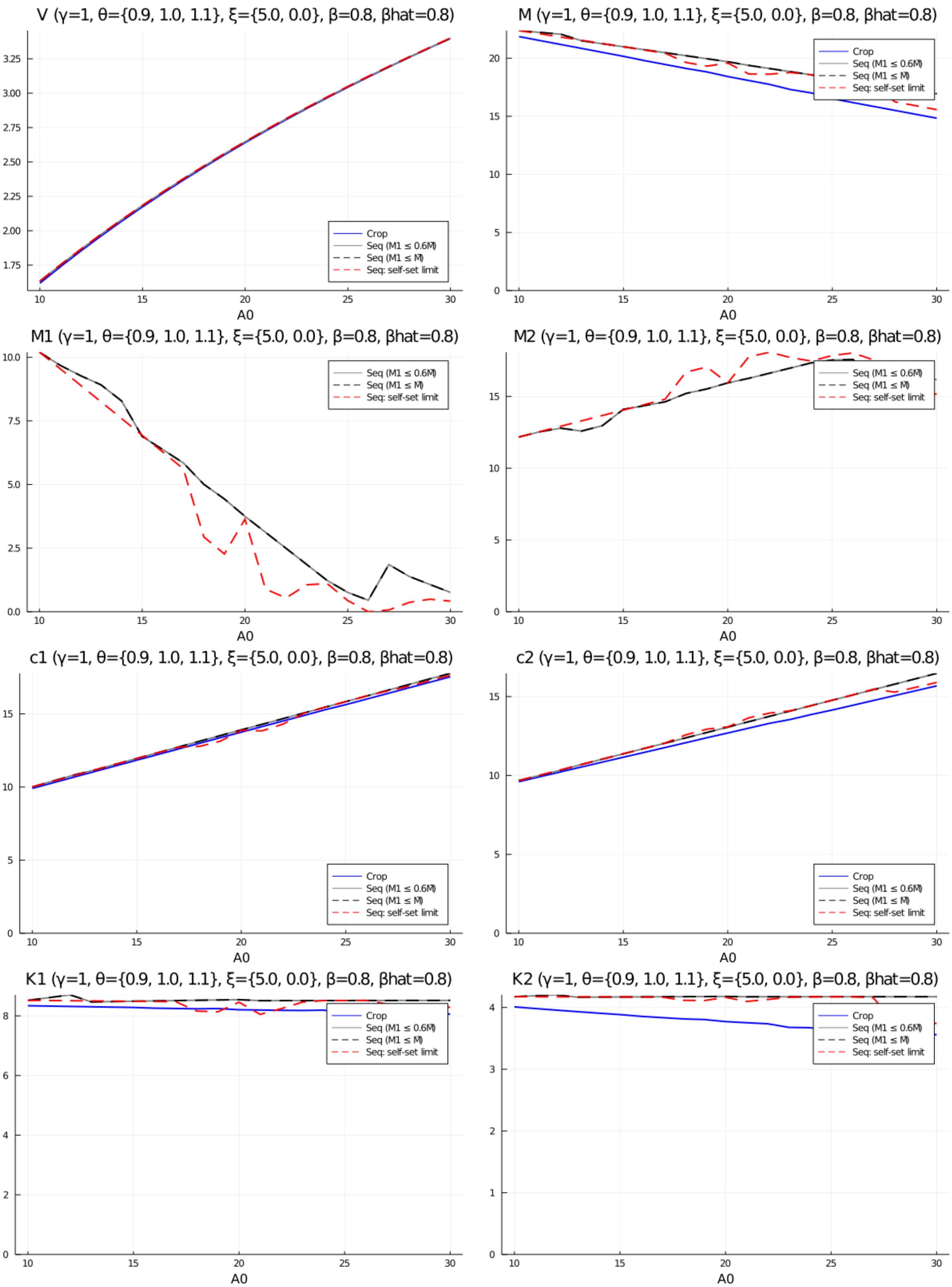
Appendix Figure 9: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = \hat{\beta} = 0.6$)



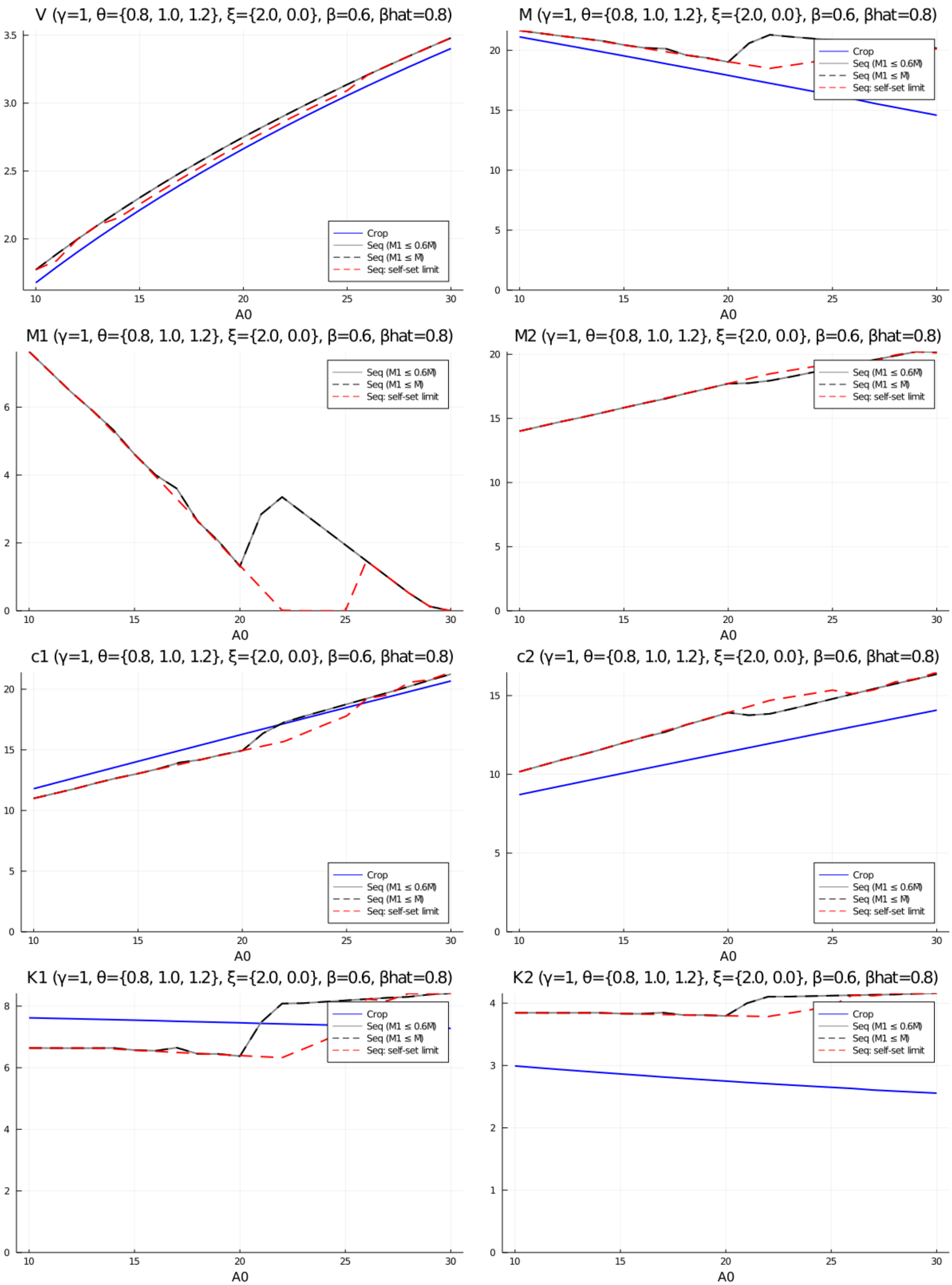
Appendix Figure 10: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = \hat{\beta} = 0.8$)



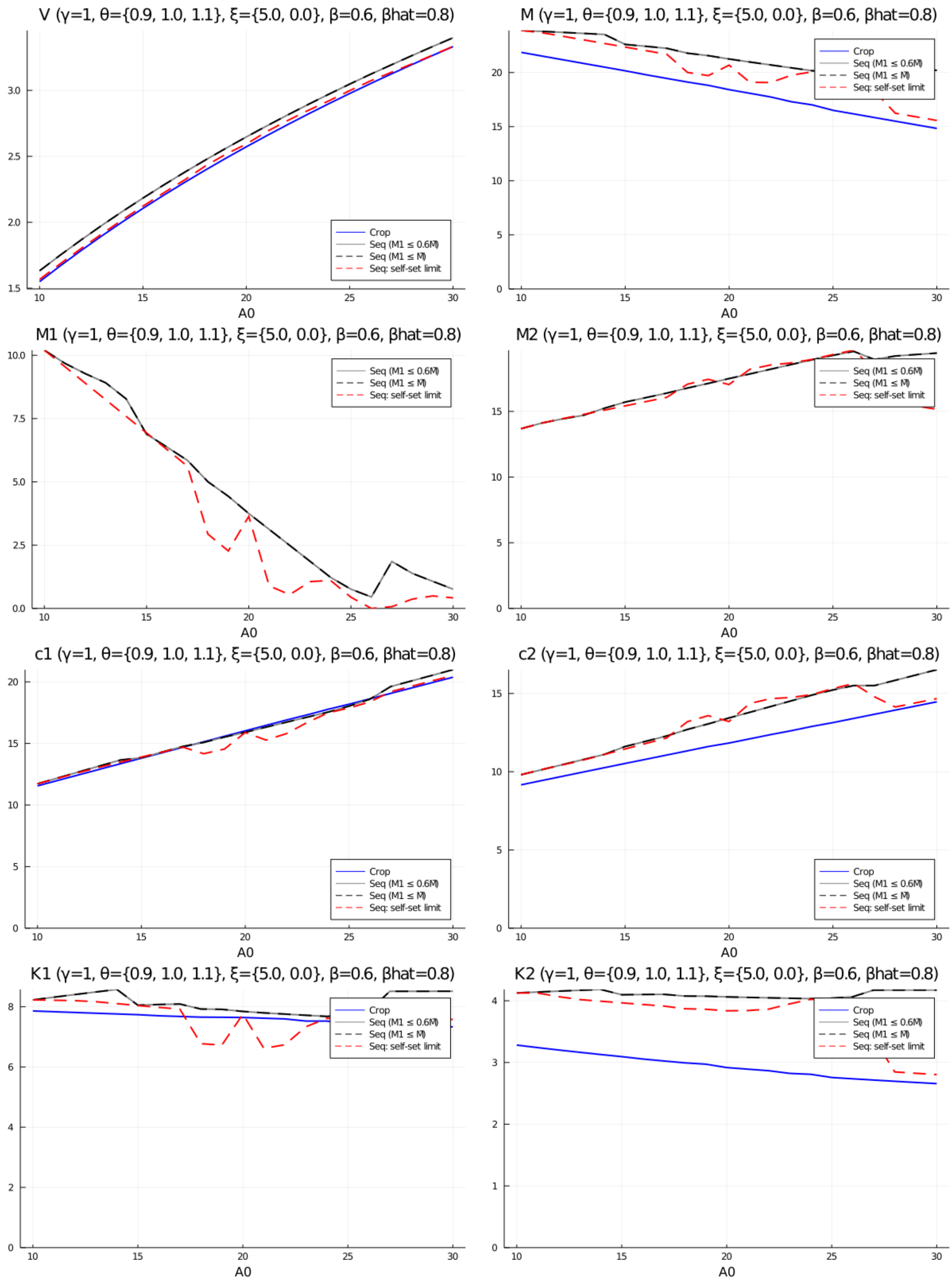
Appendix Figure 11: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = \hat{\beta} = 0.8$)



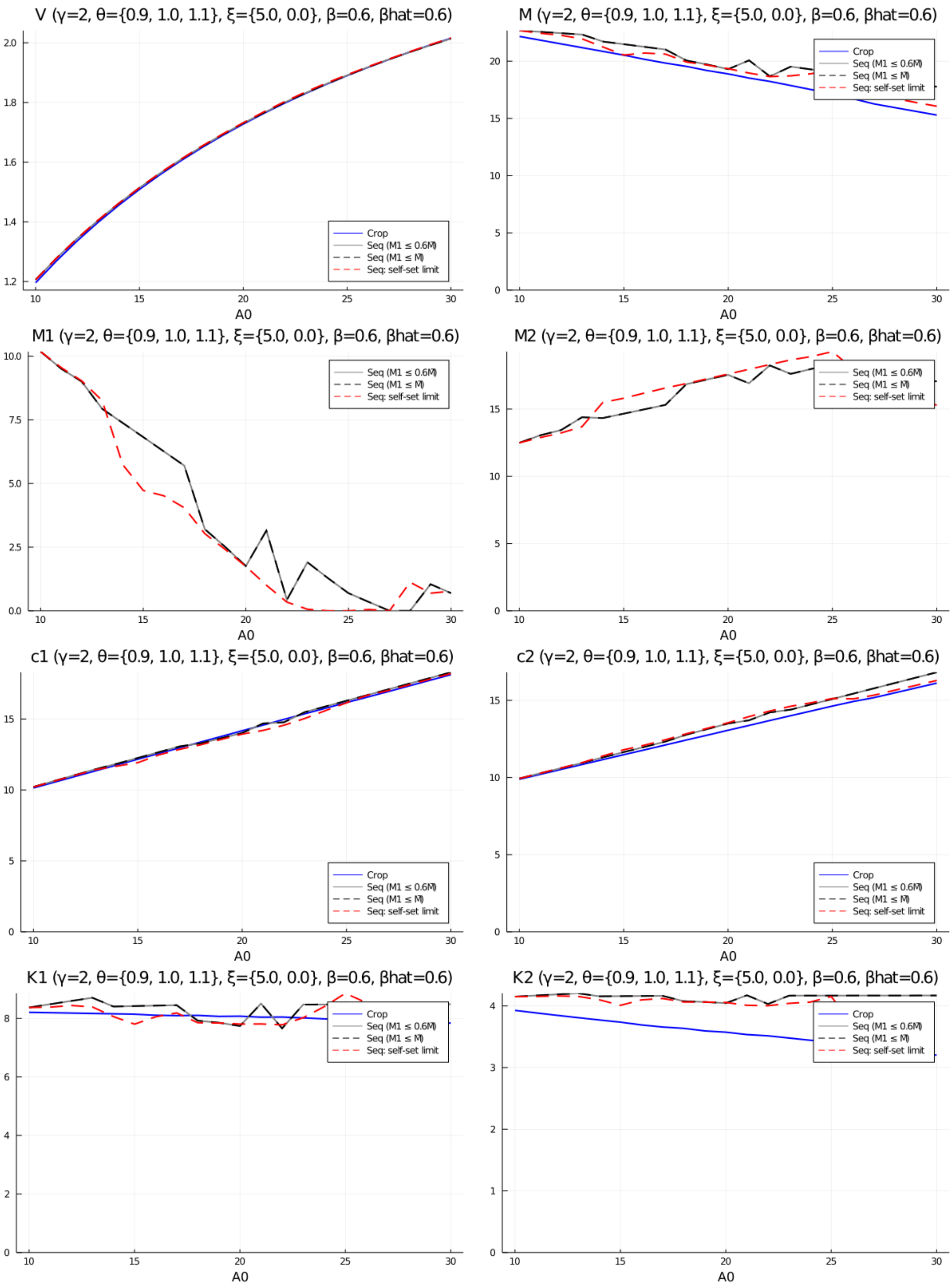
Appendix Figure 12: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = 0.8$, $\hat{\beta} = 0.6$)



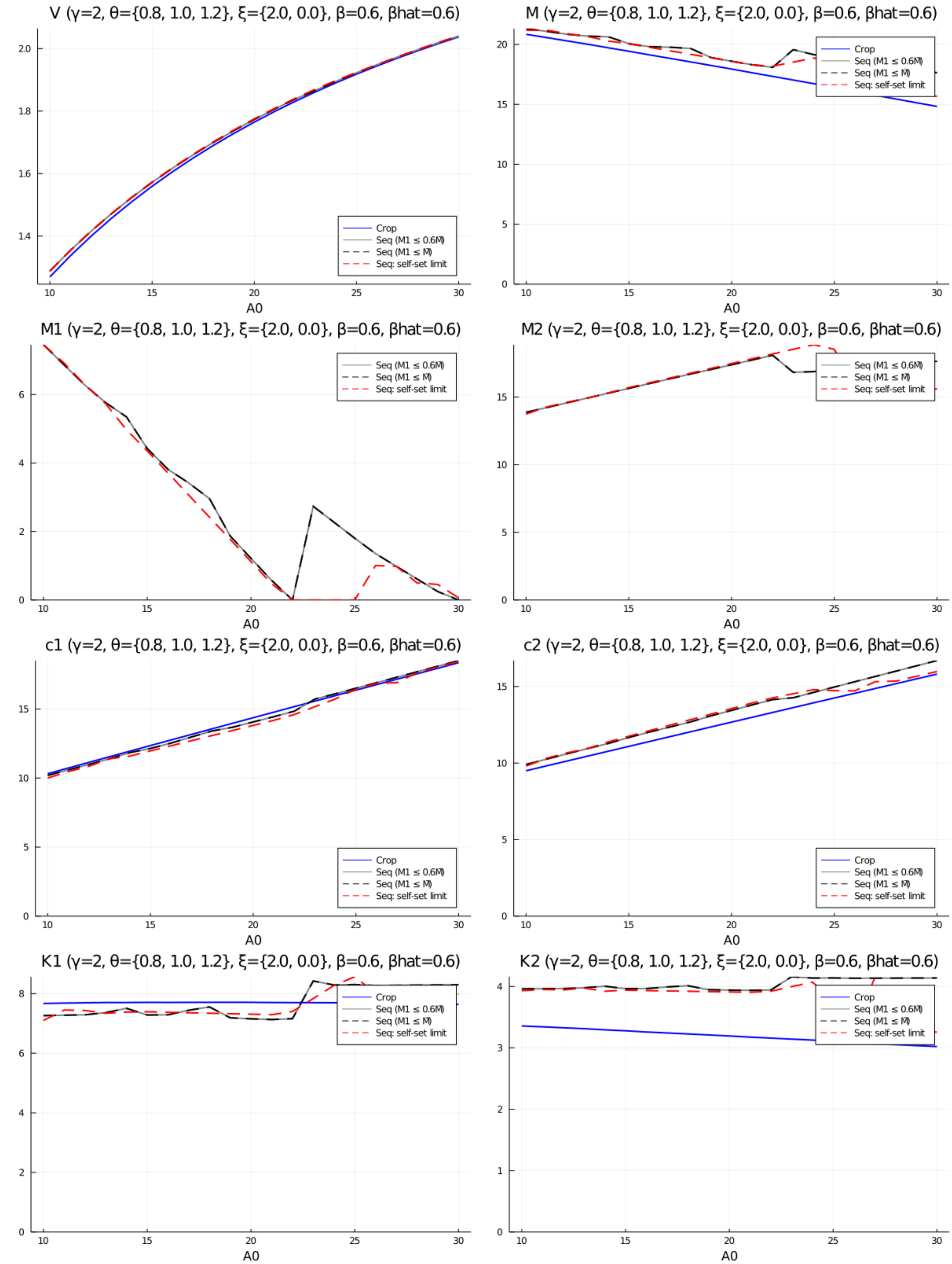
Appendix Figure 13: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = 0.8$, $\hat{\beta} = 0.6$)



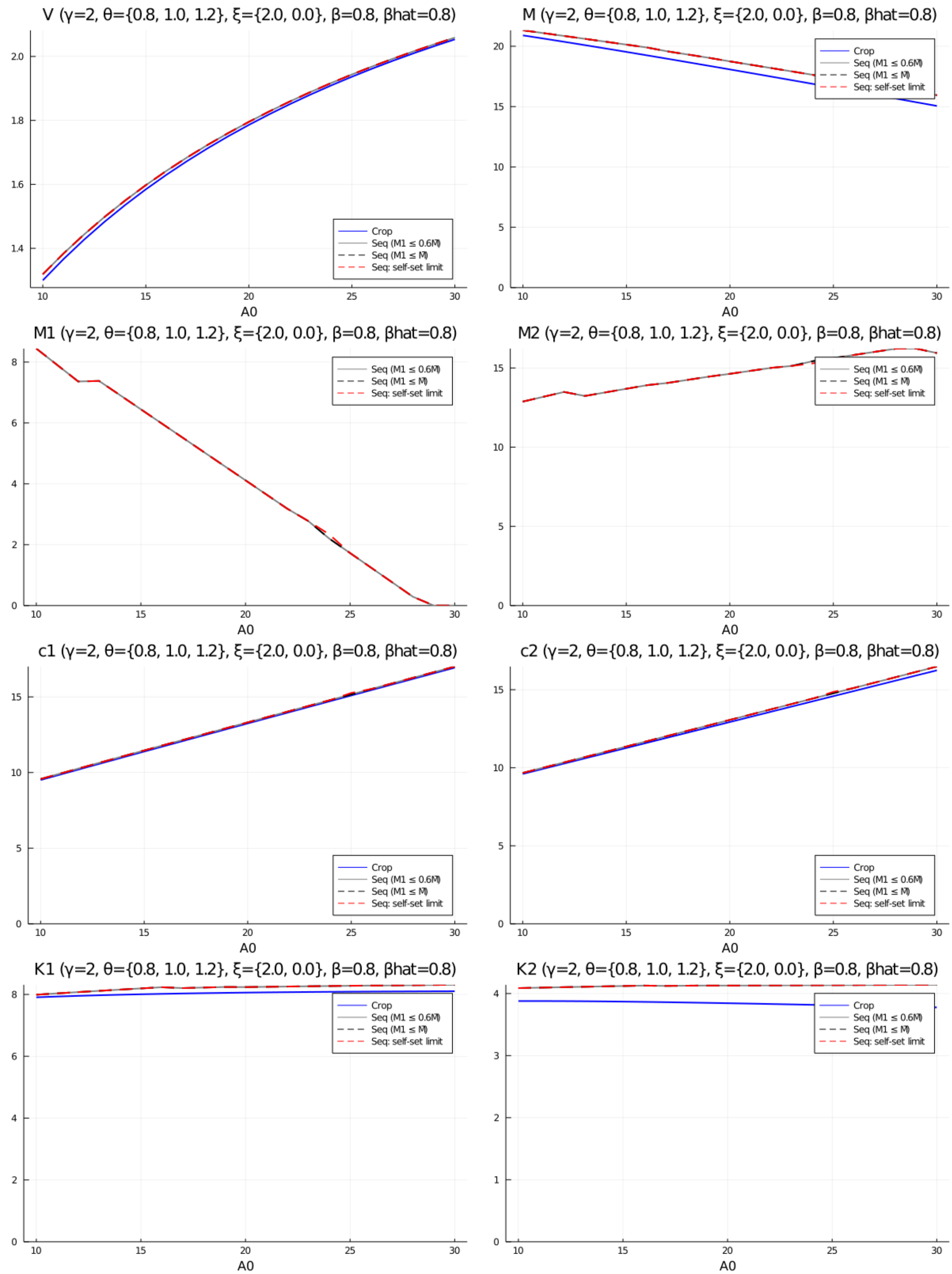
Appendix Figure 14: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = \hat{\beta} = 0.6$)



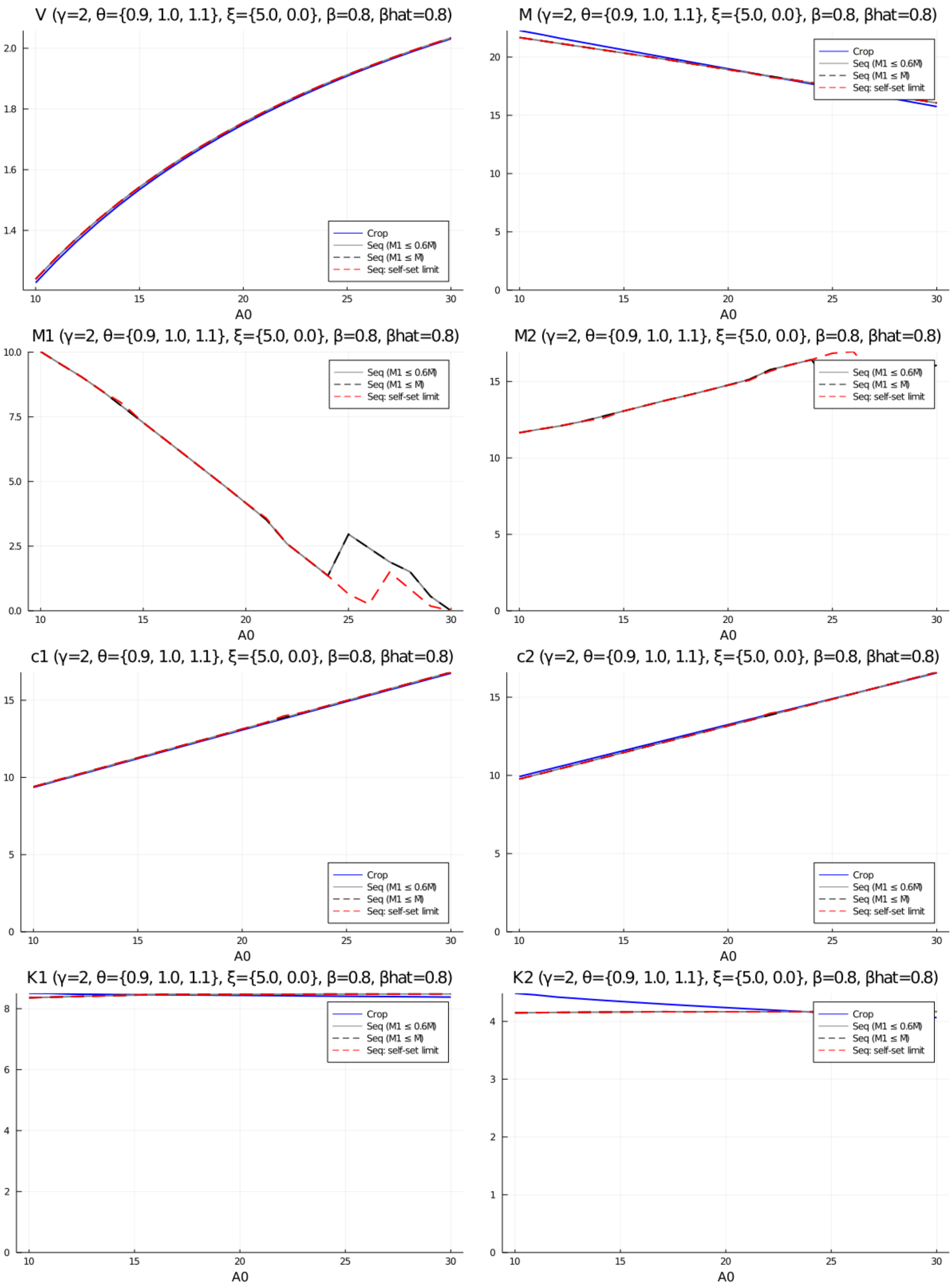
Appendix Figure 15: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = \hat{\beta} = 0.6$)



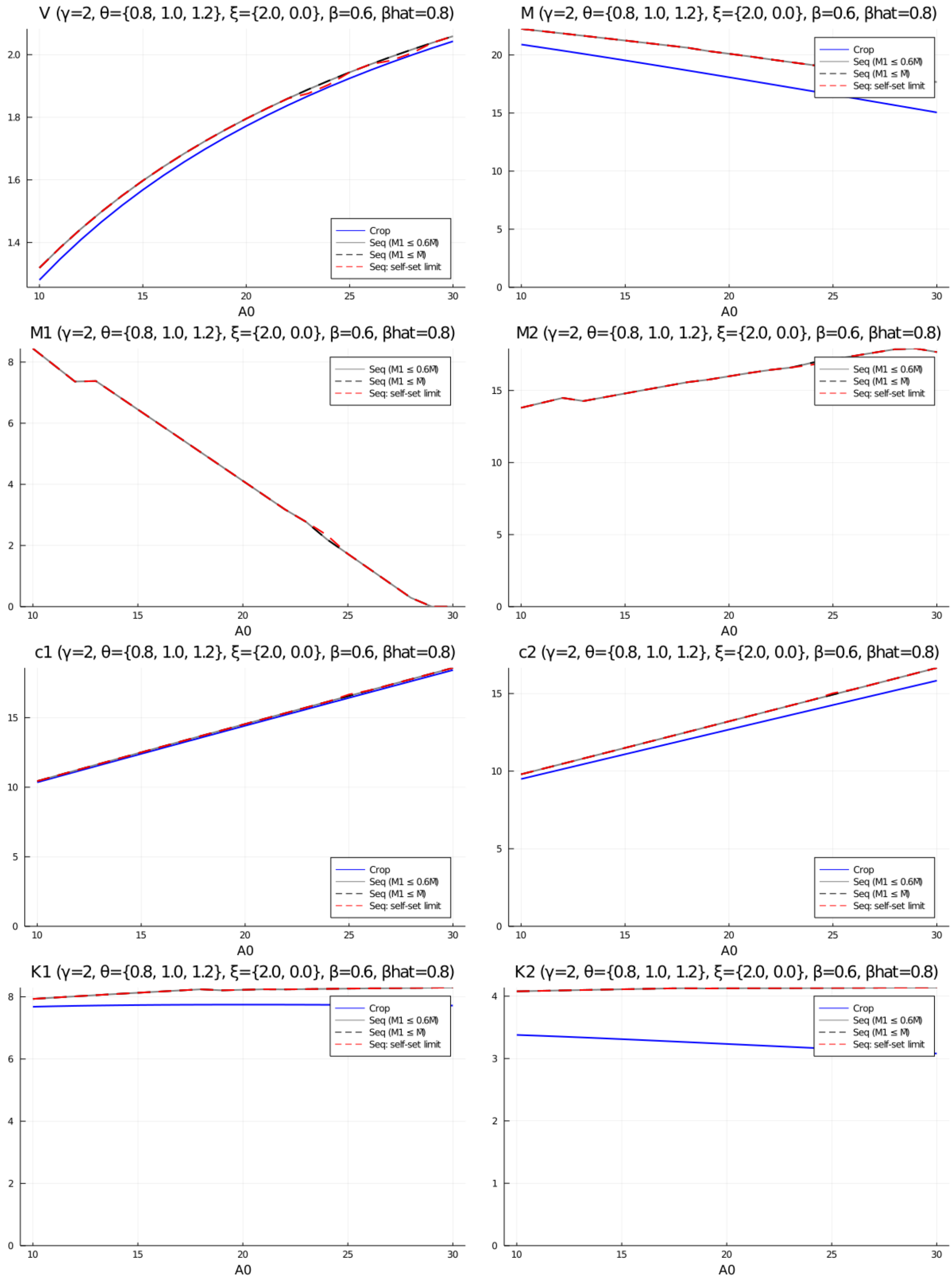
Appendix Figure 16: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = \hat{\beta} = 0.8$)



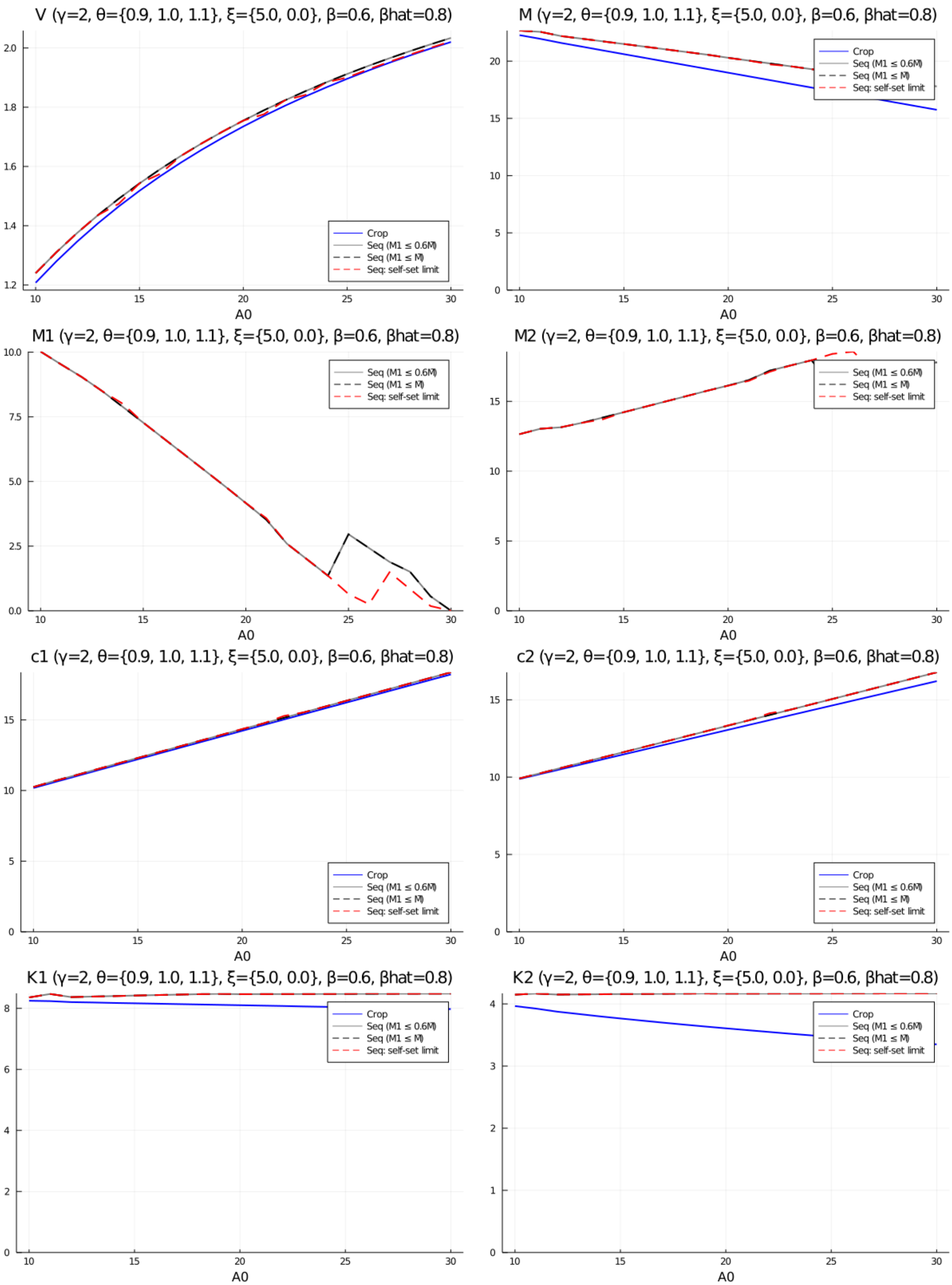
Appendix Figure 17: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = \hat{\beta} = 0.8$)



Appendix Figure 18: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = 0.8$, $\hat{\beta} = 0.6$)



Appendix Figure 19: Comparison between Crop credit, Sequential credit, and Sequential credit with self-set limit ($\beta = 0.8$, $\hat{\beta} = 0.6$)



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	-10.527	-27.595	-15.117	-40.440	4.322	16.164
	(30.716)	(40.307)	(30.755)	(39.629)	(6.061)	(16.669)
Crop Credit	11.930	20.102	2.133	30.971	10.114	-9.190
	(36.069)	(81.206)	(35.668)	(79.413)	(7.608)	(15.167)
Sequential	100.782	-24.235	-10.142	-7.643	108.805	-23.804
	(113.355)	(43.292)	(20.717)	(36.873)	(109.738)	(23.655)
In-kind	-61.499	112.070	11.186	10.035	-67.917	114.994
	(115.020)	(122.324)	(19.852)	(43.375)	(107.002)	(92.565)
PB=1		-21.921		-17.754		-6.262
		(38.142)		(37.420)		(12.098)
Traditional × PB=1		29.361		40.383		-16.977
		(43.122)		(42.766)		(22.980)
Crop Credit × PB=1		-7.617		-47.479		37.588
		(87.837)		(80.501)		(33.460)
Sequential × PB=1		230.498		-5.959		244.444
		(243.239)		(47.221)		(242.781)
In-kind × PB=1		-309.373		2.131		-323.489
		(268.861)		(58.536)		(257.889)
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	0.450	0.526	0.569	0.309	0.313	0.373
Trad_vs_SeqCash	0.315	0.920	0.780	0.016	0.340	0.292
Trad_vs_SeqKind	0.301	0.318	0.593	0.302	0.224	0.373
Crop_vs_SeqCash	0.430	0.547	0.675	0.590	0.354	0.269
Crop_vs_SeqKind	0.600	0.631	0.976	0.732	0.302	0.258
PB_Trad_vs_Crop		0.753		0.585		0.232
PB_Trad_vs_SeqC		0.363		0.665		0.331
PB_Trad_vs_SeqK		0.862		0.972		0.491
PB_Crop_vs_SeqCash		0.346		0.891		0.348
PB_Crop_vs_SeqKind		0.902		0.521		0.278

The table shows the estimated coefficients of the regression, with standard errors, clustered by 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: Investment

	(1) Invest:1st, Low other income	(2) Invest:1st, High other income	(3) Invest:2nd, Low other income	(4) Invest:2nd, High other income
Traditional	33.226	-313.612*	1.435	-198.013
	(153.836)	(157.626)	(157.035)	(178.678)
Crop Credit	87.598	136.076	-27.453	2.976
	(156.886)	(157.153)	(140.977)	(138.968)
Sequential	340.809*	107.906	351.077*	-109.459
	(200.217)	(193.043)	(189.893)	(161.394)
In-kind	50.347	-318.926*	-37.851	24.763
	(180.144)	(188.352)	(197.256)	(158.705)
Control	Yes	Yes	Yes	Yes
Observations	401	399	401	399
Mean_Control	8334.402	8334.402	4150.241	4150.241
Trad_vs_Crop	0.783	0.005	0.857	0.303
Trad_vs_SeqCash	0.075	0.041	0.035	0.654
Trad_vs_SeqKind	0.026	0.580	0.066	0.587
Crop_vs_SeqCash	0.246	0.867	0.044	0.427
Crop_vs_SeqKind	0.084	0.061	0.032	0.543

The table shows the estimated coefficients of the regression, with standard errors, clustered by 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: Cash inflow, savings at NGO, savings at MFI

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Borrow+Wage -Saving	Borrow+Wage -Saving	Saving at NGO	Saving at NGO	Savings at MFI in Jul-Sept: IPW	Savings at MFI in Jul-Sept: IPW	Cum. savings at MFI:IPW	Cum. savings at MFI:IPW
Traditional	2350.360	5320.882	1238.587***	1274.182***				
	(2806.803)	(4241.422)	(117.126)	(189.639)				
Crop Credit	-1039.155	-168.830	1523.635***	1569.519***	1.570	12.796	34.107	-35.213
	(3729.866)	(3371.006)	(111.011)	(168.220)	(74.938)	(103.086)	(73.403)	(102.932)
Sequential	-3691.429	-3999.758	1246.986***	1259.309***	-349.522***	-333.284***	-217.538***	-283.751***
	(2942.220)	(4377.376)	(110.400)	(167.650)	(90.140)	(117.551)	(71.671)	(97.392)
In-kind	398.515	1445.494	96.804	84.539	-187.823***	-248.024***	-44.071	-35.720
	(2315.738)	(3870.505)	(103.960)	(156.180)	(69.175)	(89.442)	(47.126)	(68.134)
PB=1		-1777.987		3.790		-1.347		-72.989
		(4885.674)		(99.012)		(102.350)		(101.422)
Traditional × PB=1		-5082.343		-53.688				
		(7180.300)		(175.424)				
Crop Credit × PB=1		-1357.474		-87.199		-3.490		109.598
		(6567.674)		(188.426)		(149.216)		(150.269)
Sequential × PB=1		220.757		-50.706		-15.345		98.370
		(8346.678)		(179.866)		(131.474)		(133.319)
In-kind × PB=1		-1315.338		29.993		97.828		-22.494
		(4921.834)		(183.827)		(111.991)		(93.949)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	998	986	998	986	560	551	560	551
Mean_Control	74665.779	74665.779	266.884	266.884				
Trad_vs_Crop	0.287	0.297	0.024	0.162				
Trad_vs_SeqCash	0.033	0.060	0.943	0.935				
Trad_vs_SeqKind	0.041	0.103	0.299	0.636				
Crop_vs_SeqCash	0.410	0.462	0.009	0.092	0.000	0.016	0.000	0.044
Crop_vs_SeqKind	0.405	0.561	0.084	0.205	0.000	0.000	0.000	0.005
PB_Trad_vs_Crop		0.632		0.056		0.931		0.483
PB_Trad_vs_SeqC		0.328		0.927		0.002		0.066
PB_Trad_vs_SeqK		0.275		0.456		0.000		0.019
PB_Crop_vs_SeqCash		0.468		0.030				
PB_Crop_vs_SeqKind		0.471		0.204				

The table shows the estimated coefficients of the regression, with standard errors, clustered by 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 4: 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 shows 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: * $p < .10$, ** $p < .05$, *** $p < .01$.