Timing lumpy investments with informal bridge loans and clunky formal loans: Evidence from Thailand

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Abstract. This paper theoretically and empirically explores formal and informal credit market interactions where informal credit access can help to complete a borrower's choice set. First, using Thai household data, we empirically document: the co-existence of formal and informal loans for the same household; informal loans are short with high interest rates; formal loan terms are rigid; and, little long-term borrowing. Second, we model a less-studied aspect of formal microfinance lending—short-term formal loans that with a bullet payment, where the borrower must repay the principal and interest at maturity– in a dynamic setting. We show that households can exploit flexible short-term informal loans as bridging loans, thereby, in effect, rolling a sequence of short-term formal loans into longer-term debt. Third, we characterize the conditions under which formal and informal loans are available. Finally, we evaluate the short and long-term effects of increasing the supply of formal loans and easing constraints on formal lenders (such as interest rate subsidies) on household welfare in village economies.

Keywords: Credit markets, inequality, informal lenders, liquidity

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Section 1. Introduction

In recent decades, there has been a significant expansion of formal banking in developing countries. To evaluate the effects of formal credit market expansions aimed at accelerating entrepreneurial activities in poor areas, it is important to study the terms of formal loans and how they interact with existing informal financial options to enable productive capital investments. In this paper, motivated by village financial access data from Thailand, we model the interaction of formal and informal loans in an environment with no long-term loans and lumpy capital investment. Specifically, we explicitly model a key empirical feature of formal loans—bullet payment[1]—as a novel mechanism into a model of complementary formal and informal credit market choices where informal loans provide "bridging liquidity" for formal loans. In effect, we show that the presence of informal bridging loans can turn a sequence of short-term formal loans into a single long-term loan.

This paper makes empirical and theoretical contributions. Empirically, we present four facts using monthly panel data on Thai rural households. First, there is little evidence for long-term loans, with the majority of formal and informal loans all being twelve or fewer months. Second, formal loans tend to be *rigid*—twelve months repayment requirement, fixed interests rates, and a finite set of loan sizes—whereas informal loans are *flexible*—a variety of multi-month duration, a dispersion of zero and high interest rates, and more flexible loan sizes. Third, we study the connections between formal and informal loans for village household firms at high frequencies (specifically, we track the origination and repayment dates of loans within households), to empirically show how short-term informal loans can facilitate longer-term debt. We find that informal loans often act as 'tight hooks' or 'bridge' two disconnected formal loans of similar sizes. Fourth, we show how this interplay between informal and formal loans can facilitate the investment in lumpy capital investments and consequently lead to much larger household revenues.

Motivated by the empirical facts, we develop a continuous time consumption and savings model with lumpy investments. We distinguish between three financial regimes, savings-only autarky, formal bullet-loan borrowing only, and formal bullet-loan borrowing with informal bridge loans. We analyze implications for liquidity, optimal timing of investments, and household welfare under the three regimes. Under all regimes, risk-averse households have existing income streams that could increase with an investment in lumpy high return capital. Our model sharply differs from existing models of capital investments by household firms in developing countries. Existing models generally feature two key

1. In applied finance, loans for which "no principal is due before maturity" and have a fixed repayment date are referred to by financial practitioners as bullet loans, bullet bonds, or loans with bullet payment (Carey and Nini 2007; Fabozzi 2008). In terms of repayment, bullet loans contrast with more flexible loan structures such as line-of-credit or overdraft facilities. In the setting of development micro-finance loans, we focus on the no-rollover feature of formal credits generally offered to household-firms.

assumptions: interior optimal capital investments and implicit loan-rollovers or capital rentals.(Buera, Kaboski, and Shin 2011; Moll 2014; Dabla-Norris et al. 2021),[2] These assumptions are inconsistent with our empirical observations in the Thai data. We link our model predictions on optimal investment timing to household-specific monthly panel data from the Thai monthly village survey.

To outline the key problem for households, consider a simple example where a farmer with no assets has a productive high-return indivisible investment; for example, a tractor that does not depreciate, costs \$100, and generates a return of \$66 per year. With well-functioning credit markets, the farmer could borrow the requirement amount (\$100) and slowly repay the debt over time. However in our model, we assume the farmer can borrow an unlimited amount at a given interest rate (say 10 percent) but must always fully repay the loan at the end of one year—that is, there are no long-term loans. In this scenario and no other income source, the maximum loan size the farmer feasibly repay is \$60 (and subsequently, owe \$66 at the end of the year), which is smaller than the \$100 required for the investment. Therefore, the farmer would not be able to make the investment—in effect, a poverty trap. In our model, we show that one method to overcome this financing constraint, is the use of a bridging loan. That is, even though the first lender requires full repayment before making new loans, the farmer could use a second lender to repay the first lender, and subsequently take a new loan from the first lender to repay the second lender. In effect, converting two consecutive one-year loans from the first lender, into one two-year loan.[3]

The specific features that we observe in informal and formal loans in Thailand are found in other developing countries. Many lending institutions, including both development banks as well as micro-finance lenders, often offer only relative inflexible annualized loans (Morduch 1999; Conning and Udry 2007; Banerjee, Karlan, and Zinman 2015). Despite the fact that rigidity of formal loans is widely noted by policy-makers and practitioners, to our knowledge, there are no existing models that explicitly incorporate these rigidity as frictions preventing households from making timely capital investments, and

2. The dominant set-up is a setting in which given realized productivity shocks, household-firms make optimal capital investments given capital rental price, realized productivity, and potential collateral constraint (e.g., Buera, Kaboski, and Shin 2011, 2021). Loans in these models are explicitly bullet loans, requiring repayments of principals and interests at the end of a relatively short period (12 months). However, these models have either the assumption that capital can be liquidated with limited depreciation to repay bullet debt financing principal investments, or implicitly the assumption that household firms only need to finance the rental costs of capital.

3. Specifically, assume that farmer has access to a bridge lender for a fee of 10 percent of the bridging financing. Then, the farmer could borrow \$100 from the first lender and makes the investment. At the end of the year, the farmer would owe \$110 to the first lender. To repay this debt, the farmer could use the \$66 of cashflow from the investment, and borrow the remainder (\$44) from the bridging financier. At the start of the second period, the farmer could borrow \$48.40 from the original lender to repay the bridging loan (\$44 for the bridging principal and \$4.40 for the bridging fee) and then repay the lender \$53.24 (\$48.40 in principal and \$4.84 in interest) at the end of the second period using the cashflow from the investment.

no existing literature or models that consider the role of flexible informal credit in complementing these rigid formal loan choices. In this paper, we take the rigidity of formal and flexibility of informal loans as given and expand a model with exogenous incomplete consumption, savings and borrowing choices to accommodate loan rigidity through the lens of optimal investment timing decisions problem.

While there is a large theoretical and empirical literature on financial deepening and the effects of micro-credit loans in developing areas (Greenwood and Jovanovic 1990; Banerjee 2013; Dabla-Norris et al. 2021; Breza and Kinnan 2021; Buera, Kaboski, and Shin 2021) as well as a long standing and global evidence of the strong presence of informal credit markets in developing areas (Udry 1990; Siamwalla et al. 1990; Morduch 1999), most models of financial access tend to focus on how access to loans impact occupational choices for entrepreneurs without distinguishing between how formal and informal credit markets interact in investments financing. Models that consider heterogeneous financial regimes in village settings often do so by jointly considering income, consumption and investment time series without explicit considerations of the formal and informal credit market choices that translate between these balance sheet streams (Karaivanov and Townsend 2014; Kinnan 2022). Models that do distinguish between formal and informal borrowing often do so in static or two period environments (Gine 2011; Karaivanov and Kessler 2018) and rely on variations in transaction costs and collateral bounds to justify the coexistence of formal and informal options (Gine 2011; Banerjee et al. 2017; Wang 2022). In these settings, informal loans either act as substitutes for formal loans or complement formal loans which are quantity constrained due to collateral requirements.

Given the commonly recognized rigidity in formal loans, a key area of financial innovation in recent years has revolved around increasing the flexibility of formal (microfinance) loans with mounting evidence for positive effects from increasing flexibility in loan repayment terms. For example, Field et al. (2013), using a randomized-control trial that varied loan contracts, find evidence that classic microfinance loan leads to lower investment in illiquid, high-return investments. Aragón, Karaivanov, and Krishnaswamy (2020) find that, using a randomized-control trial that varied loan contracts, loans with more flexible arrangements increased small business profits by facilitating larger investments. Additionally, in terms of liquidity, Karlan and Zinman (2008) find that microfinance loan demand is far more responsive to loan maturity than interest rates. Given the observed high returns to capital among small-scale entrepreneurs (Liu and Roth 2022), the rigidity of formal loans, in conjunction of lumpiness of investments, could be one of the key obstacles reducing the effectiveness of the microfinance push on realizing more wide-spread entrepreneurial gains.

The structure of the paper is as follows. Section 2 presents the data and key empirical findings. In Section 4, we present the theoretical model and solutions to the optimal continuous time investment timing problem with formal bullet and informal bridge loans. In Section 5, we present model comparative statics, simulation results, as well as distributional welfare analysis based on calibrated household-specific preference and technology parameters. Section 6 concludes.

Section 2. Data and Background

We present data with a panel of village household data from Thailand. The data provides key empirical facts that motivate our model and we calibrate the model to the household data. Thailand provides an excellent setting for studying the interaction between formal and informal credit markets. Thai villages have traditionally had strong informal credit markets (Siamwalla et al. 1990). Thailand also has a number of experienced state development banks led by the Bank for Agriculture and Agricultural Cooperatives (BAAC). The central government has helped to finance the expansion of these development banks and subsidize their operations. These subsidies have traditionally meant that BAAC, like development banks in other parts of the world, offers subsidized interest rates that are more uniform than loans that a commercial bank might offer. Additionally, the BAAC has by law traditionally required the full repayment of both interest rates as well as principles of loans issued (Maurer, Khadka, and Seibel 2000).

In recent year, the government made improving rural informal borrowing conditions a central focus and introduced a set of programs to achieve this goal. The most prominent policy was the Million baht Village-fund program (Boonperm, Haughton, and Khandker 2013). This program provided every single village in Thailand with one million baht in additional credits. Loans from this program generally offered identical interest rates and were offered in fixed sizes. One million baht of additional funds was transferred to villages via accounts at the BAAC, and the BAAC helped to provide logistic support for loan management to the Million baht Fund program. These are referred to as village fund loans. Unlike traditional BAAC loans, village fund loans generally had weaker repayment requirements, sometimes implicitly allowing for loan rollovers. This is partly because village committees rather than BAAC are the main administrators of these loans (Phongpaichit and Baker 2004).

We use the 1999 to 2009 waves of the Townsend Thai Monthly Survey to study how informal choices help to complete the more rigid formal financial options available to households. The dataset is very useful for studying the interaction between formal and informal credit markets. It contains extensive household level financial data for about 650 households in 16 villages of Thailand (Samphantharak and Townsend 2009).[4] 8 of these villages are located in the wealthier Central region of Thailand, and 8 of them are located in the more impoverished Northeast region of Thailand. Households in this survey consist of multiple members from multiple generations, and they operate household businesses and farms of various scales. For each household, there is detailed data on all financial transactions that take place every month during the span of the survey. Specifically, there are records of the amounts of and interest rates on borrowing from formal and informal channels.

Subsection 2.1. **Loan terms.** There are significant differences between more rigid formal and more flexible informal loans in terms of the length, size, and interest rates of loans. Formal loans predominantly are due in one year, are larger in size and limited in size selection, and have relatively homogeneous and low interest rates. Informal loans have more immediate due dates, are smaller and more varied in sizes, and have higher mean and greater variance in rates. Aggregating across provinces and years, we present in Table 1 as well as Figures 1, 2, and 3 key contrasting empirical facts on the duration, sizes, and interest rates of formal, quasi-formal, and informal loans.[5]

For our analysis, we consider both BAAC and Village-fund loans as relatively more rigid formal loans. Loans from local moneylenders, neighbor, relatives, and other local and individual lenders are categorized as informal loans and have relatively more flexible characteristics. We classify loans from village agricultural coops and production cooperative groups, which are locally-based organizations with cross-region networks, as quasi-formal.

The first striking feature of formal loans in our empirical setting is that nearly all BAAC and Village-fund loans are due in around 1 year. Specifically, we show in column 2 of Table 1 that the 20th to the 95th percentile of the formal loan due length distribution ranges from 11 to 13 months. In contrast, the distribution of informal loan length has a median of 3 months and only reaches 11 months after the 8th decile. On average, formal loans are due in 12.8 months, more than doubling the 5.8 months average due length for informal loans. Quasi-formal loans straddle between formal and informal loan length distributions with a third of its loans due in less than 11 month and 45 percent due between 11 and 13 months. The non-overlapping loan duration distributions are visualized in Figure 1.

4. There were 684 different households in 1999. For 606 households, there is credit market participation information for all years between 1999 and 2009. These households are from 16 villages, with between 33 to 44 households observed for these 11 periods in each of the villages. Overall, 304 of these households are from the two Northeast provinces, and 302 of these households are from the two Central provinces. we use information from these 606 households for generating summary statistics as well as estimating the model.

5. In Appendix Figures D.2, D.3, and D.4, we provide additional graphical illustrations contrasting between the terms of formal and informal loans, over individual lender categories within our broader formal and informal classifications.

Formal loans have a relatively more rigid menu of fixed loan sizes compared to smaller and more finely sized informal loans. Village-fund offers a menu of loan sizes with approximately 90 percent of all loans sized between 5000 and 30000 baht at 5000 baht intervals. BAAC loans have greater degree of variation, but also come generally in 5000 baht intervals.[6] Reflecting these underlying menu of sizes, the 5th, 6th, and 7th deciles of formal loans size distribution are all 20,000 baht, as shown in column 4 of Table 1. While there are some informal loans that are comparable in sizes to the largest BAAC loans, the majority of informal loans are much smaller in sizes. Specifically, comparing across columns 5 and 7 of Table 1, below the 30th and 60th percentiles, formal loans are at least 5 times and 2 time larger than informal loans, respectively. Formal and informal loan sizes only become approximately equal above the 9th decile of loan sizes. Overall, informal loans are on average 71 percent of formal loan sizes and have no repeating values across deciles, and quasi-formal loans are more similar to informal loans for their size distribution. To further contrast loan size differences, we present intersecting log loan size distributions across lender groups in Figure 2.

Interest rates on informal loans have a higher mean and wider dispersion than interest rates on formal loans. Village-fund loans generally charge identical interest rates within the same location and time period. Specifically, at the start of the Village-fund program, nearly all loans from the Village-fund had 6 percent annual interest rate; at the same time, BAAC rates were 8 percent annually. Aggregating across time, in column 8 of Table 1, we show that the combined formal loan category has a median monthly interest rate of 0.50%, a tight interquartile range between 0.46% and 0.67%, and less than 1 percentage point deviation between the 5th and 95th monthly rates percentiles. In contrast, as shown in column 9 of Table 1, while 44% of informal loans have zero percent interest,[7] the average monthly interest rate for informal loans is 2.36% compared to 0.80% for formal loans. At incremental above-median deciles, the informal and formal monthly interest rates gap grows from 1.5 percentage points to more than 5 percentage points. Finally, below the median, interest rates on quasi-formal loans are similar to informal loans; above the median, they are closer to formal loans. Patterns of interest rates distributions among the eight key lender categories reflect the general patterns across the formal and informal groupings, and we present the lender-specific interest rates densities in Figure 3.

Subsection 2.2. **Investment.** We identify investments by tracking the capital holding of a household and identifying single or consecutive months in which there are jumps

6. The discretization of formal loans choices is a standard feature of the credit offerings of development banks. From the perspective of managers at the national branches of these development banks, rather than offering individual borrowers differentiated loan products, a menu of loan options might be easier to manage and carry lower administrative costs.

7. We consider here interest rates reported by households. Ostensibly zero interest rates informal loans might require non-pecuniary payments in kinds or services.

in asset holdings.[8] We consider agricultural assets, business assets, and agricultural and business assets jointly. We consider the asset time series that combines agricultural and business assets as the capital series for our benchmark analysis.

In Table 2, we present summary statistics which show that investments happen for most households, but at low frequency. Considering the asset time series that combines agricultural and business assets, we find that 85.1% of households have positive assets. Considering all households, 29.2% of households did not make any investments during the 160 months of the survey, 36.4% of households made one investment, 20.0% made two investments, and the remaining 14.4% made more than two investments. These results are shown in column 8 of Table 2. On average, across all households, 0.1 investments is made per year. Among households that made at least one investment, average count of annual investments is 0.13. In columns of Table 2, we consider alternative definitions of investments and find more occurrences agricultural investments compared to business investments.

In Table 3, with investment as the unit of observation, we present the relative sizes of investments with respect to the levels of capital in the month preceding the investment as well as the revenue of the household-firm from the 12 months preceding the month of investment. Focusing on the benchmark series that considers agricultural and business assets, in columns 8 and 9 of Table 3, we find that investments are substantial in relative size to existing capital levels and revenues. Specifically, at the median, the investment to past 12 months revenue ratio is about one quarter, with the interquartile range between 8.4% and 117.4%. Additionally, at 130.9%, the median investment to preceding month capital ratio more than doubles preceding month's capital level, and the interquartile range is between 46.3% and 613.2%, meaning that about 75% of investments increased the combined agricultural and business capital level by at least around half.

Section 3. Linking investments to loans

In this section, we analyze the loan–investment relationship by matching the monthly timing of investments with the timing of loans. We categorize investments into those that are not associated with loans, associated with a single set of loans, associated with doubly interlinked sets of loans (hooked loans), and associated with triply interlinked sets of loans (bridged loans).

8. We present in Appendix Figure D.1 capital-asset time series and the identification of investment timing for two illustrative households. We compute deviation in assets month by month, and consider jumps as positive differences that exceed a high positive standard deviation threshold. We compute household- and asset-specific standard deviation based on monthly asset differences from the household panel.

Subsection 3.1. **Match investments with loans.** We use investment timing information jointly with the timing of the starting and ending dates of loans to identify all loans that are taken out in close proximity to the start of an investment month and repaid after the investment in assets has been made. Specifically, we identify all loans that are taken out between τ months before ($\tau = 6$ for the primary specification) and up to the month in which an investment was initiated; additionally, these loans must be due after the investment has been made.

We consider loans identified in this fashion as loans that could provide financing for the investment made within the τ window.[9] Specifically, let $\underset{\sim}{m}_{\text{inv}}$ and $\tilde{m}_{\text{inv}}$ be the starting and ending month of an investment made by a household. Let $\underset{\sim}{m}_l$ and $\tilde{m}_l$ be the month in which loan l made by the household was first initiated and the month in which it is fully repaid, respectively. Let L be the total number of loans taken out by the household during the span of survey been considered, each investment by the household has a set of "investment-linked" loans L^A:

$$L^A = \left\{ l \in \{1, \ldots, L\} \mid \; \underset{\sim}{m}_{\text{inv}} - \tau \leq \underset{\sim}{m}_l \leq \underset{\sim}{m}_{\text{inv}} \text{ and } \tilde{m}_{\text{inv}} < \tilde{m}_l \; \right\}. \tag{1}$$

L^A might contain the index for multiple loans, obtained from the same or multiple types of lenders. When that is the case, we interpret the household as jointly using multiple loan sources to support financing the initial investment, perhaps complementing loans from different sources given borrowing constraints on each, acting as top-up loans (Gine 2011). If L^A is empty, the investment is not loan-linked.

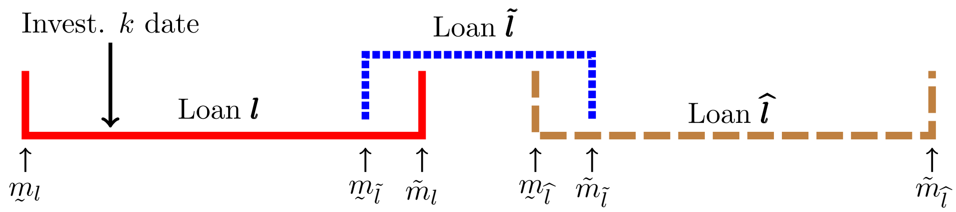
In Panel (A) of Figure 4, we show the share of investments that are linked to loans within different τ-sized backward windows, from $\tau = 0$ to $\tau = 6$. When $\tau = 0$, 40.1% of the investments are loan-linked. When $\tau = 6$, 70.3% of the investments are loan-linked. In total, there were 15,880 household-months in which new loans were initiated out of a total of 114,318 household-months. If loans were randomly timed across household-months, there would be a 13.9% chance that loans are initiated in any household-month. Figure 4 shows that the actual share of investments that are loan linked is significantly higher than the share that would be randomly linked across backward τ windows. As τ extends backward further, the chance that a investment is loan linked approaches 1 by construction.

Subsection 3.2. **Investment-linked loan hooks and bridges.** The features of rigid formal loans documented prior provide space for "bridge" loans. A borrower could ease her pending liquidity crunch by borrowing from a flexible bridge lender to help cover

9. It is possible that these newly initiated loans are marked by households as servicing other needs besides financing new investments, but the new loan is a net addition to the cash-on-hand available that would enable investment.

bullet debt obligations, and then borrow again from the same or an alternative bullet loan provider to repay the bridge debt and effectively achieve longer-term financing for the initial investment. To analyze these potential bridged investment to loan linkages, we define sets of loans that are "hooked" and "bridged" to the investment-linked set L^A loans.

For a household, loans l, $\tilde{l}$, and $\widehat{l}$ form a set of investment-linked bridge loans, if loan l is linked to a particular investment, loans l and $\tilde{l}$ as well as loans $\tilde{l}$ and $\widehat{l}$ are "hooked" together, and the end date of loan l is prior to the start date of loan $\widehat{l}$.



Specifically, the start and end dates for loans l and $\tilde{l}$ follow this sequence: $\underset{\sim}{m}_l < \underset{\sim}{m}_{\tilde{l}} \leq \tilde{m}_l \leq \tilde{m}_{\tilde{l}}$. Similarly, the start and end dates for loans $\tilde{l}$ and $\widehat{l}$ follow this sequence: $\underset{\sim}{m}_{\tilde{l}} \leq \underset{\sim}{m}_{\widehat{l}} \leq \tilde{m}_{\tilde{l}} < \tilde{m}_{\widehat{l}}$. The end date for loans l and start date for $\widehat{l}$ follow this sequence: $\tilde{m}_l \leq \underset{\sim}{m}_{\widehat{l}}$. The inequalities in these orderings accommodate limited granularity in the temporal unit of observation—when data is observed monthly, we can not distinguish loan timing sequences within the month. For the household , the set of bridge loans linked to a particular investment are:

$$\mathcal{B} = \left\{ \left(l, \tilde{l}, \widehat{l}\right) \mid l \in L^A, \tilde{l} \in L^B(l) \text{ and } \widehat{l} \in L^C\left(l, \tilde{l}\right) \right\} . \tag{2}$$

$L^B(l)$ contains loans that are "hooked" to an investment via loan $l \in L^A$, and $L^C\left(l, \tilde{l}\right)$ contains loans that are "bridge-linked" to the investment via loans l and $\tilde{l}$.[10]

Some investments are not linked to loans, other are linked to hooked and bridged sets of loans with different lender combinations. Table 4 presents the share of investments by different investment-loan linkage types. Results for 6 months backward investment-loan windows are shown. Across the columns, we consider different definitions of assets-investments. Results for alternative backward investment-loan windows are consistent with the 6 months window results and are shown in the appendix.

We find that about 30 percent of investments are "no-loan" investments, with $L^A = \varnothing$. About 19 percent of investments are "initial loan set only" investments, with $L^B(l) = \varnothing$ for all $l \in L^A \neq \varnothing$, About 6 percent of investments are "hooked loans only"

10. In Appendix B, we define loan sets L^A, $L^B(l)$, and $L^C\left(l, \tilde{l}\right)$ formally and illustrate types of investment-linked bridge loans.

investments, with $L^C\left(l,\tilde{l}\right)=\varnothing$ for all $\left(l,\tilde{l}\right)$ such that $l\in L^A\neq\varnothing$ and $\tilde{l}\in L^B(l)\neq\varnothing$. And about 45 percent of investments are "bridge-linked" investments, with non-empty $\mathcal{B}$. Bridge-linked investments account for about 64 percent of all loan-linked investments, .

Furthermore, Table 4 shows that among the bridge-linked investments, about 10 percent rollover with a single lender. In these cases, the loans tend to be from the Village-fund, even though the Village-fund officially does not allow for loan rollover. 7 percent of the bridge-linked investments have loan bridges involving either only formal lenders or only informal (including quasiformal) lenders. The remaining 83 percent of the bridge-linked investments have loan bridges involving both formal and informal (including quasi-formal) bridge components. Among these bridge-linked investments, the majority have loan bridges with formal–informal–formal linkages—for a particular investment made by a household, there exists $\left(l,\tilde{l},\widehat{l}\right)\in\mathcal{B}$ such that loans l and $\widehat{l}$ are borrowed from the BAAC or Village-fund, and loan $\tilde{l}$ comes from an informal or quasiformal lender.

Subsection 3.3. **Investments and changes in revenue.** We now compare two time-matched marginal changes: investment size and revenue change. Investment size is the difference in assets before and after the months in which an investment is made as discussed in Section 2.2, and revenue change is the difference between the average monthly revenue in the 12 months after and before the months of investment. Results for alternative revenue windows are consistent with the 12 months window results and are shown in the appendix.

In Table 5, we consider all assets for investment size and all sources of income for revenue change. In column (1), we regress changes in revenues on the size of investments without controls. We control for survey month fixed effects in column (2), village fixed effects in column (3), and both survey month and village fixed effects in column (4). In columns (5) and (6), we winsorize the sample by cutting away the top and bottom 5 percentiles of the data based on the investment size regressor. We present results based on 12 months forward and backward windows.

We find an overall positive relationship that is sensitive to outliers between investment size and household revenue changes. From column (4) of Table 5, controlling for both village and survey month fixed effects, we find that, on average, investments are associated with 3.4 percent increase in monthly revenue in the 12 months after compared to the 12 month before the date of the investment. This high average return is partly driven by investments at the tails: in column (6), we find a reduced rate of average monthly return of 1.9 percent after winsoring 10 percent of the sample. These average return rates are substantially higher than the borrowing interest rates on bullet loans from the BAAC and the Village Fund, whose monthly interest rates range from 0.31% to 1.0% from the 10th to the 90th percentiles as shown in Table 1.

Across the columns Table 5, investment size is a key factor explaining revenue variations. Investment size variations alone explains 15 percent of the variance in revenue changes, and investment size variations jointly with investment calendar timing (survey month FE) and investment location (village FE) variations explain 22 percent variance in revenue changes. Return estimates are similar across fixed effects specifications.

Our findings here relate to existing research that have found high returns to investments in village economies (Mel, McKenzie, and Woodruff 2008). In contrast to findings from randomized experiments, our estimates here do not provide the returns to exogenous increases in capital. Our coefficients on investments are jointly determined by increases in investment as well as changes in other inputs made concurrent to the investment decision and productivity shocks known to the household at the time of investment. High realized average investment returns relative to the cost of capital from formal lenders is evidence for potential credit market inefficiencies, arising possibly due to the lack of long-term loan options.

Section 4. Model

We model an infinitely-lived farmer in continuous time with a constant relative risk aversion utility function who starts with zero wealth but has a productive potential investment, that requires I units of capital. Our model explores how the farmer's optimal investment decision, consumption, time to invest, and utility change as alter the credit options available. We proceed first by outlining the farmer's utility function, income, saving options and the possible credit options from the formal and informal lender. Second, we how the model equilibrium changes as we introduce more credit options. We start with the benchmark case of no credit options (autarky), then show if there are formal loans available, and finally show what happens with informal bridging loans and formal loans.

Subsection 4.1. **Farmer Utility.** The farmer has the following the CRRA utility function with discount rate, ρ, and coefficient of relative risk aversion, σ:

$$U(c) = \int_{t=0}^{\infty} u(c_t) e^{-\rho t} dt = \int_{t=0}^{\infty} \frac{c_t^{1-\sigma}}{1-\sigma} e^{-\rho t} dt \tag{3}$$

Subsection 4.2. **Farmer income and investment.** The farmer earns a wage rate of w. The farmer can invest in a large project, which requires I units of capital (the price of capital is normalized to 1) and the capital does not depreciate. To ensure the investment is 'lumpy,' we assume that the cost of this investment, I, is strictly larger than the farmer's wage rate, w. If the farmer invests at least I units of capital in this project, the project has a rate of return of i, otherwise the return is zero.[11]. Since, we assume that the farmer's capital does not depreciate, the farmer's holding of capital at time t, K_t, is simply equal to the cumulative amount of investment, k, invested in the project by time t:

$$K_t = \int_{s=0}^{t} k_s \, ds \tag{4}$$

Therefore, the farmer's income stream can be written as:

$$Income(t) = w + i \cdot \mathbb{1}_{\{K_t \geq I\}} + \underline{r} a_t \tag{5}$$

where $\mathbb{1}_{\{K_t \geq I\}}$ is an indicator function for whether the farmer has invested at least I in the project at time t in the project.

Subsection 4.3. **Farmer saving.** We assume that the farmer starts with zero wealth and the farmer can save income over time to build wealth and potentially finance their project. We assume that the farmer has access to some relatively poor saving technology that earns a return of $\underline{r}$, where we assume that the return of this technology is strictly less than the farmer's discount rate (that is, $\underline{r} < \rho$). In the simple case where the farmer has no borrowing options, the change in the farmer's liquid asset holdings, $\dot{a}$, can be written as:

$$\dot{a} = w + i \cdot \mathbb{1}_{\{K_t \geq I\}} + \underline{r} a_t - c_t - k_t \tag{6}$$

Equation (6) states that liquid asset accumulation is equal to income $(w + i \cdot \mathbb{1}_{\{K_t \geq I\}} - c_t)$, plus return on savings, $(\underline{r}a)$, minus the sum of consumption, (c_t), and capital investment, (k_t). Since the farmer starts with zero wealth $(a_0 = 0)$.

We require the farmer to have a cashflow constraint—specifically, the farmer must always have non-negative liquid assets therefore combining that the farmer starts with zero wealth, this becomes:

$$a_t = 0 \text{ and } a_t \geq 0 \quad \forall\, t \tag{7}$$

Subsection 4.4. **Formal lender.** The farmer can borrow from a formal lender. The formal lender is willing to lend the farmer an unlimited amount, but requires the farmer to repay the full loan (including interest) by the time the loan maturity date (we assume that the farmer has an enforcement technology to ensure the farmer repays). We assume

11. We assume that the farmer retains the wage return even after investing, as such, i can also be considered the net additional return from investing in the project

the formal lender offers loans with a maturity of one unit of time and charges an interest rate r, which is strictly greater than the farmer's discount rate (that is, $r > \rho$). Finally, we assume that the farmer cannot take additional formal loans if there is any outstanding debt to the formal lender.

We define D_t^F the amount of total debt outstanding from the farmer to the formal lender at time t and L_t^F the net payment of the lender to the farmer at time t, that is, a positive value for L_t^F denotes the farmer is borrowing from the lender, and a negative value denotes that the farmer is repaying the lender.

We can write the conditions on the formal debt as the following:

(8) $D_t^F = \int_0^t L_s^F \exp[(t-s)r]ds$

(9) $D_t^F \geq 0$

(10) If $L_t^F > 0$, then there must exist some s $\in (t, t+1]$ s.t. $D_s^F = 0$

(11) $L_t^F \leq 0$ iff there exists a positive epsilon such that forall s $\in [t-\epsilon, t)$ that $D_s^F = 0$

Where equation (8) states the value of the farmer's outstanding debt to the formal lender at time t as a function of the loan payments. Equation (9) states the farmer cannot have negative debt to the formal lender. Equation (10) requires that the farmer must fully repay the formal loan prior to the maturity of the loan. Equation (11) requires that the farmer cannot take more formal debt prior to fully repaying any existing formal debt.

Subsection 4.5. **Informal Lender.** We define D_t^F the amount of total debt outstanding from the farmer to the formal lender at time t and L_t^F the net payment of the lender to the farmer at time t, that is, a positive value for L_t^F denotes the farmer is borrowing from the lender, and a negative value denotes that the farmer is repaying the lender.

We assume the informal lender is willing to offer a "bridging' loan, for a fee of f. This bridging loan has a very short maturity period such that if the farmer takes a informal loan at time t, the loan is due to be repaid at time $t + \varepsilon$, where ε is very small. For modelling convenience, we assume that the informal lender is only willing to offer one informal loan ever. Similar, to the notation for formal credit, we define D_t^I the amount of total debt outstanding from the farmer to the informal lender at time t and L_t^I the net payment of the lender to the farmer at time t.

We can write the conditions on the informal debt as the following:

(12) If $L_t^I > 0$ then there must exist some small ε such that $L_t^I \cdot f + L_{t+\varepsilon}^I = 0$

(13) If $L_t^I > 0$ for some t, then forall $s > t$, $L_t^I \leq 0$

(14) $D_t^I \geq 0$

Where equation (12) states that the farmer must repay the informal debt, equation (13) states that the farmer can only use the informal lender once, and finally equation (14) states the farmer cannot have negative debt to the informal lender.

Therefore, we can now rewrite the farmer's liquid asset holdings with formal and informal borrowing as:

$$\dot{a} = \underbrace{w + i \cdot \mathbb{1}_{\{K_t \geq I\}} + \underline{r} a_t}_{\text{Income}} \underbrace{- c_t - k_t}_{\text{Consumption and Investment}} + \underbrace{L_t^F + L_t^I}_{\text{Loan payments}} \tag{15}$$

Subsection 4.6. **Farmer's problem.** We can now write the farmer's problem as:

$$V(c) = \max_{\{c_t, k_t, L_t^F, L_t^I\}_{t=0}^{\infty}} \int_{t=0}^{\infty} \frac{c_t^{1-\sigma}}{1-\sigma} e^{-\rho t} dt \tag{16}$$

$$\text{s.t. equations (4), and (7) to (15) are satisfied}$$

Subsection 4.7. **Farmer's optimal choices.** The farmer's feasible choice set for consumption (c_t), capital investment (k_t), formal loan (L_t^F) and informal borrowing (L_t^I) is incredibly large. However, we show that the farmer's has four possible optimal strategies (with the optimal choice depending on the model environment's parameters). We start by stating the optimal strategy and then explain the intuition, the proofs are in the appendix.

Proposition 4.1. *The farmer's optimal choice of consumption, capital investment, formal loan, and informal loans is one of the following four strategies:*

- *Never Invest (s_1): The farmer never invests and solely consumes the wage rate in all time periods. Specifically, $s_1 = \{c_t = w, k_t = L_t^F = L_t^I = 0, \forall t\}$*
- *Save and invest with no borrowing (s_2): The farmer saves and invests when accrued sufficient liquid assets and subsequently consumes investment return and wages. Specifically, $s_2 = \{c_t = c_t^s, k_t = k_t^s, L_t^F = L_t^I = 0, \forall t\}$ where c_t^s and k_t^s are defined*

as (and exact values depend on parameters):

$$c_t^s = \begin{cases} \underline{c}^s & \text{if } t < T_{saving} \\ \bar{c} = w + i & \text{if } t \geq T_{saving} \end{cases}$$

$$k_t^s = \begin{cases} 0 & \text{if } t \neq T_{saving} \\ I & \text{if } t = T_{saving} \end{cases}$$

$$T_{saving} = \frac{1}{\underline{r}} \ln\left(\frac{1 + (\underline{r} \cdot I)}{w - \underline{c}^s}\right)$$

- *Save and only borrow from the formal lender and invest (s_3): The farmer saves and invests when accrued sufficient liquid assets when combined with a formal loan, and subsequently consumes investment return and wages once the loan is fully repaid. Specifically, $s_3 = \{c_t = c_t^f, k_t = k_t^f, L_t^F = L_t^f, L_t^I = 0, \forall t\}$ where c_t^f, k_t^f, and L_t^f are defined as (and exact values depend on parameters):*

$$c_t^f = \begin{cases} \underline{c}^f & \text{if } t < T_{FL} + 1 \\ \bar{c} = w + i & \text{if } t \geq T_{FL} + 1 \end{cases}$$

$$k_t^f = \begin{cases} 0 & \text{if } t \neq T_{FL} \\ I & \text{if } t = T_{FL} \end{cases}$$

$$L_t^f = \begin{cases} \frac{\exp(r) - 1}{r \cdot \exp(r)}(w + i - \underline{c}^f) & \text{if } t = T_{FL} \\ -(w + i - \underline{c}^f) & \text{if } t \in (T_{FL}, T_{FL} + 1) \\ 0 & \text{otherwise} \end{cases}$$

$$T_{FL} = \frac{1}{\underline{r}} \ln\left(\frac{1 + \underline{r} \cdot \left[I - L_{T_{FL}}^f\right]}{w - \underline{c}^f}\right)$$

- *Save and borrow from both the informal and formal lenders (s_4): The farmer saves and invests using a formal loan. This formal loan is "bridged" using an informal loan and all debt is fully repaid two units of time after initially investing. Once the debt is fully repaid, the farmer consumes the investment return and the wage. Specifically, $s_4 = \{c_t = c_t^i, k_t = k_t^i, L_t^F = L_t^{Fi}, L_t^I = L_t^{Ii}, \forall t\}$ where c_t^i, k_t^i, L_t^i, L_t^i are* *defined as (and exact values depend on parameters):*

$$c_t^i = \begin{cases} \underline{c}^i & \text{if } t < T_{IL} + 2 \\ \overline{c} = w + i & \text{if } t \geq T_{IL} + 2 \end{cases}$$

$$k_t^i = \begin{cases} 0 & \text{if } t \neq T_{IL} \\ I & \text{if } t = T_{IL} \end{cases}$$

$$L_t^{Fi} = \begin{cases} [1 + f \cdot exp(r)] \frac{\exp(r)-1}{r \cdot exp(r)} (w + i - \underline{c}^i) & \text{if } t = T_{IL} \\ -(w + i - \underline{c}^i) & \text{if } t \in (T_{IL}, T_{IL} + 1 - \epsilon) \\ -\frac{\exp(r)-1}{f \cdot r \cdot \exp(r)} (w + i - \underline{c}^i) & \text{if } t = T_{IL} + 1 - \epsilon \\ \frac{\exp(r)-1}{r \cdot \exp(r)} (w + i - \underline{c}^i) & \text{if } t = T_{IL} + 1 \\ -(w + i - \underline{c}^i) & \text{if } t \in (T_{IL} + 1, T_{IL} + 2) \\ 0 & \text{otherwise} \end{cases}$$

$$L_t^{Ii} = \begin{cases} \frac{\exp(r)-1}{f \cdot r \cdot \exp(r)} (w + i - \underline{c}^i) & \text{if } t = T_{IL} + 1 - \epsilon \\ -\frac{\exp(r)-1}{\cdot r \cdot \exp(r)} (w + i - \underline{c}^i) & \text{if } t = T_{IL} + 1 + \epsilon \\ 0 & \text{otherwise} \end{cases}$$

$$T_{IL} = \frac{1}{\underline{r}} \ln \left(\frac{1 + \underline{r} \cdot \left[I - L_{T_{IL}}^{Fi} \right]}{w - \underline{c}^i} \right)$$

where ϵ is a very small number.

The proof is in Appendix (A).

Section 5. Results

To gain intuition for our model, figure (5) shows how changing the formal interest rate and informal bridging loan affects the farmer's optimal choice of strategy (top-left right); time till investment, T, (top-right); consumption while saving, $\underline{c}$ (bottom-left); and resultant utility, V (bottom-right).

The key results from figure (5) is that as interest rates rise and the informal loan fee rise, the farmer is less likely to borrow (less likely to use strategy $s4$ and $s3$ as seen in the top-left panel) and invests at a later time (top-right panel). These results are intuitive, as the cost of borrowing becomes more expensive, the farmer is less likely to borrow. As the farmer, borrows less, it takes longer to make the investment.

The figure also offers some more interesting results. First, as the interest rate rises, the farmer is less likely to borrow from the informal lender *even if the informal loan fee* *does not change* (top-left panel). The intuition for this result follows from the overall cost of borrowing becomes higher so the farmer is less willing to borrow. Second, the farmer's consumption before investment is non-monotonic in the interest rate. As the interest rate initially rises, the farmer's consumption rises and saves less. However, if the interest rate rises sufficiently, the farmer actually decides to never borrow (for instance, switches from strategy $s3$ to $s2$) and starts saving a lot more (bottom-left panel).

Proposition 5.1. *As the interest rate rises, assuming the farmer still invests, the time to invest increases.*

Section 6. Conclusion

In recent decades, formal financial services have expanded significantly in developing countries. This paper evaluates the impacts of improving access to the formal credit market on rural households, taking into consideration the impacts of changing Formal credit market conditions on the informal credit market.

We built a continuous time consumption, savings, and investment model in which households make optimal timing decisions with respect to lumpy investments. The model allows for evaluating the impacts of formal credit market expansions that allow for formal credit as bullet loans and account for the role of informal loans as bridge loans. Policy evaluations take into consideration how informal options help to rollover formal loans and accelerate the pace of lumpy capital investments, and the degree to which bullet payment requirements delay capital investments

In the empirical section of the paper, we explored detailed data on formal and informal credit market interactions from Thai villages and documented key facts on terms of loans and the monthly interactions and bridging between formal and informal loans. We connected the model with the Thai micro-data by calibrating the model, at a household-specific level to obtain household-specific preference and technology parameters that explain the timing of households' lumpy investment decisions as well as effects of these investments on consumption and profits.

Using the estimated model, in the case of these Thai villages, we show that the welfare effects of having informal loans complement the expansion of bullet-loan-based formal microfinance loans. We also show the potentially welfare effects of changing formal interests rates and bullet-duration on households with heterogeneous investment opportunities, and the relative effective and ineffectiveness of these formal shifts in the context of informal bridge loans.

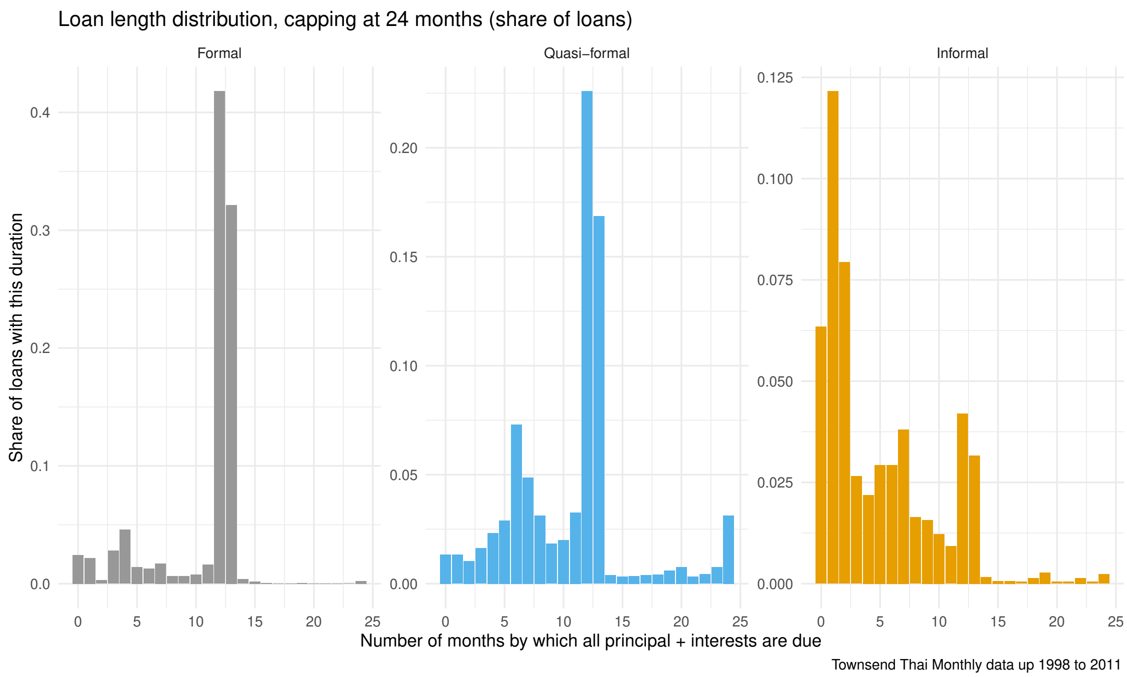


Fig. 1. Loan length distribution

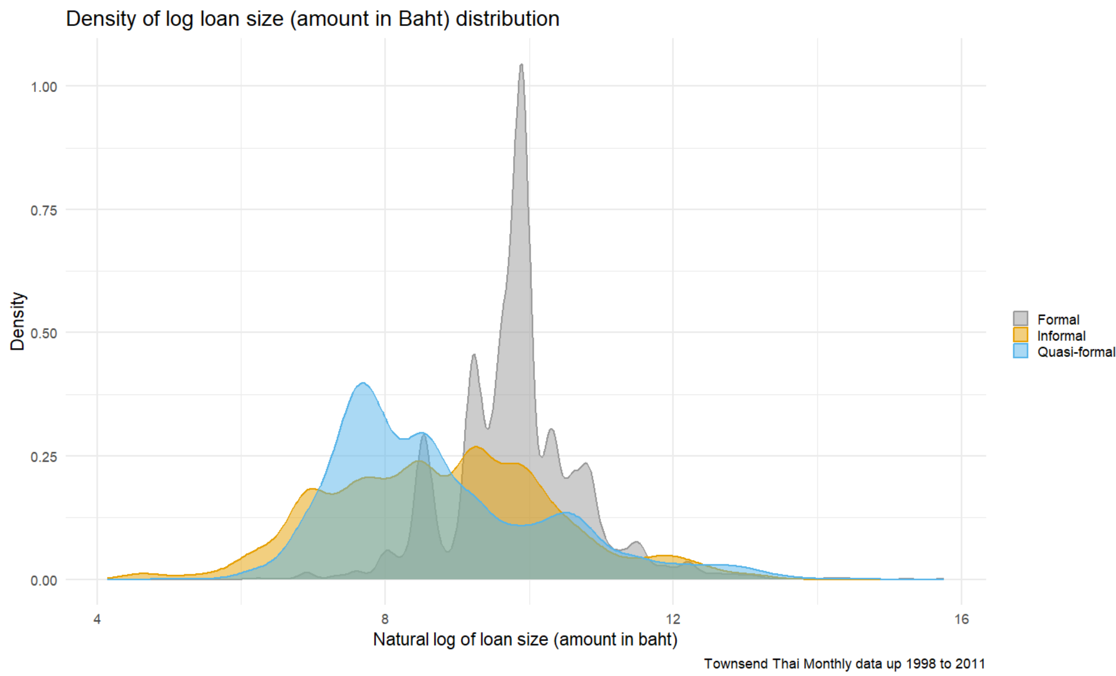


Fig. 2. Loan size distribution

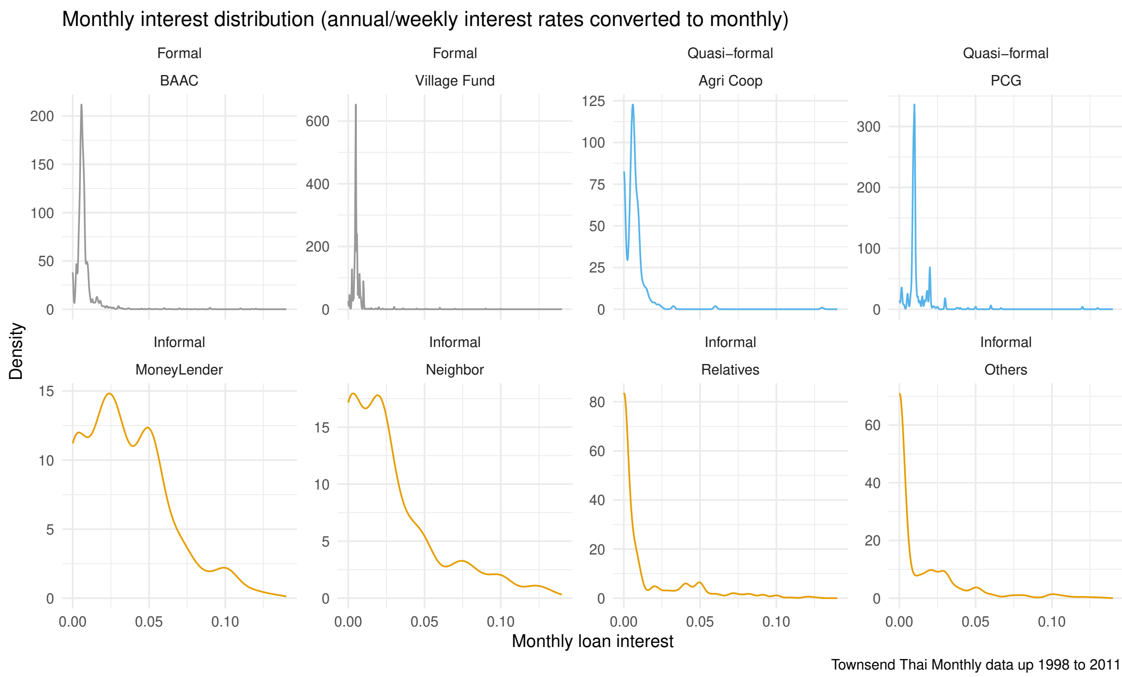
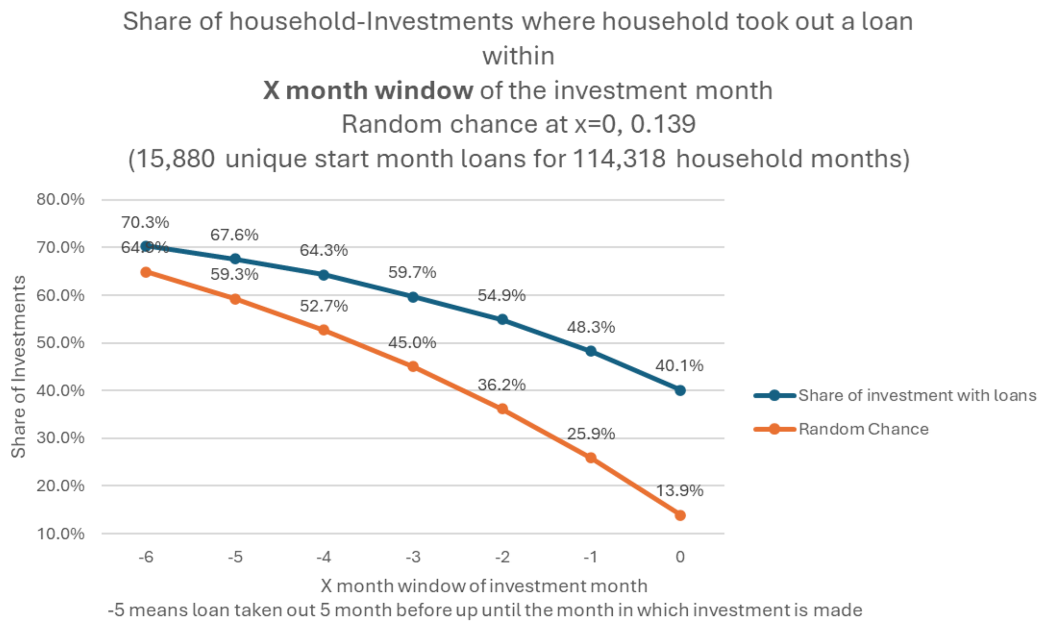


Fig. 3. Loan interest rate distribution

(a) Share of investments with loans



(b) Share of bridged-loans among investments with loans

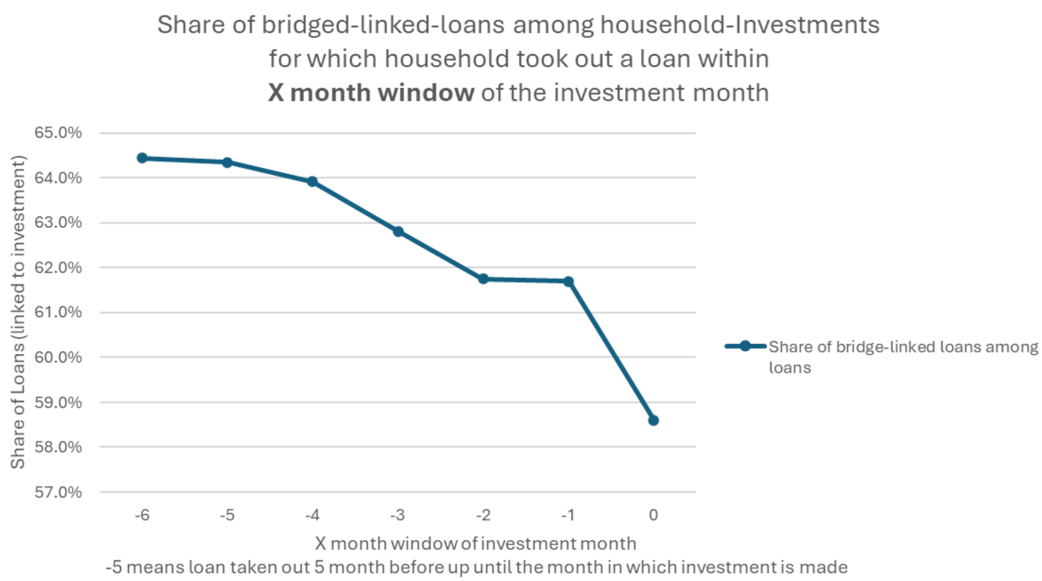


Fig. 4. Investments with loan and bridge-loan linkages.

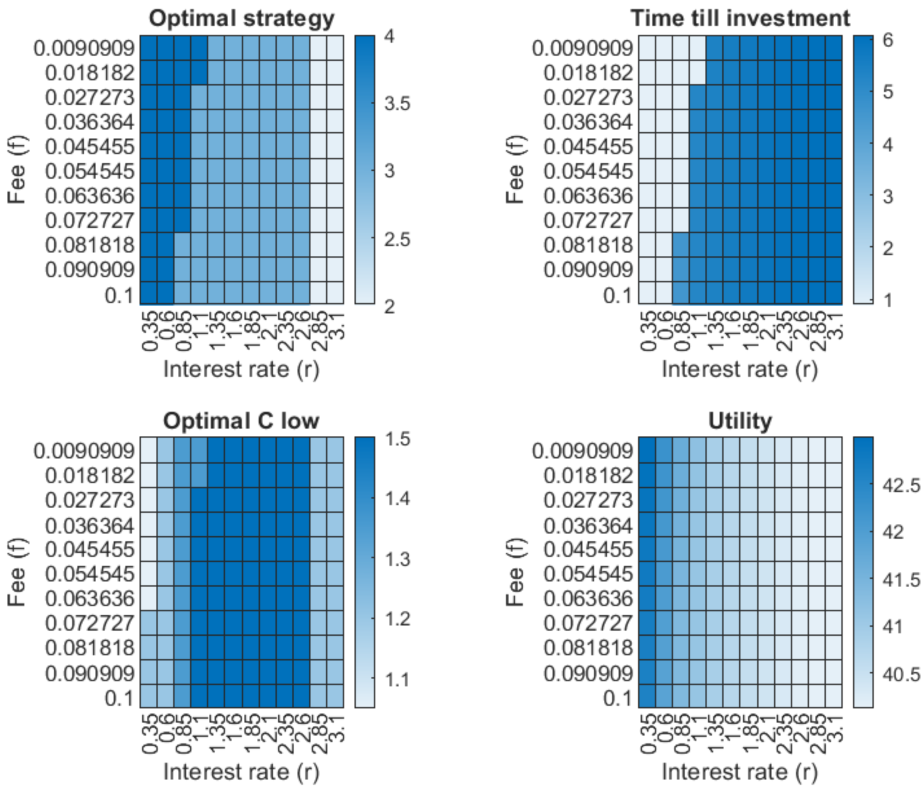


Fig. 5. Comparative statics: Changing formal interest rates and informal loan fees. This figure shows how changing the formal interest rate and informal bridging loan affects the farmer's optimal choice of strategy (top-left right); time till investment, T, (top-right); consumption while saving, $\underline{c}$ (bottom-left); and resultant utility, V (bottom-right). The colors for the optimal strategy (top-right panel) map to the strategies listed in Proposition (**??**), that is strategy $s4$ (borrowing from both formal and informal lender) is coded as dark blue, strategy $s3$ (borrowing from only the formal lender) is blue, strategy $s2$ (investing but never borrowing) is light blue. Note, if the borrower uses strategy $s2$ or $s1$, the borrower's utility—and therefore optimal choice—is independent of the formal interest rate and the informal lender's fee, so regardless of the parameter values, the figure will only ever show one of these strategies.

TABLE 1. Length, size, and interest rates of loans.

Percentiles	Length (months)			Amount (baht)			Interest (monthly)		
	Formal	Quasi-formal	Informal	Formal	Quasi-formal	Informal	Formal	Quasi-formal	Informal
Below median deciles									
5	3.0	3.0	0.0	5,000	1,000	630	0.23%	0.00%	0.00%
10	4.0	5.0	0.0	5,000	1,400	1,000	0.31%	0.00%	0.00%
20	11.0	7.0	1.0	10,000	2,000	1,800	0.46%	0.00%	0.00%
30	12.0	10.0	1.0	13,000	2,380	2,700	0.46%	0.00%	0.00%
40	12.0	12.0	2.0	16,000	3,000	5,000	0.50%	0.33%	0.00%
Quartiles									
25	12.0	8.0	1.0	11,000	2,000	2,000	0.46%	0.00%	0.00%
50	12.0	12.0	3.0	20,000	5,000	6,000	0.50%	0.45%	0.71%
75	13.0	13.0	8.0	30,000	15,000	20,000	0.67%	1.00%	3.00%
Above median deciles									
60	12.0	12.0	5.0	20,000	6,000	10,000	0.58%	0.69%	2.00%
70	13.0	13.0	7.0	20,000	10,000	15,000	0.62%	0.92%	2.62%
80	13.0	18.0	10.0	30,000	23,520	20,000	0.75%	1.00%	4.00%
90	13.0	26.0	13.0	50,000	50,000	45,000	1.00%	1.85%	6.25%
95	13.0	60.0	13.0	90,000	108,750	110,000	1.27%	3.00%	9.23%
Mean									
mean	12.8	15.5	5.8	31,876	27,271	22,628	0.80%	0.86%	2.36%

Note: The distribution of loan length (in month), loan amount (in baht), and loan interest rates (monthly) across lender types.

Table 2. Number of investments made by households.

# of investments	Agricultural assets		Business assets		Agricultural + business assets		
	Land + livestock + agri assets	Agricultural assets	Business + household assets	Business assets	Land + livest + agri + biz + household	All (w/o household assets)	Agri + business assets
Share of households with different number of investments over 160 months							
0	14.4%	35.1%	2.3%	79.7%	5.0%	13.6%	29.2%
1	30.5%	33.9%	22.4%	14.0%	20.6%	29.7%	36.4%
2	25.8%	19.2%	30.0%	4.5%	23.4%	26.0%	20.0%
3	13.8%	7.6%	23.1%	1.0%	24.5%	14.4%	8.6%
4	9.7%	3.1%	14.0%	0.5%	15.6%	10.1%	4.4%
5	3.4%	1.0%	4.7%	0.2%	7.0%	4.1%	0.8%
6	1.9%	0.2%	2.8%	0.2%	2.4%	1.8%	0.6%
7	0.2%	0.0%	0.6%	0.0%	1.3%	0.2%	0.0%
8	0.2%	0.0%	0.2%	0.0%	0.2%	0.2%	0.0%
Mean number of investments per year over 160 months							
Include 0	0.14	0.08	0.19	0.02	0.20	0.15	0.10
Exclude 0	0.17	0.13	0.19	0.11	0.21	0.17	0.13
Share of household having any month with non-zero assets over 160 months							
Share	97.2%	81.3%	98.4%	23.5%	98.5%	97.6%	85.1%

Note: The distribution of number of investments made by each household during 160 months, considering different asset definitions across columns.

Table 3. Ratio of investment to prior month assets and prior 12 months revenues

Percentiles	Agricultural		Business		Agricutural + business investments			
	Invest/assets/rev		Invest/assets/rev		All prod assets/rev		Agri + biz assets/rev	
	$\frac{\text{Invest size}}{\text{Pre mth assets}}$	$\frac{\text{Invest size}}{\text{Pre 12 mth rev}}$	$\frac{\text{Invest size}}{\text{Pre mth assets}}$	$\frac{\text{Invest size}}{\text{Pre 12 mth rev}}$	$\frac{\text{Invest size}}{\text{Pre mth assets}}$	$\frac{\text{Invest size}}{\text{Pre 12 mth rev}}$	$\frac{\text{Invest size}}{\text{Pre mth assets}}$	$\frac{\text{Invest size}}{\text{Pre 12 mth rev}}$
Bottom decile								
5	16.5%	2.4%	11.1%	0.7%	0.2%	1.3%	14.2%	1.6%
10	24.4%	4.1%	15.6%	1.4%	0.4%	2.2%	22.3%	2.6%
Quartiles								
25	49.2%	11.2%	38.9%	3.9%	1.0%	5.2%	46.3%	8.4%
50	138.0%	41.9%	85.5%	13.9%	4.1%	16.2%	130.9%	26.4%
75	670.7%	171.4%	356.5%	59.4%	15.3%	52.9%	613.2%	117.4%
Top decile								
90	4,531.1%	605.3%	1,869.6%	315.6%	57.9%	193.3%	3,755.8%	405.4%
95	14,037.2%	1,284.0%	6,587.3%	1,459.6%	127.4%	432.7%	12,872.7%	1,037.4%

Note: Comparing the relative size of investment to asset prior to investment as well as preceding 12 months total household revenue, considering different investment/asset definitions across columns.

Table 4. Investments, loans, and bridge loans.

	Number (#) and percent (%) of investments by credit arrangements							
	All assets		Agri. + biz assets		Agricultural assets		Business assets	
	#	%	#	%	#	%	#	%
Non-bridge investment-loans:								
No-loan	426	29.7%	131	27.2%	112	26.8%	27	27.3%
Initial loan set only	278	19.4%	98	20.4%	86	20.6%	25	25.3%
Hooked loans only	82	5.7%	27	5.6%	27	6.5%	3	3.0%
Formal or informal bridges:								
Single-lender	65	4.5%	19	4.0%	11	2.6%	9	9.1%
Formal combinations only	39	2.7%	16	3.8%	16	5.1%	1	1.0%
Informal combinations only	5	0.3%	3	0.6%	1	0.2%	2	2.0%
Joint formal and informal bridges:								
Formal—informal—formal bridges	298	20.8%	105	21.8%	86	20.6%	20	20.2%
Other joint formal informal bridges	243	16.9%	82	17.0%	79	18.9%	12	12.1%

Note: The number and share of investments linked to different types of credit structures, considering different investment definitions across columns, and using 6 months backward window.

Table 5. Change in 12 months average monthly revenue before and after investment month and the size of investment.

	Outcome: pre-post difference in monthly revenue					
	All investments				Cut 5% tails	
	(1)	(2)	(3)	(4)	(5)	(6)
Investment (pre-post asset difference)	0.0326	0.0332	0.0336	0.0339	0.0177	0.0185
	(0.0019)	(0.0020)	(0.0020)	(0.0021)	(0.0049)	(0.0054)
R^2	0.148	0.212	0.162	0.224	0.009	0.104
Observations	1629	1629	1629	1629	1475	1475
Survey-month FE	No	Yes	No	Yes	No	Yes
Village FE	No	No	Yes	Yes	No	Yes

Note: Standard errors in parenthesis. Table reports coefficient from regressing the difference in average monthly revenue from 12 months preceding and after the investment month on the size of investments. Investment size is the difference in asset before and after investment, and we use all assets for these regressions. In column 2, we control for all survey month fixed effects; in column 3, we control for village fixed effects for all 16 Thai monthly survey villages; in column 4, we control for survey month and village fixed effects. In columns 5 and 6, we winsorize the data by cutting away the top and bottom 5 percentile of the data based on the investment size regressor.

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ONLINE APPENDIX

Timing lumpy investments with informal bridge loans and clunky formal loans: Evidence from Thailand

Anil K. Jain, Robert M. Townsend and Fan Wang

Appendix A. Proofs

Subsection A.1. **Proof of Proposition 4.1.** To be completed.

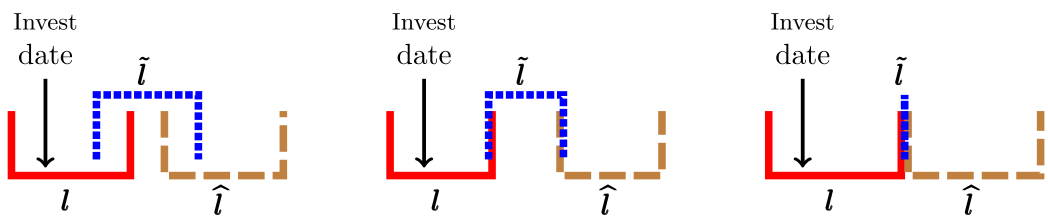
Note that if the farmer makes an investment, it will always be equal to $k_t = I$, because any investment less than I has zero output and the farmer has the opportunity cost of investing in the safe, low-return, technology that has a return of $\underline{r}$, which is strictly greater than zero. Further, the farmer's investment in total capital (K_t) would never strictly exceed I units of capital, because more than I units of capital is costly and has no benefits to the farmer.

Next note, if the farmer is not credit or liquidity constrained, the farmer would prefer to smooth consumption over time. The farmer's Euler equation would suggest that the following equation should hold, if the farmer could borrow or save at an interest rate of $\underline{r}$.

$$\dot{c} = c_t \frac{\underline{r} - \rho}{\sigma} \tag{A.1}$$

Subsection A.2. **Proof of Proposition 5.1.** abc

Subsection B.1. **Defining investment-linked loan hooks and bridges.** Building on the discussions in Section 3.2 of the main text, here we define loan sets $L^A_{j,k}(\tau)$, $L^B_{j,k}(l)$, and $L^C_{j,k}\left(l, \tilde{l}\right)$ and illustrate types of investment-k-linked bridge loans. For added precision, in this section, we redefine L^A from Eq. (1) and $\mathcal{B}_{j,k}(\tau)$ from Eq. (2) with additional notations for household j, investment k, and investment-loan windows τ.



(a) Loans l and $\tilde{l}$ as well as loans $\tilde{l}$ and $\widehat{l}$ are "loosely-hooked" to each other—bridge loan $\tilde{l}$ originates before l is due and $\tilde{l}$ is due after $\widehat{l}$ originates.

(b) The loans are "tightly–hooked"—bridge loan $\tilde{l}$ originates when l is due and $\tilde{l}$ is repaid when $\widehat{l}$ originates.

(c) The "bridge" is lengthless—the bridge loan $\tilde{l}$ originates and is repaid in the same unit of time that l is repaid and $\widehat{l}$ originates.

Fig. B.1. We illustrate in three panels the origination and repayment timelines for three types of investment-linked bridge loans allowed by Eq. (B.5). Investment-linked loan l is shown in solid-red, bridge-loan $\tilde{l}$ is shown in dotted-blue, and third loan $\widehat{l}$ is shown in dashed-brown. The left and right vertical bounding edges for each loan illustrates origination and due dates (months) for each loan, and the horizontal span for each loan illustrates loan duration. A black arrow points to the date when the investment is made, which is within τ-window of loan l as defined in Equation (1).

Let $m^{\mathrm{I},s}_{j,k}$ and $m^{\mathrm{I},e}_{j,k}$ be the starting and ending month of the kth investment made by household j; superscript I denotes investments. Let $m^{\mathrm{L},s}_{j,l}$ and $m^{\mathrm{L},e}_{j,l}$ be the month in which loan l made by household j was first initiated and the month in which it is fully repaid, respectively; superscript L denotes loans. Let L_j be the total number of loans taken out by household j during the span of survey been considered, each investment k by household j has a set of "investment-linked" loans $L^A_{j,k}(\tau)$:

$$\text{(B.1)} \qquad L^A_{j,k}(\tau) = \left\{ l \in \{1, \ldots, L_j\} \mid \ m^{\mathrm{I},s}_{j,k} - \tau \leq m^{\mathrm{L},s}_{j,l} \leq m^{\mathrm{I},s}_{j,k} \text{ and } m^{\mathrm{I},e}_{j,k} < m^{\mathrm{L},e}_{j,l} \ \right\}.$$

Loan set $L^B_{j,k}(l)$ loans that are "hooked" to investment k via loan l from loan $L^A_{j,k}(\tau)$. Specifically, loan $\tilde{l} \in L^B_{j,k}(l)$ is taken out by household j after loan l has *originated* and before or in the month in which loan l is *due*, and loan $\tilde{l}$ is repaid after or in the month in which loan l is *due*:

$$L^{B}_{j,k}(l)=\left\{\tilde{l}\in\{1,\ldots,L_j\}\setminus L^{A}_{j,k}(\tau)\;\middle|\;\begin{array}{c} m^{\mathrm{L},s}_{j,l}<m^{\mathrm{L},s}_{j,\tilde{l}}\le m^{\mathrm{L},e}_{j,l}\\ \text{and } m^{\mathrm{L},e}_{j,l}\le m^{\mathrm{L},e}_{j,\tilde{l}}\end{array}\right\}\text{ for } l\in L^{A}_{j,k}(\tau)\,. \tag{B.2}$$

For household j, the set of investment-k-linked hooked loans are:

$$\mathrm{HOOK}_{j,k}(\tau)=\left\{\left(l,\tilde{l}\right)\mid l\in L^{A}_{j,k}(\tau)\text{ and }\tilde{l}\in L^{B}_{j,k}(l)\right\}\,. \tag{B.3}$$

We define loan set $L^{C}_{j,k}\left(l,\tilde{l}\right)$ as containing loans that are "bridge-linked" to investment k via sets $L^{B}_{j,k}(l)$ and $L^{A}_{j,k}(\tau)$ loans. Specifically, the origination date of loan $\widehat{l}\in L^{C}_{j,k}\left(l,\tilde{l}\right)$ satisfies three conditions: Loan $\widehat{l}$ originates after or in the same month that loan l is *due*, after or in the same month that loan $\tilde{l}$ *originates*, and before or in the same month that loan $\tilde{l}$ is *due*. Additionally, the due month for loan $\widehat{l}$ must come after the *due* date of loan $\tilde{l}$:

$$L^{C}_{j,k}\left(l,\tilde{l}\right)=\left\{\widehat{l}\in\{1,\ldots,L_j\}\setminus\left(L^{A}_{j,k}(\tau)\cup L^{B}_{j,k}(l)\right)\;\middle|\;\begin{array}{c} m^{\mathrm{L},e}_{j,l}\le m^{\mathrm{L},s}_{j,\widehat{l}}\,,\\ m^{\mathrm{L},s}_{j,\tilde{l}}\le m^{\mathrm{L},s}_{j,\widehat{l}}\le m^{\mathrm{L},e}_{j,\tilde{l}}\,,\\ \text{and } m^{\mathrm{L},e}_{j,\tilde{l}}<m^{\mathrm{L},e}_{j,\widehat{l}}\end{array}\right\} \tag{B.4}$$
$$\text{for }\tilde{l}\in L^{B}_{j,k}(l)\text{ and } l\in L^{A}_{j,k}(\tau)\,.$$

For household j, the set of investment-k-linked bridge loans are:

$$\mathcal{B}_{j,k}(\tau)=\left\{\left(l,\tilde{l},\widehat{l}\right)\mid l\in L^{A}_{j,k}(\tau),\tilde{l}\in L^{B}_{j,k}(l)\text{ and }\widehat{l}\in L^{C}_{j,k}\left(l,\tilde{l}\right)\right\}\,. \tag{B.5}$$

Eq. (B.5) allows for three types of "bridges" as visualized in Figure B.1. In Panel (a), the loans are "loosely-hooked"—the bridging loan is taken out before the due date of the first loan and repaid after the origination date of the third loan. Conforming to Eqs. (B.1), (B.2) and (B.4), the investment, loan origination, and loan due dates are such that: $m^{\mathrm{L},s}_{j,l}<m^{\mathrm{I},s}_{j,k}<m^{\mathrm{L},s}_{j,\tilde{l}}<m^{\mathrm{L},e}_{j,l}<m^{\mathrm{L},s}_{j,\widehat{l}}<m^{\mathrm{L},e}_{j,\tilde{l}}<m^{\mathrm{L},e}_{j,\widehat{l}}$. In Panel (b), the loans are "tightly-hooks"—the bridging loan is taken out in the same month the first loan is due and repaid in the same month that the third loan originates, with $m^{\mathrm{L},s}_{j,l}<m^{\mathrm{I},s}_{j,k}<m^{\mathrm{L},s}_{j,\tilde{l}}=m^{\mathrm{L},e}_{j,l}<m^{\mathrm{L},s}_{j,\widehat{l}}=m^{\mathrm{L},e}_{j,\tilde{l}}<m^{\mathrm{L},e}_{j,\widehat{l}}$. In Panel (c), the "bridge" is length-less—the bridge loan originates and is repaid in the same month, with $m^{\mathrm{L},s}_{j,l}<m^{\mathrm{I},s}_{j,k}<m^{\mathrm{L},s}_{j,\tilde{l}}=m^{\mathrm{L},e}_{j,l}=m^{\mathrm{L},s}_{j,\widehat{l}}=m^{\mathrm{L},e}_{j,\tilde{l}}<m^{\mathrm{L},e}_{j,\widehat{l}}$.

Presumably, to function as parts of a loan-bridge, loan $\tilde{l}$ is taken out at a time prior to when loan l is due, and loan $\widehat{l}$ is taken out before loan $\tilde{l}$ is repaid. But temporal unit of observation in surveys, which is month in our empirical data, is unlikely allow allow for sufficiently fine temporal granularity to distinguish the orders of these events.

Subsection B.2. **Inter-loan gaps and loan hooks and bridges definition.**

B.2.1. *Loan hooks.* we identify all within-individual loans that have overlaps, and create a file where the unit of observation is each binary combination of overlapping loans for each household. loans that overlap are "hooked", with a loan that is in the upper hook position, and the paired loan in the bottom hook position.

for each within household paired loan we compute the three gaps:

- `gl`: top left - bottom left
- `gm`: bottom left - top right
- `gr`: top right - bottom right

where "top left" refers to the start date of the first loan, and "bottom right" refers to the end date of the second loan. consideration all possible combinations of loan pairings, two loans are hooked only when all three gaps are positive or non-zero:

- $gl > 0$: the bottom loan is taken out after the top loan.
- $gm \geq 0$: the top loan is not due yet or just due when the bottom loan is taken out.
- $gr > 0$: the bottom loan is due after the top loan is due.

during this process, we also identify loan pairs that have identical timing, these are loan pairs where $gl = gr = 0$. for these loans, $gm + 1 > 0$ is the length (including start and end) of both loans. if $gm = 0$, we have two paired loans that both start and end in the same month. furthermore, we check on whether the hooked loans are provided by the same lender. we document the same of loan hooks that are:

- top and bottom hook from the same lender.
- top and bottom hook have duplicative start and end times: $gl = gr = 0$
- top and bottom hook both start and end in one month: $gm = gl = gr = 0$

issue 18[B.12] handles the implementation identifying loan hooks.

B.2.2. *Loan bridges.* A loan bridge consists of three components, left-bank loan (loan A), bridge loan (loan B), and right-bank loan (loan C).

We compute three sets of three gaps.

1. Gaps between left-bank and bridge loans:
    - `G12L`: start of B - start of A
    - `G12M`: end of A - start of B
    - `G12R`: end of B - end of A
2. Gaps between left-bank and bridge loans:

B.12. https://github.com/fanwangecon/prjthaihfid/issues/18

- `G23L`: start of C - start of B
- `G23M`: end of B - start of C
- `G23R`: end of C - end of B

3. Within-loan gap, duration of each lona:
   - `GW1`: loan A gap
   - `GW2`: loan B gap
   - `GW3`: loan C gap

In addition, we compute river, abutment and approach widths. Jointly there are 12 bridge related widths statistics for each loan ridge.

1. River width (`GRV`) = `G12R` - `G23M` = `G23L` - `G12M`
2. Abutment width (`GAB`) = `G12M` + `G23M`
   - Left-abutment width = `G12M`
   - Right-abutment width = `G23M`
3. Approach width (`GAP`) = `G12L` + `G23R`
   - Left-approach width = `G12L`
   - Right-approach width = `G23R`

Having computed these statistics, two most basic requirements are:

1. Must be positive: $GRV > 0$, which means brige A must end in a month prior to the start of bridge C.
2. Middle loan must not be longer than loans A and B: $\min(GW1, GW3) > GW2$, note that $GW2 > GRV$.
3. we define typical bridge as satisfying additionally these conditions: $\min(GW1, GW3) \geq 11 > GW2$

Algorithm part 1 of issue 19[B.13] in the repository handles the implementation of identification of loan bridges.

B.13. https://github.com/FanWangEcon/PrjThaiHFID/issues/19

Appendix C. Additional Empirical Results (online)

Subsection C.1. **Coterminous formal and informal loans.** In Appendix Figure D.5, we present information on the overlaps between formal and informal loans. Appendix Figure D.6 shows the household-specific shares of months in which there are any loans outstanding. Here, to simplify the consideration of conditional probabilities, we group the quasi-formal loans jointly with the informal loans. We consider, for each household month, whether the household has a formal loan outstanding, an informal loan outstanding, or both. For each household, conditional on the months in which there are outstanding informal loans, we count the number of months in which there are concurrently also outstanding formal loans. We then compute the household-specific probability of having formal loans conditional on having informal loans. Following the reverse procedure, we also compute the household-specific probability of having informal loans conditional on having formal loans. Aggregating across households, we arrive at the cross-household distributions of formal and informal conditional probabilities, which are presented in Figure D.5.

If informal loans are used, at least by some households, as bridge loans to rollover formal loans, we might expect the chance of seeing a formal loan during months in which there are informal loans to be high for these households. First, in one scenario, formal loans would be outstanding during the entire duration of an informal loan: an informal bridge loan is taken out close to the last month in which a formal loan is outstanding, a new formal loan is taken out immediately after the prior one is repaid with the help of the bridge loan, and soon after the issuance of the new formal loan, the informal bridge loan is repaid. Corresponding to this possibility, in Figure D.5, following the blue solid line, we observe a high concentration of households close to having 100% for their household-specific $P(\text{Formal} = 1|\text{Informal} = 1)$ conditional probabilities. Second, households with high $P(\text{Formal} = 1|\text{Informal} = 1)$ but not as close to 100% could be using informal loans as bridge loans but have time gaps between when the prior formal loan is repaid and when the new formal loan is issued, which would lead to the household having some months in which an informal loan is not accompanied by a formal loan. Third, given the observed diversity of informal loans, there could also be households that use informal loans for non-bridging purposes, and these might explain the small concentration of $P(\text{Formal} = 1|\text{Informal} = 1)$ around zero.

In contrast, in the bridge loan scenario, given that formal loans have substantial longer average duration, one would expect there to be many months—in between the issuance and repaid dates of formal loans—in which formal loans are outstanding without yet-unneeded informal bridge loans. We find evidence for this in Figure D.5: the $P(\text{Informal} = 1|\text{Formal} = 1)$ distribution is relatively uniform, indicating that many households predominantly have months in which there are formal loans but no informal loans.

Subsection C.2. **Additional results on investment-linked loan hooks and bridges.** Table 4 in the main text presents the share of investments by different investment-loan linkage types for 6 months backward investment-loan window. In Appendix Table D.1, we present results for 3 months backward investment-loan window. Across the columns of Table D.1, we consider different definitions of assets-investments.

In Table D.1, we find that "no-loan" investments increases to 40 percent of all investments, which is larger than the 30 percent from Table 4. For proportions of types of loans among investment-linked loans, Table D.1 shows that 63 percent of loan-linked investments having bridge-loans and 83 percent of bridge-linked investments having both formal and informal components. These statistics are similar to results from Table 4. Additionally, Panel (B) of Figure 4 shows that when we further contract the backward investment-loan window to $\tau = 0$, bridge-linked investments remains dominant, accounting for 59% of all loan-linked investments.

Subsection C.3. **Additional results on investments and changes in revenues.** In the main text, we present Table 5 and discuss the relationship between investments and changes in revenues by comparing changes in average monthly revenue in the 12 months after and before the months of investment. In Appendix Table D.2, we tighten the window and compute changes in revenues as differences in average monthly revenue in the 6 months after and before the months of investment.

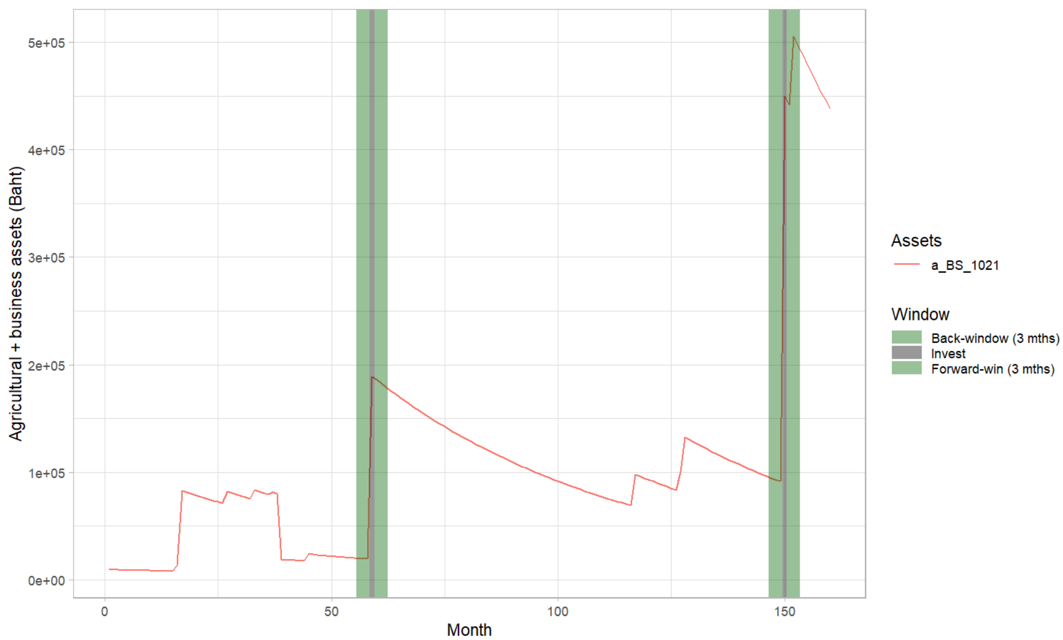
Similar to Table 5, in Appendix Table D.2, we consider all assets for investment size and all sources of income for revenue changes. In column (1), we regress changes in revenues on the size of investments without controls. We control for survey month fixed effects in column (2), village fixed effects in column (3), and both survey month and village fixed effects in column (4). In columns (5) and (6), we winsorize the sample by cutting away the top and bottom 5 percentiles of the data based on the investment size regressor.

From column (4) of Appendix Table D.2, We find that investments are associated with a 5.9 percent increase in monthly revenue, which is larger than the finding for the 12 months window from Table 5. The 6 months window results are driven by tail investments; we find no relationship between investment size and revenue changes after winsoring the top 5 and bottom 5 percentiles of the investment distribution. Our shorter window finding indicates that, in comparison to Table 5 findings, fewer investments are yet to generate positive increases in revenues, but those that do have high immediate returns that become tempered by the longer return window.

Across the columns Table D.2, investment size is a key factor explaining revenue variations. Investment size variations explain between 9 to 17 percent of the return variance, which are about half to three fourth of the finding from Table 5. Return estimates are similar across fixed effects specifications.

Appendix D. Additional Figures and Tables (online)

(a) Illustrative household example 1



(b) Illustrative household example 2

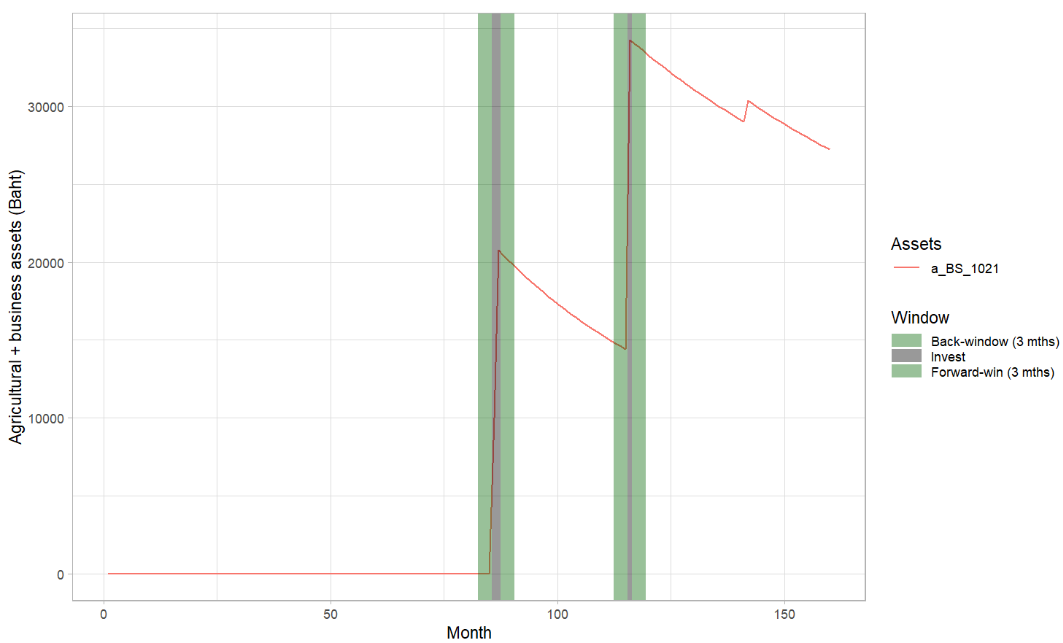
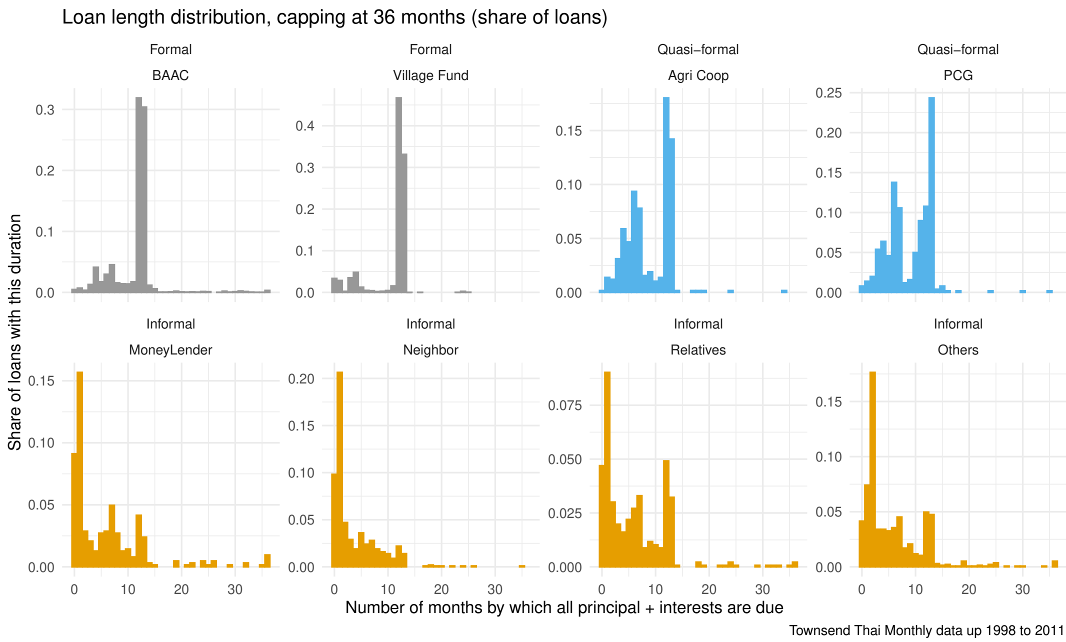


Fig. D.1. Identifying investments (shifts in capital-assets).

(a) Shares



(b) Number of Loans

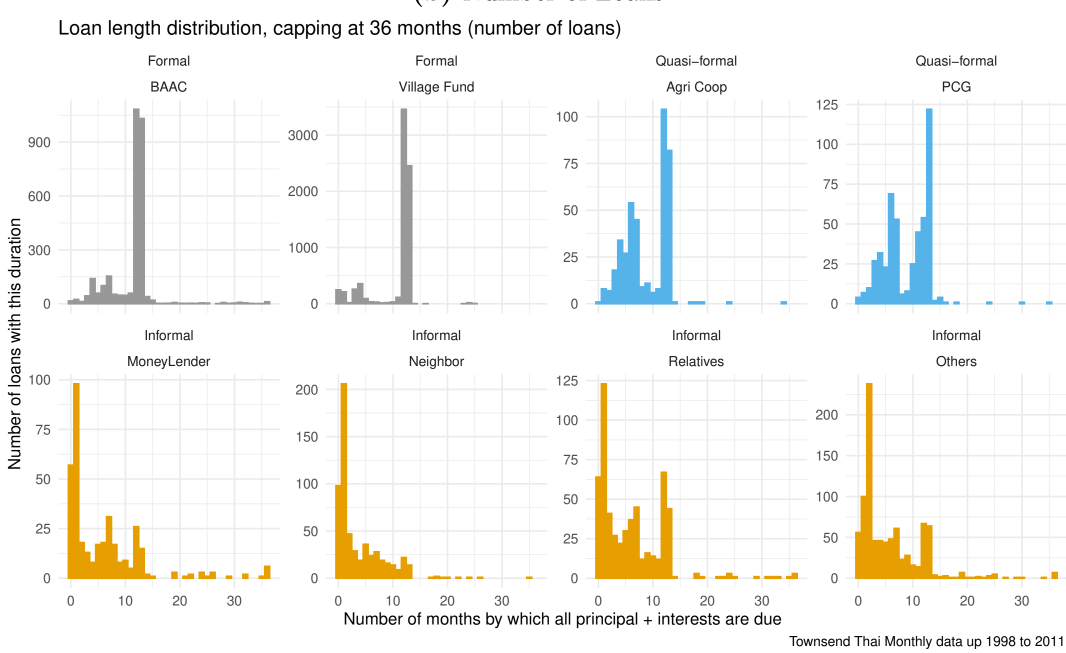


Fig. D.2. Length of loan distribution, across eight key lender types.

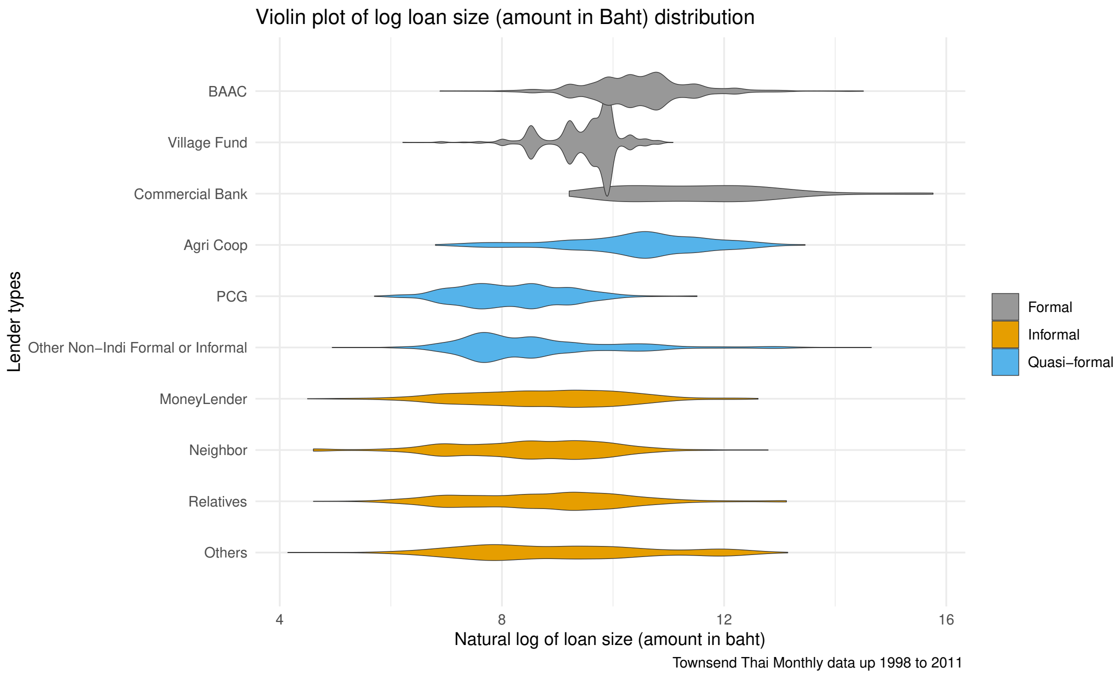


Fig. D.3. Loan size distribution across all lender types

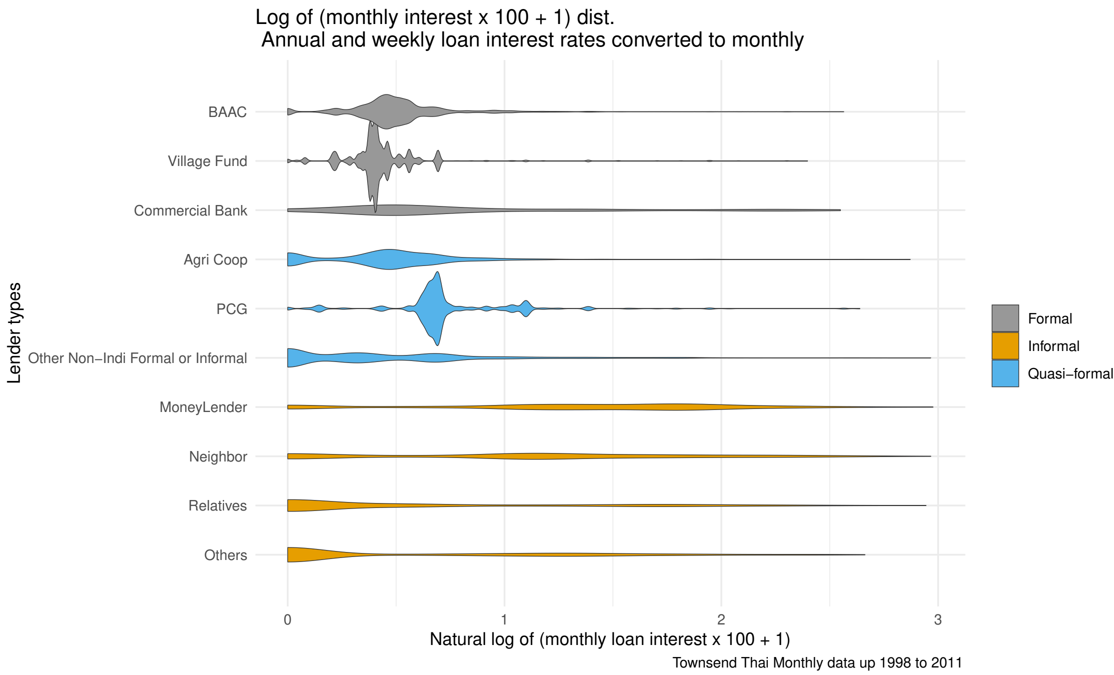


Fig. D.4. Loan interest rates distribution across all lender types

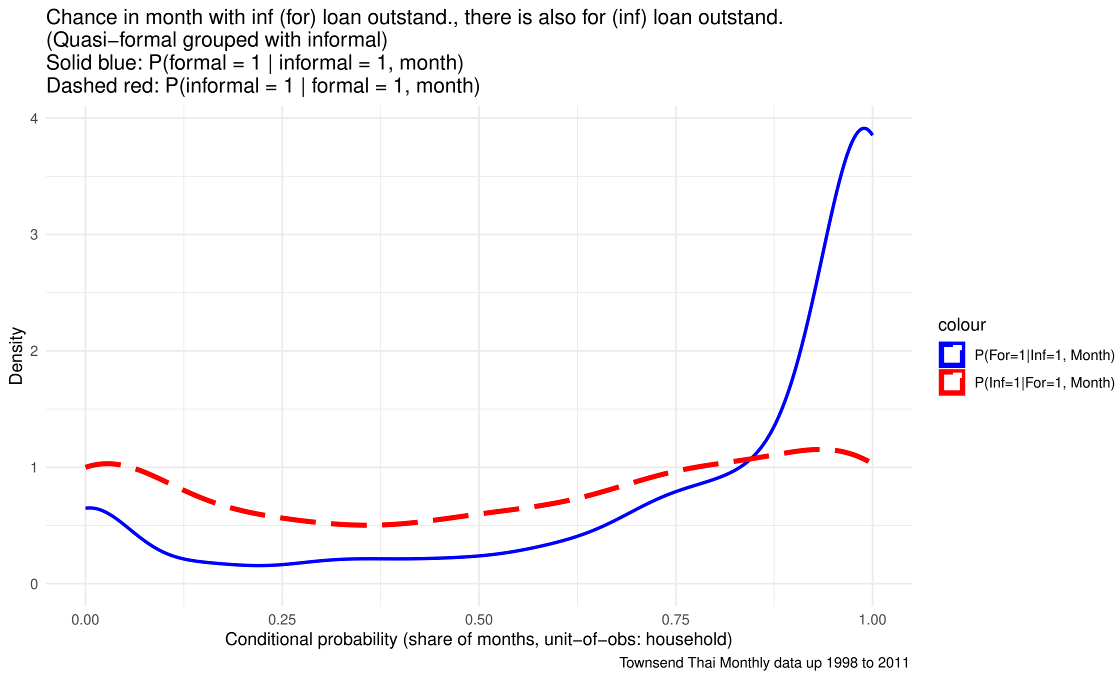


Fig. D.5. Household-specific conditional loan overlap distribution
For each household, we consider the months in which there are informal loans outstanding, and then we count the presence of outstanding formal loans during these informal loan months. This is the household-specific conditional probability of having a formal loan in a month in which the household has formal loans. We also consider the reverse household-specific conditional probability of having informal loans outstanding in months in which a household has formal loans outstanding. Aggregating across households, we present the distribution of these two conditional probabilities.

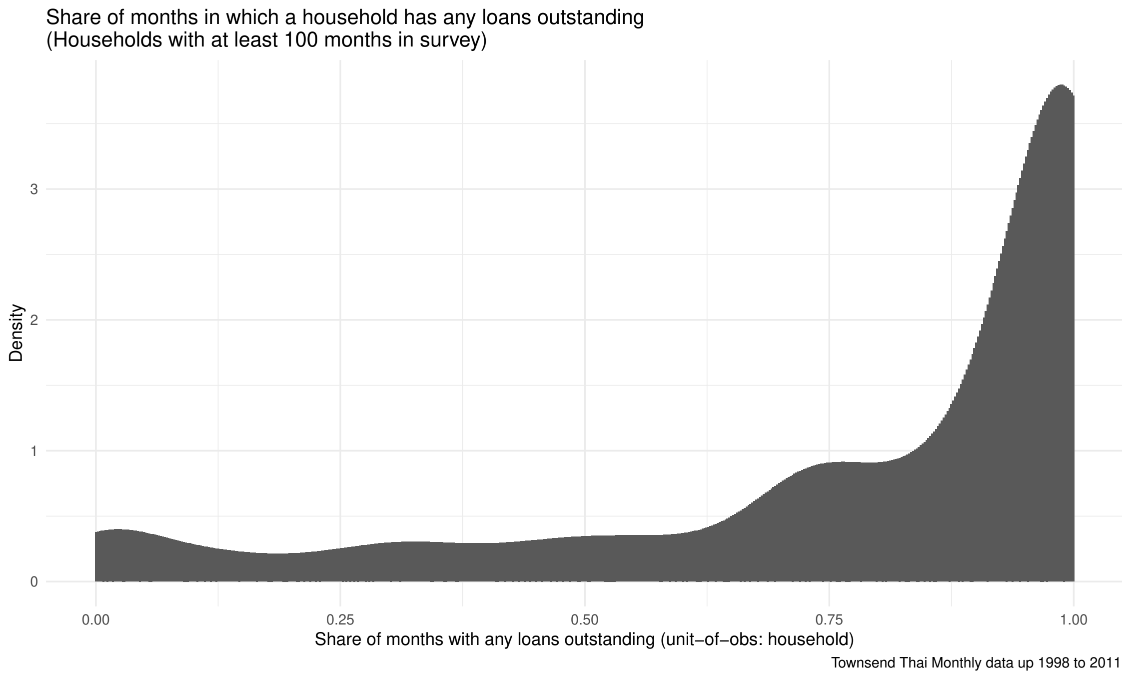


Fig. D.6. Distribution of household-specific share of months with loans

Table D.1. Investments, loans, and bridge loans with 3 months backward window.

	Number (#) and percent (%) of investments by credit arrangements							
	All assets		Agri. + biz assets		Agricultural assets		Business assets	
	#	%	#	%	#	%	#	%
Non-bridge investment-loans:								
No-loan	426	29.7%	131	27.2%	112	26.8%	27	27.3%
Initial loan set only	278	19.4%	98	20.4%	86	20.6%	25	25.3%
Hooked loans only	82	5.7%	27	5.6%	27	6.5%	3	3.0%
Formal or informal bridges:								
Single-lender	65	4.5%	19	4.0%	11	2.6%	9	9.1%
Formal combinations only	39	2.7%	16	3.8%	16	5.1%	1	1.0%
Informal combinations only	5	0.3%	3	0.6%	1	0.2%	2	2.0%
Joint formal and informal bridges:								
Formal—informal—formal bridges	298	20.8%	105	21.8%	86	20.6%	20	20.2%
Other joint formal informal bridges	243	16.9%	82	17.0%	79	18.9%	12	12.1%

Note: The number and share of investments linked to different types of credit structures, considering different investment definitions across columns, and using 3 months backward window.

Table D.2. Change in 6 months average monthly revenue before and after investment month and the size of investment.

	Outcome: pre-post difference in monthly revenue					
	All investments				Cut 5% tails	
	(1)	(2)	(3)	(4)	(5)	(6)
Investment (pre-post asset difference)	0.0326	0.0332	0.0336	0.0339	0.0177	0.0185
	(0.0019)	(0.0020)	(0.0020)	(0.0021)	(0.0049)	(0.0054)
R^2	0.148	0.212	0.162	0.224	0.009	0.104
Observations	1629	1629	1629	1629	1475	1475
Survey-month FE	No	Yes	No	Yes	No	Yes
Village FE	No	No	Yes	Yes	No	Yes

Note: Standard errors in parenthesis. Table reports coefficient from regressing the difference in average monthly revenue from 6 months preceding and after the investment month on the size of investments. Investment size is the difference in asset before and after investment, and we use all assets for these regressions. In column 2, we control for all survey month fixed effects; in column 3, we control for village fixed effects for all 16 Thai monthly survey villages; in column 4, we control for survey month and village fixed effects. In columns 5 and 6, we winsorize the data by cutting away the top and bottom 5 percentile of the data based on the investment size regressor.