An Empirical Equilibrium Model of Formal and Informal Credit Markets in Developing Countries

Fan Wang

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Abstract

In this paper, I develop and estimate a dynamic equilibrium model of household borrowing and savings decisions in formal and informal credit markets. The model features households with heterogeneities in productivity and wealth, and characterizes credit market access by interest rates, fixed costs, and borrowing constraints. Households have access to an exogenous formal credit market and to an informal credit market in which the interest rate is endogenously determined by the local demand and supply of credit. My application focuses on Thailand which implemented policies in 2001 that primarily encouraged borrowing. I estimate the model by simulated maximum likelihood using data from the Townsend Thai Monthly Survey. Based on the estimated model, I find that lower fixed costs increased the proportion of households borrowing formally, and that relaxed formal borrowing collateral constraints lowered informal interest rates. In terms of welfare, I find that low wealth but productive households benefited from Thai policies to expand credit access, but the gains were smaller than suggested by previous studies that ignored the informal market. Moreover, approximately 18% of households suffered welfare losses because of diminished opportunities for informal saving. Counterfactual policy simulations suggest that policies that combine borrowing and savings subsidies could yield higher average social welfare at a cost similar to the implemented policies.

*latest version available at: [http://tinyurl.com/econ-fan-wang](http://tinyurl.com/econ-fan-wang). Department of Economics, University of Pennsylvania (email: fanw@econ.upenn.edu). I am deeply grateful to Flavio Cunha and Jere Behrman for their constant support and guidance throughout the course of this project, and I would like to thank Petra Todd, Dirk Krueger and Robert Townsend for their invaluable support and extensive feedback. I would also like to thank Andrew Shephard, Jeremy Greenwood, Holger Sieg, Kenneth Wolpin, Cecilia Fieler, Esteban Puentes, Victoria Prowse, Jeremy Tobacman, Eun-Young Shim and seminar participants in the Empirical Micro Seminar, GCC Development Seminar and Empirical Micro Club at Penn for useful discussions and comments.
1 Introduction

In recent decades, governments in developing countries have funded the expansion of formal financial institutions into rural areas and subsidized interest rates. Despite these expansions, informal credit markets persist. Much research separately studies formal or informal markets, but less is known empirically about how the two markets interact. In this paper, I show that this interaction is critical to understanding the effects of expanding access to formal credit markets. The same formal credit policy can have very different impacts depending on households’ informal alternatives.

To formalize this interaction and quantitatively evaluate the impact of formal credit expansions on households’ credit market choices and welfare, I develop and estimate a dynamic equilibrium model of household investment, borrowing and savings decisions. My application focuses on Thailand, which implemented policies in 2001 to encourage formal borrowing through subsidies and other means. My findings show that these policies led to winners and losers. Low-wealth but productive households benefited from expanding credit, but the gains were more limited than suggested by previous studies. Approximately 18% of households suffered welfare losses because of diminished opportunities for informal lending. Counterfactual policy simulations based on the estimated model suggest that policies that combine borrowing and savings subsidies could yield higher average social welfare at a cost similar to the implemented policies.

In my model, households are infinitely-lived, risk-averse, and have varying productivity and wealth. In each period, households choose risky capital investments and savings, and they can finance their capital investments through borrowing. I characterize households’ access to credit markets along three dimensions: interest rates, fixed costs, and formal borrowing constraints. Households have access to an exogenous formal credit market and to an informal credit market in which the interest rate is endogenously determined by the local demand and supply of credit. Households pay a per-period fixed costs to access any of the different credit market options. If households decide to borrow from the formal credit market, they face a collateral constraint that limits borrowing up to a fraction of their physical capital holdings. When the constraint binds, households can supplement their formal borrowing with informal borrowing. Up to their collateral constraints, households can also arbitrage between the formal and informal markets by borrowing formally and lending informally—a behavior that I observe in the data. Given i.i.d. productivity and credit shocks, households with different financial needs optimize over consumption, physical capital investment, and financial choices within each credit choice category.
I estimate the model using panel data from the Townsend Thai Monthly Survey, which contains extensive information about the sizes and rates of formal and informal credit transactions for 650 households between 1999 and 2009. During this period, in 2001, the Thai government, under Prime Minister Thaksin, implemented a wave of large-scale policies, including the Million Baht Village Fund program, aimed at broadening rural households’ access to formal borrowing. Specifically, the policies reduced interest rates by offering a low fixed borrowing rate, reduced fixed costs by directly administering formal loans via village committees, and relaxed collateral constraints by increasing the quantity of formal loans available. As a result of these policies, the proportion of households who used formal borrowing increased by 25 percentage points, and formal interest rates decreased by up to 8 percentage points in some areas. The informal interest rate also dropped by up to 14 percentage points. I introduce the Thaksin policy shift in my model as changes in formal interest rates, in formal fixed costs and in formal borrowing collateral constraints.

I estimate the model using simulated maximum likelihood. The estimation allows for the identification of unobserved fixed costs and collateral constraints, and of the distributions of household preferences and productivities. I allow the parameters that characterize the credit market to vary over time and estimate their changes based on changes in credit choice type participation probabilities conditional on assets. I find that the fixed costs to access the formal credit market dropped from about 5% of average annual income to about 1%, and the collateral constraints were also significantly relaxed, more than doubling how much each household could borrow formally given the same amount of physical capital as before. Along with the lowering of formal borrowing interest rates, these changes resulted in significant improvements in households’ access to formal borrowing.

In terms of welfare, the estimated model suggests that there were winners and losers. The vast majority of rural households are slightly better off under Thaksin’s policies, although the estimated gain of 0.1% in consumption-equivalent variation is much smaller than previous welfare calculations that disregard the informal sector. For example, Buera et al. (2014) and Townsend and Ueda (2010) estimate welfare gains in the order of 5% to 15%. Welfare effects are heterogeneous across households. Households with lower wealth and high productivity gain about 5%. These households were previously constrained by the collateral constraints or by the fixed costs from investing more in their household farms or businesses. However, larger money-lending households and unproductive households lose up to 1% in consumption-equivalent variation. These welfare losses, experienced by about 18% of households, arise through the general equilibrium effects of the policy changes, which lowered interest rates in the informal sector by 14
I conduct counterfactual experiments to decompose the relative contributions of each of the three formal-borrowing-access dimensions in explaining effects of the Thaksin policies. First, I find that reductions in formal borrowing fixed costs are responsible for 83% of the changes in the proportion of households using formal credit options. Second, relaxing the formal borrowing collateral constraint is responsible for 77% of the informal interest rate drop. Third, the reduction in formal borrowing interest rates had limited effects on aggregate choices and the informal market interest rate. The three measures of access have different impacts because they shift the average costs of formal loans differently for different types of households.

Currently, development financial institutions tend to be oriented towards lending or savings-only. In contrast, my counterfactual simulations suggest that in an environment where heterogeneous households have differential needs for borrowing and saving, unbalanced efforts that mainly improve formal access for either borrowing or saving could lead to more limited financial options for some households and their subsequent welfare losses.

**Literature Review**  The analysis in this paper is related to several literature. First, there has been substantial research on the impact of greater financial access on rural economies. (Greenwood and Jovanovic, 1990; Lloyd-Ellis and Bernhardt 2000; Gine and Townsend, 2004; Townsend and Ueda, 2010; Kaboski and Townsend 2012; Buera, Kaboski, and Shin, 2013; Greenwood, Sanchez, and Wang, 2013) In this literature, the main channel for potential welfare losses is from the labor market and an overall equilibrium interest for the whole economy. In this paper, I show instead that welfare losses could also arise from the interaction between formal and informal credit markets, and that welfare gains from greater financial access might be lower if existing informal options are considered.

Second, there is a growing literature that studies the expansion of microfinance service providers into developing areas (see review in Banerjee, 2013). These studies have shown that despite the growth in formal-loan use after the expansion of formal lenders, aggregate demand for informal loans do not always decline (Angelucci et al., 2013), and the share of rural households using informal loans could still be higher than those adopting formal loans (Banerjee et al., 2013). In this paper, I provide a model that can explain how formal and informal credit markets coexist and interact, and the model sheds light on issues such as what determines the take-up rate of formal credit options.

Third, this paper contributes to works that study the interaction between formal and
informal credit markets (Hoff and Stiglitz, 2007; Gine, 2011; Kinnan and Townsend, 2012; Mookherjee and Motta, 2013; Alem and Townsend, 2014; Madestam, 2014). This paper synthesizes some core features of formal and informal credit markets into an empirical dynamic equilibrium framework. One important departure that this paper takes from the existing literature is that the supply side of the informal credit market has been endogenized through the dynamics of savings. This paper allows formal credit market policies to influence informal interest rates and participation decisions, and investigates the equilibrium welfare implications of formal credit market policies on households which are heterogeneous in productivity and wealth.

Fourth, there is a literature that studies how the provision of formal insurance could crowd-out informal insurance (Attanasio and Rios-Rull, 2000, Golosov and Tsyvinski, 2007, Krueger and Perri, 2001). These papers find that more formal insurance provisions might worsen informal conditions and lead to welfare losses. In this paper, I study formal and informal market interactions in the context of exogenously incomplete credit markets. The welfare gains and losses in this paper arise out of a competitive informal credit market’s interaction with an exogenous formal credit market. This contrasts with the insurance literature where welfare losses arise in the context of an endogenously incomplete market structure usually with limited commitment.

The structure of the paper is as follows. In Section 2, I describe the data and background. Section 3 develops the model. Section 4 describes the solution to the dynamic programming problem and estimation procedure. Section 5 describes mechanisms of the model and the relationship between assets and credit category choice probabilities. Section 6 describes estimation results and counterfactuals. I offer conclusion in Section 7.

## 2 Data and Background

I estimate and test the model with a panel of village household data from Thailand. 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 lead by the Bank for Agriculture and Agricultural Cooperatives (BAAC). The central government has helped to finance the expansion of these development banks and continues to subsidize their operations (Maurer, 2000).

The election of Prime Minister Thaksin Shinawatra in 2001 brought about a significant change in Thai rural development policies. The government made improving rural for-
mal borrowing conditions a central focus and introduced a wave of programs to achieve this goal. The most prominent policy was the Million Baht Village Fund program (Boonperm et al., 2009). This program, sometimes called the largest microfinance program in the world, provided every single village in Thailand with one million Baht in additional credits. Crucially, the power to approve loans was directly in the hands of local committees rather than bank managers. Formal development banks provided important support for the program. For example, the 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. In addition to the Million Baht Fund program, the government gave BAAC itself a greater mandate to expand its lending programs, and the government also created a range of additional lending programs through government agencies and other development banks (Phongpaichit, 2004).

I use the 1999 to 2009 waves of the Townsend Thai Monthly Survey to study the impact of the credit expansion program under Thaksin’s policies. The dataset is very useful for studying the interaction between formal and informal credit markets. It contains extensive household level financial data for 650 households in 16 villages of Thailand. 8 of these villages are located in the wealthier Central region of Thailand, and 8 of them are located in the poorer Northeast region of Thailand. Figure 1 presents the location of these villages. Households in this survey consists 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 and savings transactions with both formal and informal channels.

2.1 Formal and Informal Channels for Borrowing and Savings

I group household borrowing and savings decisions into those that are conducted with outside banks and those that are conducted with other villagers. I consider the first group of credit market activities as formal, and the second group as informal. Informal transactions with other villagers could be conducted directly between individuals or indirectly via village groups.

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1For example, the Government Savings Bank was given additional resources. There were also lending programs aimed at supporting small businesses, lending programs aimed at allowing households to purchase low-priced household goods, and lending programs focused on supporting students.

2It is possible to potentially categorize village groups such as Production Cooperative Group (PCG) and Village Agricultural Coops as formal institutions, but since the supply and demand for credit in these semi-formal institutions are largely locally determined, I consider transactions with these groups as informal.
Before analyzing changes over time in credit market participation rates, I first show here the relative significance of different formal and informal credit market players. Data indicates that both borrowing and savings activities are prevalent among rural households, and that both informal and formal credit markets are frequently used by households.

For borrowing, Table 1 presents the relative popularity of five main formal and informal lenders. The five lenders are: Million Baht Fund, BAAC, Village Coops (Production Cooperative Groups and Village Agricultural Cooperatives), friends or neighbors, and village moneylenders.\(^3\) The data shows first that most households borrowed at least once formally and informally between 1999 and 2009. Second, most informal borrowing transactions were with other households that were friends and neighbors. Third, households borrowed more in the Northeast region, especially informally. Specifically, in the Northeast Region, between 1999 and 2009, 78% percent of households borrowed at least once from the Million Baht Fund program, 61% of households borrowed from the BAAC, 35% of households borrowed from Village Coops, 83% of households borrowed from friends and neighbors, and finally 37% of households borrowed from village moneylenders. In the Central region, the informal credit market participation rate was roughly half of the rate in the Northeast region. In both regions, for households that borrowed at least once from formal lenders, on average they took out new loans in more than half of the years between 1999 and 2009. Informal borrowing was frequent as well, averaging 4 years in which loans were taken out between 1999 and 2009 for the 83% of households that borrowed from friends and neighbors.

For savings, Table 2 presents the relative popularity of four common ways for households to save. The four ways are: saving with commercial banks, saving with the BAAC or the Government Savings Bank (GSB), saving with Village Coops, or saving by lending to other individuals in the village. The data shows first that most households in both regions saved at least once formally or informally between 1999 and 2009. Second, a large proportion of households lent directly to other households at least once. Third, household saved at government sponsored development banks more than at commercial banks. Specifically, in the Northeast region, 94% of households saved with either the BAAC or the GSB between 1999 and 2009, 37% saved with commercial banks, 64% saved with Village Coops and finally 66% of households lent directly to other households. In the Central region, usage of commercial banks for saving was twice as often as in the Northeast, and the frequency of direct individual lending was half the level of the Northeast.

\(^{3}\)Moneylenders who are categorized also as friends and neighbors are grouped under friends and neighbors.
east. For households that used the BAAC or the GSB for saving, they made new deposits in approximately 7 out of the 11 years between 1999 and 2009. For households that lent directly to other individuals, they lent new loans on average for 2.5 years out of the 11 years between 1999 and 2009.

### 2.2 Aggregated Formal and Informal Credit Categories

I aggregate households’ monthly credit activities over the span of a calendar year, and identify the types of credit transactions each household undertakes during that year. This aggregation serves as an approximation of the more detailed credit market activities described in the previous section. For example, if a household only borrowed formally in a year, then the household for that year is identified as a formal borrower. After aggregation, I find that there are some households that use no credit options, and some households that only use one credit option: borrowing or saving formally, or borrowing or saving informally. There are also households that borrow both from formal and informal sources, as well as households that both borrow from formal sources and save informally in the span of a year. Together, these constitute seven main credit category alternatives. Most households could be classified as undertaking credit transactions in one of the manners just mentioned. For households that have other combinations of credit market activities, I also group them into these seven categories just mentioned based on the quantity of borrowing and savings they undertake formally and informally.

The results of classifying credit market transactions across seven categories can be seen in Tables 4 and 3. These tables show the average annual probability of households participating in the seven credit market choice categories before and after the full implementation of Thaksin’s policies. Although some of Thaksin’s policies started in the second half of 2001, they did not come into full force until 2002. Hence, I divide data into two periods, 1999 to 2001 and 2002 to 2009. Reflecting information shown in Tables 1 and 2, in both regions of the country, households participate both in the formal and the informal credit markets. Overall the formal credit market participation rate is higher in the Central region than in the Northeast, and the overall participation rates in saving is greater in the Central region than in the Northeast region.

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4The two joint credit choice categories are important. Together with the exclusive credit market choices, they mean that formal and informal credit markets could be substitutes or complements, and that demand and supply in the informal credit market is driven by nuanced interactions. These joint credit choices are often discussed in the theoretical and empirical literature on informal and formal credit market interactions. Bell et al. (1997), for example, emphasize the importance of joint formal and informal borrowing. Hoff and Stiglitz (1997) and Floro and Ray (1997), for example, focus on households that borrow formally and lend informally.
Strikingly, over time, the data show a large shift in credit market participation rates across different categories after the implementation of Thaksin’s policies. Tables 4 and 3 show that after 2001, the proportion of households in the Northeast who only borrow or save formally increased by 20 percentage points, and the proportion of households who only borrow or save informally decreased by 21 percentage points. In the Central region, these shares increased by 7 percentage points and decreased by 2 percentage points respectively. Interestingly, in both regions, the proportion of households using both formal and informal credit markets increased after 2001. For example, in the Central region, this ratio increased from 6.7 percent of households to 18 percent of households.

2.3 Formal and Informal Interest Rates

I analyze the interest rate data by looking at interest rates on individual credit transactions and then aggregating them up to the village level for each calendar year. Table 5 and Figure 2 show distributions and means of the annualized average village real interest rates in the data for formal and informal categories. Loan interest rates are annualized real rates which take into consideration pecuniary repayment as well as reported repayments in kind. These annual interest rates are for loans with average lengths of slightly longer than 12 months. For formal interest rates, there is little variation within areas and time periods. For households that borrow and lend directly to other households who might be friends, neighbors or moneylenders, I average across reported rates within each village and for each year. For these individual-to-individual informal credit market activities, borrowing and savings interest rates are the same. For interest rates on borrowing and savings conducted via village groups, I take the interest rates reported on borrowing from village groups as the interest rates for both borrowing and savings via these groups.

Overall, I find that throughout the years from 1999 to 2009, informal interest rates were higher than formal interest rates, and formal borrowing interest rates were higher than formal savings interest rates. Both formal and informal interest rates decreased significantly over time. The average informal interest rate in the Northeast was 27% before 2002, compared to 15% for formal borrowing and 3.3% for formal savings. In the Central

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5 I compute interest rates on individual loans via a combination of methods to obtain the most accurate values possible.

6 While the variance in informal interest rates could also be important, the large gap between formal and informal interest rate captures a crucial difference between the two credit markets (see review in Conning and Udry 2007 for interest rates in other countries). I do not study potential differences in interest rates across individuals in this paper.

7 Although informal groups such as PCG and Agricultural Coops are semi-formal, I classify them as informal because the demand and supply of credit for these informal groups are largely local.

region, before the policy shift, the average informal interest rate was 17.5%, compared to 13% for formal borrowing and 3.2% for formal savings. After the Thaksin policy shift, the informal interest rate in the Northeast region decreased by 14 percentage points to 13.9%, and in the Central region decreased by 8 percentage points to 9.4%. Accompanying these were reductions in the formal interest rates both for borrowing and for savings. Formal borrowing interest rate decreased by 8 percentage points in both the Northeast and Central regions to approximately 6%, and formal savings interest rate in both regions also decreased by approximately 2 percentage points to about 1%.

It is important to note that changes in formal interest rate on borrowing and savings could be driven by changes in international rates as well as policy changes. The BAAC, for example, uses a system called transfer-pricing to allow local branch managers to borrow from or deposit savings at BAAC’s headquarters in Bangkok at specified internal borrowing and savings interest rates. These rates are considered policy instruments of the banks, and could be changed as international rates change or as policy makers try to subsidize rural lending or mobilize rural savings (Maurer, 2000).

### 2.4 Amounts of Borrowings and Savings

I present distributions of the amounts of formal and informal borrowing and savings activities in Figures 3 and 4. Figure 3 presents the distributions of borrowing and savings loan sizes in the formal and the informal sector. The data are based on annualized sums of formal or informal borrowings activities and the flow levels of formal or informal savings activities. The figure shows that formal loan sizes tend to be larger than informal loan sizes, and that the sizes for informal savings tend to be larger than sizes for formal savings. Specifically, median formal borrowing loan sizes over time and across both regions is approximately 27,000 Baht per year. The median size for informal loans is approximately 15,500 Baht per year. For savings, median informal individual lending size is approximately 17,500 Baht per year. While there are some households with large amounts of formal savings at formal banks, aggregating across all households, the flow of formal saving has a median of approximately 8000 Baht per year. This formal savings size represents net inflow taking into consideration withdraws. I provide additional details on borrowing amounts across lenders in Figure 4. This figure shows that BAAC loans tend to be larger in size, and that the loan sizes from those that are categorized as village moneylenders and friends are similar.
2.5 Fixed Costs

The survey also captures some aspects of the pecuniary fixed costs for acquiring each loan. Table 6 and Figure 5 show averages and distributions of reported fees and transportation costs for each loan that households have taken out. There was a large reduction in these costs after 2001 for formal borrowing. Most of the drop is due to the prevalence of the Million Baht Fund program as shown in Figure 5. Loans from the Million Baht Fund had fees and transportation costs similar to borrowing informally, which is likely due to the fact that the Million Baht Fund was administered by village committees inside villages.

Fees and transportation costs for the BAAC also went down over time. These might have been driven down by improvements in the BAAC itself or reductions in transportation and communication costs. Table 6 shows that costs at the BAAC, however, are still twice as large as the average costs reported for borrowing from relatives or moneylenders. Strikingly, the fees and transport costs on the few reported commercial bank loans is on average 7 times larger than those for BAAC loans, and almost 35 times larger than the costs for Million Baht Fund loans or informal loans.

2.6 Repayment

In the literature on informal credit markets, repayment rates for informal borrowing have often been found to be high (Morduch 1999). Recently, repayment rates for formal borrowing have also been found to be high (Buera, Kaboski, and Shin, 2013). Consistent with these findings, in the Townsend Monthly Survey Villages, both formal and informal repayments are high. Tables 7 and 8 show some aspects of repayment information from the survey villages. These on-time repayment rates are directly calculated from the data: every month, new loans that households take out are recorded and the month in which repayment should be completed is also recorded; then every month, repayment amounts of each loan is tracked until full repayment.

Overall, Tables 7 and 8 show that less than 5% of households do not eventually pay their loans back fully. Specifically, eventual full repayment rate for formal loans is 97% and for informal loans is 95%. Interestingly, households that do not fully pay back their loans still pay a significant proportion of their debts, as shown in Table 8. Taking partial repayments into consideration, 98.2% of every Baht of principal lent is paid back for formal loans, and 96.5% of every Baht of principal lent is paid back for informal loans.
3 The Model

In this model, for a village economy, there is a continuum of infinitely-lived households that are heterogeneous in their productivity type $A$, their physical capital $k$, and their financial asset $b$. Productivity type $A$ is fixed for an individual household over time, and represents a household’s heterogeneous ability to earn income for its household firm. Physical capital $k$ is input for the household firm. Financial asset $b$ is the total sum of principal and interests due from or owed to both formal and informal sources by a household. Forward looking savings behaviors, and comparison of expected productivity and rates of interest endogenously determine households’ asset holdings.

In each period, households face two kinds of shocks. An i.i.d. productivity shock $\epsilon$, which determines, together with productivity type $A$, a household firm’s productivity, and a vector of i.i.d. credit category utility shocks $\Phi$ for alternative formal and informal credit choice categories. Given these shocks, in each period, households make continuous asset choices within joint formal and informal credit choice categories.

3.1 Preference

Households are risk-averse with respect to consumption within each time period, and utility over consumption is separable over time. Individual expected utility over lifetime sequence of consumption $c_t$, is $E\left[ \sum_{t=0}^{\infty} \beta^t u(c_t) \right]$, where within each period, utility from consumption is $\frac{(c_t)^{1-\sigma}}{1-\sigma}$. $\beta$ is the discount factor, $\sigma$ is the coefficient of relative risk aversion. The expectation is over realized values of productivity shocks $\epsilon$ and credit category shocks $\Phi$.

3.2 Technology

At the beginning of each period, for each household, the household productivity type $A$, i.i.d. productivity shock $\epsilon$, and physical capital $k$, which is chosen previously by the household based on expected productivity, jointly determine the income of the household in the current period.

$$Y = A \cdot \exp(\epsilon) \cdot k^\alpha$$

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8Given the complexity of credit choices, the model focuses only on financial and physical capital choices. The production function does not include labor inputs, and the model does not consider labor choices.
3.3 Credit Markets

In this model, villages are small open economies with respect to externally offered formal financial choices. Villages also contain an informal credit market in which households of varying levels of productivity and wealth borrow from and lend to each other. These mean that households have access to an exogenous formal credit market and to an informal credit market whose interest rate is endogenously determined by the local demand and supply of credit.

I define financial access in formal and informal credit markets along three dimensions: fixed costs, interest rates and collateral constraints. Given these dimensions of access, households with different borrowing and savings need can choose among seven credit alternatives: leave cash under mattress, borrow from the informal credit market only, borrow from the formal market only, save in the informal credit market only, save in the formal market only, borrow jointly from the formal and informal markets, or finally, borrow from the formal market and save in the informal market.

There are four fixed costs associated with formal and informal borrowing and savings choice: \{ψ^{FB}, ψ^{IB}, ψ^{FS}, ψ^{IS}\}. In each period, households have to pay the fixed costs associated with the credit category they choose. These fixed costs represent the average pecuniary and non-pecuniary costs associated with formal and informal credit market activities. I do not explicitly allow these fixed costs to vary for individuals in each period, but I do allow for households’ preference for the seven different credit categories to be influenced by i.i.d. preference shocks \(Φ \in \mathbb{R}^7\). These preference shocks provide a computationally manageable way for the model to capture random variations in pecuniary and non-pecuniary fixed costs across individuals.

There are three interest rates: the formal borrowing interest rate \(r^{FB}\), the formal savings interest rate \(r^{FS}\), and the informal interest rate \(r^{I}\). The two formal interest rates are exogenous, and the informal interest rate is an equilibrium interest rate. The informal interest rate is determined by local demand and supply competitively given formal interest rates, fixed costs and collateral constraints. I model interest rates in this way to capture

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9 The word saving and lending mean the same in this model.
10 It is not possible to separately identify pecuniary and non-pecuniary fixed costs.
11 Pecuniary components of the fixed costs include transportation costs, fees, and opportunity costs among others. Non-pecuniary components of fixed costs include aversion or preference towards different credit market activities.
12 Although an important feature of informal credit market is the variation in informal interest rate, to make the model tractable, I only model a single equilibrium informal interest rate. This interest rate captures the most striking difference between formal and informal interest rates, which is that informal interest rates are on average larger than formal interest rates.
the fact that in many emerging economies, subsidized development financial institutions
are large with respect to the rural economy, but are only a small part of the developed
urban formal financial sector where these institutions raise their capital (Buttari, 1995,
Meyer, 2011). The demand for formal borrowing and savings is unlikely to influence ur-
ban formal interest rates, but formal credit market conditions might have large impacts
on the informal market.

Collateral constraint $\gamma$ constrains how much households could borrow when they
borrow formally. Formal banks will only allow rural households to borrow up to $\gamma$ frac-
tion of their physical capital asset $k$. There is no collateral constraint in the informal credit
market. This set up captures the common finding that rural households are relatively
well-informed and closely tied to each other, and that formal lenders often set implicit or
explicit collateral constraints on borrowing based on observable physical capital because
formal banks are relative less well informed about the conditions of rural households
(Evans and Jovanovich, 1989; Conning and Udry, 2007).

Default is not possible in this model. There exists combinations of the potential bor-
rowing choices that would make it impossible for households to repay debt in some pos-
sible state in the future when productivity shock $\epsilon$ is low. However, since households
have infinite marginal utility as consumption approaches zero, they will not choose as-
et choices that could lead to infinite negative utility in any future state. In this model,
household choices are hence bound by the natural borrowing constraint (Aiyagari, 1994).
This assumes that households are fully committed to pay back their loans. Because of full
repayment, in the current period, households will pay all interests and principals owed
to creditors for debts acquired in the last period. Households will also receive all interests
and principals owed to them from lending and savings they conducted in the last period.
Since formal and informal credit choices do not have default, only the sum of principals
and interests matters for future periods. In this model, although there is no default, col-
lateral constraint is still essential because it enables households to make joint formal and
informal credit market choices.

3.4 Recursive formulation of the household’s problem

Households maximize their life-time utility functions by choosing sequences of consum-
tion, physical capital, and formal and informal financial asset position, subject to a se-
quence of budget constraints and formal borrowing limits.

Let $R$ denote cash-on-hand. $R$ is the sum of financial asset, depreciated physical capi-
tal, and income which is realized given productivity shock $\epsilon$:

$$ R(A, k, b, \epsilon) = \exp(\epsilon) \cdot A \cdot k^\alpha + (1 - \delta) k + b $$

(2)

Since there is no default, households will always pay back $b$ if it is a negative value, and will always get paid $b$ if it is a positive value.

At the beginning of a period, the state-space $s$ of the household is summarized by its productivity type $A$, its physical capital level $k$, its cash-on-hand $R$, and the vector of credit type specific utility shock $\Phi$. Together, $s = (A, k, R, \Phi)$. A household chooses between seven different credit categories. The value for the household, $v(A, k, R, \Phi)$, is the maximum over the value of these seven alternatives. As discussed previously, the seven credit choice categories are, from one to seven respectively: cash-under-matress, formal saving, informal saving, formal borrowing, informal borrowing, formal and informal borrowing, and joint formal borrowing and informal saving.

$$ v(A, k, R, \Phi) = \max_{j \in \{1, \ldots, 7\}} \{ v_1(A, k, R, \phi_1), \ldots, v_7(A, k, R, \phi_7) \} $$

(3)

I denote the optimal credit category choice by $o(A, k, R, \Phi) \in \{1, \ldots, 7\}$

Value $v_j(A, k, R, \phi^j)$ is the maximum for each credit category $j$ over continuous asset and consumption choices. The state space elements $(A, k, R)$ determine the credit category specific optimal continuous asset and consumption choices. Credit category shock $\phi^j$ only influences the relative values of the seven credit choice categories but not the relative values of asset alternatives within each credit category. For each credit category $j$, asset and consumption choices are restricted to choice sets that are individual and category specific. For example, the possible set of physical capital and borrowing choices are different for formal and informal borrowing for the same household due to different fixed costs, interest rates and collateral constraints. Additionally, two households with different $k$ and $R$ will face different choice sets even if they both borrow informally. These choice sets are bound by the natural borrowing constraint, borrowing collateral constraint and positive consumption constraints. I discuss solving for these individual and credit category specific choice bounds for each of the seven credit categories and their resulting choice sets in Section 4.1. Each of the seven value functions $\{v_j\}_{j \in \{1, \ldots, 7\}}$ is listed in equation 6 through equation 12.

Equation 4 and 5 represent the generic forms of the seven credit category value functions. For all categories, a household chooses consumption $c$, risky physical capital investment $k'$, and next period financial position $b'$, which equals to the sum of cash-under-
mattress \( b'M \), net informal financial position \( b'I \), and net formal financial position \( b'F \), subject to period budget constraint:

\[
v_j (A, k', R', \phi') = \max_{c, k' \in K'_j, b'M \in B'_jM, b'I \in B'_jI, b'F \in B'_jF} \left\{ u(c) + \phi' + \left\{ \beta E_{\epsilon', \Phi'} \left( v \left( A, k', R', \Phi' \right) \right) \right\} \right\}
\]

s.t.: \( c = R - k' - \psi' \)

\[
\left\{ \frac{b'M}{1} + \frac{b'F_1 \{ b'F > 0 \}}{1+r's} + \frac{b'F_1 \{ b'F < 0 \}}{1+r'b} + \frac{b'I}{1+r'i} \right\}
\]

\[
b' = b'M + b'I + b'F
\]

The budget constraint for each credit category includes the fixed costs \( \psi' \) and the associated interest rates. Collateral constraint \( \gamma \) helps to determine the asset choice sets \( K'_j, B'_j \) for formal borrowing related credit categories.

The continuation value is a function of the state space elements \( (A, k', R', \Phi') \). Where \( R' \) is a function of a household’s productivity type \( A \), financial asset choices at the end of this period, \( b' \), physical capital choice \( k' \), and next period i.i.d. productivity shock \( \epsilon' \). The financial position \( b' \) represents the net amount of principals plus interest owed and earned from borrowing and savings undertaken by the household in the current period. The expectation operator \( E_{\epsilon', \Phi'} \) stands for integration with respect to the i.i.d. productivity shock \( \mu (\epsilon') \) and the i.i.d. credit type utility shock \( \mu (\Phi') \).

### 3.5 Stationary Competitive Equilibrium

I now define a stationary recursive Competitive Equilibrium for this economy.

Given formal interest rates for savings \( rFS \) and borrowing \( rFB \), collateral constraint \( \gamma \), and a vector of fixed costs \( \Psi \), a Recursive Competitive Equilibrium are the values and policy function for the household \( v : S \to R, o : S \to \{1, ..., 7\}, \{ c_j, k'_j, b'I_j, b'F_j, b'M_j : S \to R \}_{j \in \{1, ..., 7\}} \), informal interest rate \( rI \), as well as stationary measure \( \mu \), such that:

1. Given \( rFS, rFB, rI, \gamma, \Psi \), the value function \( v \) solves equation 3 and the value functions \( \{v_j\}_{j \in \{1, ..., 7\}} \) solves equations 6 through 12 and \( o \) and \( \{ c_j, k'_j, b'I_j, b'F_j, b'M_j \}_{j \in \{1, ..., 7\}} \) are the associated policy functions.
Credit Choice Category Value Functions

\[
v_1(A, k, R, \phi^1) = \max_{k' > 0, b'^r, b'^I = 0, b'^M > 0} \left\{ u\left( R - k' - b'^M \right) + \phi^1 \right\} \quad (6)
\]

\[
v_2(A, k, R, \phi^2) = \max_{k' > 0, b'^I, b'^M = 0, b'^r > b'^{FS}} \left\{ u\left( R - k' - \frac{b'^r}{1+r^{FS}} - \psi^{FS} \right) + \phi^2 \right\} \quad (7)
\]

\[
v_3(A, k, R, \phi^3) = \max_{k' > 0, b'^I, b'^M = 0, b'^I > b'^{IS}} \left\{ u\left( R - k' - \frac{b'^I}{1+r^{IS}} - \psi^{IS} \right) + \phi^3 \right\} \quad (8)
\]

\[
v_4(A, k, R, \phi^4) = \max_{k' > 0, b'^I, b'^M = 0, \gamma k \leq b'^r \leq b'^{FB}} \left\{ u\left( R - k' - \frac{b'^r}{1+r^{FB}} - \psi^{FB} \right) + \phi^4 \right\} \quad (9)
\]

\[
v_5(A, k, R, \phi^5) = \max_{k' > 0, b'^r, b'^M = 0, b'^I < b'^{IB}} \left\{ u\left( R - k' - \frac{b'^I}{1+r^{IB}} - \psi^{IB} \right) + \phi^5 \right\} \quad (10)
\]

\[
v_6(A, k, R, \phi^6) = \max_{k' > 0, b'^M = 0, b'^I \leq b'^{IB}, \gamma k \leq b'^r \leq b'^{FB}} \left\{ u\left( R - k' - \frac{b'^I}{1+r^{IB}} - \frac{b'^r}{1+r^{FB}} - \psi^{IB} - \psi^{FB} \right) + \phi^6 \right\} \quad (11)
\]

\[
v_7(A, k, R, \phi^7) = \max_{k' > 0, b'^M = 0, b'^I \geq b'^{IS}, \gamma k \leq b'^r \leq b'^{FB}} \left\{ u\left( R - k' - \frac{b'^I}{1+r^{IS}} - \frac{b'^r}{1+r^{FB}} - \psi^{IS} - \psi^{FB} \right) + \phi^7 \right\} \quad (12)
\]

Notes: See Section 3.3 and Section 4.1 for detail.
2. Informal credit market clears\textsuperscript{13}

\[
\int \left\{ \sum_{j \in \{1, \ldots, 7\}} p_j(A, k, R, \pi) \cdot b_j' (A, k, R) \right\} \, d\mu (dA, dk, dR)
\]

where \(p_j(A, k, R, \pi)\) denotes the probability of a households with \((A, k, R)\) choosing credit category \(j\), given the distribution over the credit category shocks \(\pi\).

In this stationary equilibrium, the measure \(\mu\) over state space is invariant with respect to the Markov process induced by the i.i.d. productivity shock \(\epsilon\), i.i.d. credit category shock \(\Phi\), productivity type distribution over \(A\), and the policy functions.

For policy experiment, welfare in aggregate village economy is measured by a social welfare function in the steady state that is Utilitarian with equal weights assigned to all households. All welfare analysis is based on stationary steady state\textsuperscript{14}.

There is always a unique equilibrium in this model because both households that borrow only informally and households that borrow both formally and informally have downward sloping demands for informal loans. Additional, both households that lend only informally and households that arbitrage between formal and informal credit markets have upward sloping supply curve for informal loans. The smoothness and presence of these demand and supply curves are guaranteed by credit category utility shocks that create demand and supply for informal loans given any formal interest rates combinations.

Finally, I assume that the formal credit market does not clear to capture the way in which development financial institutions operate in many emerging economies today that have large developed urban sectors. In these countries, lending or saving focused development institutions are capitalized by the state and receive continuous state subsidies in their operations (Buttari, 1995; Meyer, 2011). Development banks in these countries are often policy arms of national governments that do not have to make profits or match demand to supply. Additionally, although many large lending only development banks do try to raise funds on international and national capital markets, their capital market activities are unlikely to influence overall interest rates in developed urban economy.

\textsuperscript{13}Note that in this model, the formal credit market does not need to clear. The idea is that in many emerging economies, there is a large developed urban economy that subsidizes credit and savings in underdeveloped rural areas. Formal credit market policies could influence the informal credit market, but formal credit market choices by rural households will not impact the urban developed sector’s interest rates.

\textsuperscript{14}This is mostly to be consistent with the fact that estimated coefficients are based on model in the stationary steady state since it is not clear how to impose transition path position in the process of estimation.
4 Solving the Stochastic Dynamic Programming Problem and Maximum Likelihood Estimation

In this section, I present the solution and estimation methods necessarily for empirical implementation of the model.

4.1 Solving the Stochastic Dynamic Programming Problem

In each period, a household solves the value function subject to the inter-temporal budget constraint and production function. To solve this problem, there are two important steps. First, finding optimal continuous asset choices. Second, integrating over productivity shocks \( \epsilon \) and credit choice type shocks \( \Phi \).

**Asset Choice Sets** Within each period, a household optimizes over 2 continuous choice variables, the physical capital choice, \( k' \), and the aggregate net financial position \( b' \). In order to find optimal choices, I set up a two dimensional choice grid with fixed percentages of cash-on-hand values within feasible choice ranges for \( k' \) and \( b' \) for each of the credit choice categories. These choice ranges also are specific to each individual’s current asset holdings. Increasing the number of grid points increases the accuracy of this solution method. I solve for optimal choices using grids rather than newton search to increase solution stability and speed.

The feasible choice ranges for \( k' \) and \( b' \) are found by restricting choices so that they do not lead to infinite negative utility in the current and the next period: In the current period, the combinations of \( k' \) and \( b' \) should not lead to negative consumption; in the next period, in the tradition of natural borrowing constraint (Aiyagari, 1994), \( k' \) and \( b' \) should not lead to negative consumption in the worst possible state for productivity shock \( \epsilon' \).

For informal borrowing, with income equal to \( Y' \left( \epsilon_{\min}' \right) \) in the worst state of productivity shock tomorrow, the maximum amount that could be borrowed is:

\[
- \left( R( A, k, b, \epsilon) - \psi^{IB} + \frac{Y' \left( \epsilon_{\min}' \right)}{(1 - \delta)} \right) \left( \frac{(1 + r^I) (1 - \delta)}{(\delta + r^I)} \right) \equiv \min \left\{ B_{IB}' \right\} \quad (13)
\]

This bound on informal borrowing depends on the cash-on-hand available today \( R( A, k, b, \epsilon) \), the informal borrowing fixed costs \( \psi^{IB} \), and the informal interest rate \( r^I \). If cash-on-hand today and minimal income tomorrow \( Y' \left( \epsilon_{\min}' \right) \) are larger, households can borrow more.
In the context of the production function \( Y'(\epsilon'_{\text{min}}) = 0 \). Therefore, without cash-on-hand today, households can not borrow. Additionally, the maximum amount that could be borrowed is less if fixed costs for informal borrowing is high and the informal interest rate is high. The fraction \( \frac{(1+r^I)(1-\delta)}{\delta+r^I} \) acts as a multiplier on cash-on-hand today, determining how much maximum borrowing leverage cash-on-hand today provides. Given the maximum amount of informal borrowing, the maximum amount of physical capital choice is:

\[
\left( R \left( A, k, b, \epsilon \right) - \psi^{IB} + \frac{Y'(\epsilon'_{\text{min}})}{(1-\delta)} \right) \frac{(1+r^I)}{(\delta+r^I)} \equiv \max \left\{ K'^{IB} \right\} \tag{14}
\]

The maximum \( k' \) and maximum informal borrowing choice jointly determine a limiting point for the asset choice space for informal borrowing. There are two additional constraints on assets choices for informal borrowing:

Positive \( c \) Bound: \( R - k' - \frac{b'^I}{1+r^I} - \psi^{IS} = 0 \) \( \tag{15} \)

Positive \( c' \) Bound: \( k' (1-\delta) + b'^I + \frac{Y'(\epsilon'_{\text{min}})}{(1-\delta)} = 0 \) \( \tag{16} \)

Feasible choices of \( k' \) and \( b'^I \) must be less than the maximum asset bounds, and also must be within the these two consumption bounds. Figure 21 presents a graph where the x-axis represents \( b'^I \) and y-axis represents \( k' \) choices. The full choice range for a particular household for informal borrowing is the interior of the red region in Figure 21. The top-left corner of the red-box is the maximum point from equation 13. The two red lines leading from the top-left corner to the y-axis represent the two consumption bounds lines. In solving the model, this red box is filled with equally spaced choice grid points, and the combination of \( b'^I, k' \) that gives the highest utility is picked as optimal choice for informal borrowing.

The feasible choice set for formal borrowing is similar to the one for informal borrowing with one crucial difference. Because formal borrowing is constrained also by \( \gamma \cdot k \), there is an additional bound on feasible asset choices. This is shown graphically in Figure 21. In the figure, a vertical blue line cuts through the red triangular area, this line represents the collateral constraint bound. To solve for the feasible choice set for formal borrowing, equations 13 and 15 are again invoked with informal borrowing fixed costs and interest rate replaced by formal borrowing fixed costs and interest rate. The result-
ing triangular choice area is then cut by the collateral constraint line, making the feasible choice region for formal borrowing a quadrilateral in the context of Figure 21.

The feasible asset choice set for households that borrow formally and informally at the same time is shown graphically in Figure 22. Due to the fact that formal borrowing interest rate is lower than informal borrowing interest rate, households that borrow formally will first exhaust their formal borrowing up to their collateral constraint bound before they choose to pay the fixed costs for informal borrowing and begin borrowing informally. For this credit category, the maximum amount of informal borrowing feasible is:

\[
- \left( R - \left( \frac{\gamma k}{1 + r^{FB}} \right) \left( \frac{\delta + r^{FB}}{1 - \delta} \right) - \psi^{IB} - \psi^{FB} \right) \frac{(1 + r^{I}) (1 - \delta)}{(\delta + r^{I})} \equiv \min \{ B'_{FBIB} \}
\]

And the maximum amount of choice for this credit category is:

\[
\left( R - \psi^{IB} - \psi^{FB} \right) \frac{(1 + r^{I})}{(\delta + r^{I})} + \gamma k \cdot \left( \frac{r^{I} - r^{F}}{(1 + r^{FB}) (\delta + r^{I})} \right) \equiv \max \{ K'_{FBIB} \}
\]

The fraction \( \left( \frac{r^{I} - r^{F}}{(1 + r^{FB}) (\delta + r^{I})} \right) \) shows that the maximum k’ under joint formal and informal borrowing could only be higher than the maximum k’ choice under informal borrowing if informal interest rate is larger than formal interest rate. With the maximum asset choice determined, equations similar to equation \ref{15} can be applied to find the full asset choice set. In comparison to the formal borrowing and informal borrowing only choices before, there is now also a minimal amount of k’ required because households need sufficient physical capital tomorrow to pay back its formal borrowing if the worst state of shock occurs.

It is straightforward to construct the feasible choice set for formal and informal savings choices. These are shown graphically in Figure 23. Figure 24 depicts the choice set when households borrow formally and lend informally. Similar to the joint formal and informal borrowing category, there is again a minimal amount of k’ required for this joint choice category.

**Integrating over Continuation Value Function** In addition to solving for feasible choice sets, in order to solve for the dynamic stochastic programming problem, I also need to

\footnote{Given category specific utility shock, it is possible that a household will get a very large utility shock for formal and informal joint borrowing choices and choose to borrow both formally and informally, yet they do not have enough borrowing needs to exhaust formal borrowing feasible. When this happens, they will choose the optimal amount of formal borrowing given that they pay both the fixed costs for formal and informal borrowing and also borrow the minimal amount required for informal borrowing choice.}
integrate over the value of the continuation value function in equation 4:

\[
E_{\epsilon', \Phi'} \left( v \left( A, k', R', \Phi' \right) \right) = \int \left\{ \int \max_{j \in J} \left( v_j \left( A, k', R', \phi'^j \right) \right) \, dF \left( \Phi' \right) \right\} \, dF \left( \epsilon' \right)
\]

where \( \{ \phi'^j \}_{j \in \{1, \ldots, 7\}} \) and \( \epsilon' \) are both i.i.d and not correlated.

To save significantly on computation time, I assume that each of the i.i.d. credit category \( \{ \phi'^j \}_{j \in \{1, \ldots, 7\}} \) shocks is extreme-value distributed. Under this assumption:

\[
\int \max_{j \in J} \left( v_j \left( A, k', R', \phi'^j \right) \right) \, dF \left( \Phi' \right) = \log \left( \sum_{j \in J} \exp \left( \hat{v}_j \left( A, k', R' \right) / \sigma_{\phi} \right) \right)
\]

where \( \sigma_{\phi} \) is the standard deviation of the preference shock, and \( \hat{v}_j \) is \( v_j \) without the utility shock term \( \phi'^j \). Formulating the problem as one with continuous choices and multinomial choice structure puts it within the category of non-linear multinomial choice models (Train, 2009; Dubin and McFadden, 1984; Hanemann, 1984). The assumption that \( \Phi \) and \( \epsilon \) shock are i.i.d and uncorrelated, and that \( \epsilon \) applies to all credit categories simplify the problem here. Additionally, because \( \epsilon \) shock applies to all choice categories, the multinomial choice alternatives do not have the independence of irrelevant alternatives characteristic.

Given equation 17, the integral over continuation value function is:

\[
E_{\epsilon'} v \left( A, k', R' \right) = \int v \left( A, k', R' \right) \, dF \left( \epsilon' \right)
\]

where \( v \) is the expected maximum over \( v_j \). Since \( \epsilon' \) only influence \( R' \left( A, k', b', \epsilon' \right) \), the expected continuation value function can be found by integrating over values of \( v \) for a distribution of \( R' \) values induced by only shifting \( \epsilon' \) along its invariant i.i.d. distribution.

Given continuous asset and productivity state space, it is not feasible to solve for all possible values of state space and integrate over them. To maintain tractability, I approximate \( E_{\epsilon'} v \left( A, k', R' \right) \) with a polynomial function following the tradition of Keane and Wolpin (1994, 1997, 2001). I adopt a specific set of steps to approximate the value function here given the unique features of the problem in a manner that is similar to the procedures.

\[ ^{16} \text{In particular, in a framework similar to the model here, Train and McFadden (1978) explore a static non-linear multinomial logit choice models where households with quadratic utility choose different modes of transportation that have different variable and fixed costs, and then optimize over the number of hours worked within each transportation category.} \]
adopted in Imai and Keane (2004). In any iteration in the process of value function iteration, given current approximation for expected continuation value function, I first solve $\upsilon(A, k, R)$ for a subset of continuous state space $(A, k, R) \in S^*$. Second, I estimate a polynomial regression function over the points in $S^*$. The predicted value of this polynomial is $\tilde{\upsilon}(A, k, R)$, which allows me to approximately evaluate $\upsilon$ at any state space point. Third, I integrate over $\tilde{\upsilon}$ to approximate this expected value:

$$E_{\epsilon'} \upsilon (A, k, R(b)) \approx E (A, k, b) = \int \tilde{\upsilon} (A, \{b + (1 - \delta) k + \exp (\epsilon) \cdot A \cdot k^\alpha\}, k) \, dF (\epsilon)$$

Given that there is only one shock to integrate over, I find this expected value by averaging over $\tilde{\upsilon}$ for $D$ draws of $\epsilon'$ from its distribution with $A$, $b$ and $k$ fixed. I do this for each point in $S^*$. Note that the resulting expectation, $E(A, k, b)$, is over the choices $k$ and $b$. Fourth, using $E(A, k, b)$ for each point in $S^*$, I generate another polynomial approximation function so that I can find $\tilde{E}$ for $s \notin S^*$. The resulting polynomial generates the expected value function:

$$\tilde{E}(A, k, b) \approx E_{\epsilon'} \upsilon (A, k, R(b))$$

Fifth, I move now to the next round of value function iteration, and substitute the $\tilde{E}$ just derived for the integral over expected value function in equation 4. This process continues until convergence, which is defined as convergence over the parameters of the approximating polynomial function $\tilde{E}$.

For this model, it is crucial to approximate the integral over continuation value function as closely as possible, bad approximation will not preserve the relative marginal returns to physical capital investments and savings. Given the nature of constant relative risk aversion utility function when households have infinite negative utility as consumption approaches zero, for both polynomial approximations described above, I regress the log of negative utility on the linear and quadratic terms of log of cash-on-hand. Productivity types and physical capital levels are joint interaction terms for this regression to allow for different relationship between cash-on-hand and integrated value function for different combinations of productivity types and physical capital levels. This approximation is accurate, with R2 exceeding 0.999 for the polynomial approximation for all

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17Imai and Keane (2004) present a model with both continuous state space and continuous choice space. In that model, there are two asset choices, human capital and financial asset choices. In the problem here, I have physical capital and financial asset choices along with discrete credit category choices. Keane and Wolpin (2001) present a model with both continuous and discrete choices, but the state space also contains both continuous and discrete elements.
productivity and physical capital combinations. This approximation also preserves the correct relationship between risky capital investment and safe savings asset choice.

Finally, after solving for value function, for each combination of credit category \( j \), physical capital level \( k \) and productivity type \( A \) solved for, I approximate optimal asset choices and credit category choice probability using linear spline along values of cash-on-hand. Ratio of asset choices to cash on hand is regressed on log of cash on hand, smoothing out percentage grid jumps points in optimal policies. For optimal choices where the state space includes values of \( k \) and \( A \) that were not solved for, I find the policy function specific to this \( k \) and \( A \) combination by weighting the policy functions of the closest points of solved for \( k \) and \( A \) values by their distance to the new \( k \) and \( A \) point.

### 4.2 Maximum Likelihood Estimation

Given the Thai data, I estimate the model using Simulated Maximum Likelihood following methods of Keane and Wolpin 2001 and Imai and Keane 2004. I interpret the Thaksin policy shifts in terms of changes in formal interest rates, in formal fixed costs and in formal borrowing collateral constraints. The goal of estimation is to identify the two unobserved dimensions of credit access, namely fixed costs and collateral constraints, before and after policy shift, as well as parameters for household preference and productivity distribution.

To implement estimation, I divide the data into a pre-Thaksin period and a post-Thaksin period. For each period, I estimate separate values for fixed costs and collateral constraints for villages in the Northeast and Central regions of Thailand. The main parameters that need to be estimated are:

\[
\Theta_{TT} = \begin{pmatrix}
\rho_{cTT}, \sigma_{\phi}, \alpha_{A}, \sigma_{A}, \sigma_{\epsilon}, \psi_{TT}, \gamma_{TT}
\end{pmatrix}
\]

where \( r \) is region, and \( \tau \) represents the two time periods. Preference parameters are fixed over time periods and regions, production parameters are fixed over time periods but differ across regions, and credit market parameters are different across time periods and regions.

I estimate the model assuming that households are in stationary steady state before and after policy shift[18] I assume that households do not predict the changes in measures

[18]In reality, data might be in transition, however, it is difficult to pin down where along transitions paths
of access that took place after 2001\textsuperscript{19} Note that because production function parameters are fixed over time, the model does not allow for growth, so changes in asset positions will purely come from changes in credit market conditions. The idea here is to see how much changes in credit market conditions alone can be used to explain changes in credit participation choices and asset choices.

Identification for the credit access parameters $\psi_{\tau \tau}$ and $\gamma_{\tau \tau}$ come from the fact that changes in fixed costs and collateral constraints have separate impacts on households’ credit choice probabilities. Specifically, if the fixed costs for formal savings increases, it will tend to reduce the probability of households choosing the formal savings credit category but will increase the probability of households choosing the other 6 credit categories. Additionally, if the fixed costs for formal borrowing increases, that will tend to reduce the probability of formal borrowing along with the probability of choosing the two joint formal and informal credit choice categories. Finally, the collateral constraint is identified based on households’ probability of choosing credit categories conditional on wealth and physical capital holdings. For households with the same level of cash-on-hand, those with more physical capital holding will have higher probability of choosing the three credit categories that involve formal borrowing.\textsuperscript{20} This is shown graphically in Figure\textsuperscript{8}

In addition to the credit access parameters, identification for utility parameters $\rho_{\text{ctra}}$ and $\sigma_{\phi}$ comes from households’ preference for borrowing versus savings, and the identification of production function parameters $\{\alpha_r, \mu_{\Delta_r}, \sigma_{\Delta_r}, \sigma_{\epsilon_r}\}$ comes the relationship between risky capital investment and output.

**Maximum Likelihood** I estimate the model using simulated maximum likelihood with measurement error following Keane and Wolpin 2001 and Imai and Keane 2004. The choice likelihood generated by this model is a product of a household’s probability of choosing each credit category and probability of getting observed outcomes for the different continuous choice variables given measurement errors.

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\textsuperscript{19}Households are unlikely to have predicted the changes in formal credit market conditions and how the rise in formal borrowing would have lead to changes in informal interest rates. In the data, the informal credit market, and households’ credit participation choices responded quickly to policy changes, but only after the policies were implemented.

\textsuperscript{20}These identification ideas are demonstrated partly in Figure\textsuperscript{8} which shows the relationship between the probability of choosing credit categories and households’ asset positions. The Figure shows that for the 3 credit categories involving formal borrowing, the probability of these categories increase for those with higher levels of physical capital conditional on cash-on-hand if collateral constraint is more binding.
The Probability of choosing one of the credit categories is:

\[
p \left( o_{it} = j | A_i, k_{it}, b_{it}, \epsilon_{it}, r^{FS}_{rt}, r^{FB}_{rt}, r^{I}_{rt}, \Theta_{rt} \right) = \prod_{j=1}^{J} \left( \frac{\exp \left( \hat{v}_{itj} \left( A_i, k_{it}, b_{it}, \epsilon_{it} \right) / \sigma_{\phi} \right)}{\sum_{l=1}^{J} \exp \left( \hat{v}_{itl} \left( A_i, k_{it}, b_{it}, \epsilon_{it} \right) / \sigma_{\phi} \right)} \right)^{1 \{ o_{it} = j \}}
\]

For the continuous choices, the model generates these optimal asset choices:

\[
k^{*'}_j (A_i, b_{it}, k_{it}, \epsilon_{it}), \quad b^{*'}_j (A_i, b_{it}, k_{it}, \epsilon_{it})
\]

Measurement errors are needed for these continuous physical capital and financial choices because within each credit choice type, the model generates deterministic continuous choices based on current state space. The individual’s discrete and continuous choice probabilities are conditional on the households’ current asset holdings, unobserved productivity type and unobserved productivity shocks. With measurement error, observed data \( k_{it+1j} \) is different from model choice \( k^{*}_{it+1j} \) by \( \zeta' \). Combining both credit category and the continuous asset choices, the overall likelihood is:

\[
\prod_{i=1}^{N} \prod_{t=1}^{T} \left\{ \int \int \prod_{j=1}^{J} \left\{ p^j_{it} \cdot f_{\zeta'k} \left( k_{it+1j} \right) \cdot f_{\zeta'b} \left( b_{it+1j} \right) \right\} \right\}^{1 \{ d_{it} = j \}} \text{d}F \left( \epsilon_{it} \right) \text{d}F \left( A_i \right)
\]

where \( f_{\zeta'k} \) and \( f_{\zeta'b} \) represent the probability of observing physical capital and financial position choices given measurement errors.

Finally, to take the equilibrium aspect of the model into consideration, I solve for the equilibrium informal interest rate given current estimation parameters, and impose the difference between observed and model informal interest rate as a constraint on the model likelihood. To solve for the equilibrium interest rate, for each region and time period, I find the aggregate demand and supply for informal credit under stationary steady state given current estimation parameters.

5 Model Mechanism

5.1 Choice Diagrams

Given interest rates, fixed costs and collateral constraints, heterogeneity in productivity and assets across individuals mean that households have differential needs for borrowing and saving. These differential needs are crucial for the welfare impacts of policies. To
understand these differential needs, I analyze credit choice diagrams here. In Figure 6, I first analyze households’ credit category choices along productivity and physical capital dimensions holding financial asset position constant. I then analyze households’ credit category choices along cash-on-hand and physical capital dimensions holding productivity constant in Figure 7. Finally, in Figure 8 I analyze households’ credit category choice probabilities along cash-on-hand and physical capital dimensions holding productivity constant.

First, I analyze the choice diagram along productivity and physical capital dimensions holding net financial asset position constant. The choice diagram for this is shown in Figure 6. Overall, along the productivity dimension, households that are more productive are more likely to borrow because their household farms or businesses are more likely to have sufficient returns to pay for the cost of loans. Along the physical capital dimension, households that have more physical capital are more likely to jointly participate in formal and informal credit markets. Specifically, for savings choices, as physical capital holding increases while financial asset stays constant, low productivity households switch from formal savings to informal savings as their savings needs increase. With higher savings needs, these households are willing to pay for the higher fixed costs for informal saving in order to earn the higher informal savings interest rate. For borrowing choices, productive households that have lower levels of physical capital tend to borrow informally since they face tight formal borrowing collateral constraints. Conditional on productivity type, as the physical capital holding of a household increases, more productive households becomes more likely to borrow formally rather than informally. Finally, conditional on sufficiently high levels of physical capital, more productive households are more likely to jointly borrow from formal and informal sources because their greater borrowing needs might not be met by constrained formal borrowing.

Second, I analyze the choice diagram for households with different levels of cash-on-hand and physical capital holding productivity constant. The choice diagram is shown in Figure 7. Overall, along the cash-on-hand dimension, households with higher levels of cash-on-hand want to save, households with lower level of cash-on-hand want to borrow, and households with medium level cash-on-hand prefer to keep cash under the mattress because their borrowing and savings need do not justify paying for the fixed costs for formal or informal credit market activities. Overall, along the physical capital dimension, 21 To allow for each credit category to have the highest likelihood of occurring for some households, in a context where formal interest rates for borrowing and savings are both lower than informal interest rates, fixed costs have to be in a specific order. Specifically, the fixed costs for formal borrowing needs to be higher than the fixed costs for informal borrowing, and the fixed costs for formal saving needs to be lower than the fixed costs for informal savings.
households with lower levels of physical capital prefer to either participate in the formal credit market or the informal credit market, and households with higher levels of physical capital prefer to participate in both jointly. Specifically, for saving choices, households that have sufficient saving needs will first save formally and then switch to informal saving as their cash-on-hand increases. Households with the highest saving needs as well as higher levels of physical capital prefer to borrow formally up to their collateral constraint and then lend informally at the same time to take advantage of the interest rate differential between the formal and informal credit markets. For borrowing choices, households that have sufficient borrowing needs will first borrow informally, and some households will switch to formal borrowing as their cash-on-hand decreases if they also have sufficient physical capital. Households with insufficient physical capital continue to borrow informally even if they have low levels of cash-on-hand. Finally, Households with medium level of physical capital and low levels of cash-on-hand prefer to jointly borrow from formal and informal credit markets.

Finally, I present another choice diagram that provides intuition for how the category-specific credit utility shocks influence which credit alternatives households will choose. This is shown in Figure 8. This figure holds productivity type constant. Each of the graphs in this figure show a different credit category. The y-axis shows the probability of a household choosing each credit category, and the x-axis shows the cash-on-hand position of households. Households with higher levels of physical capital are colored with red points, and those with lower levels of physical capital are colored with blue points. The figure shows that households with more wealth have higher probability of saving and less wealth have lower probability of saving, and that households with more physical capital conditional on cash-on-hand are more likely to participate in joint formal and informal credit choices and formal borrowing choices. Figure 8 graphically shows the probabilities generated by this model across credit categories; these probabilities are main components of the likelihood function discussed earlier.

5.2 Three Dimensions of Access and Informal Credit Market

The seven alternative credit categories generate interesting dynamics in the demand and supply for informal credit. In this model, formal and informal credits are potentially complements or substitutes. A policy that lowers formal borrowing interest rate serves as an example. Intuitively, this policy should have a substitution effect on the demand for informal loans. But given the possibility for joint choices, a lower formal interest rate also increases the demand for joint formal and informal borrowing given formal borrow-
ing collateral constraints, and will also drive up the supply of informal loans by making it more profitable for households to arbitrage by borrowing formally and lending informally. On top of this, improved borrowing conditions might also reduce households’ incentives to save informally. Given these complicated interactions between demand and supply in the informal credit market, a drop in formal borrowing fixed costs has complicated impacts on credit market participation rates and the informal interest rate.

Despite the complicated impacts of potential changes in different dimensions of formal credit market access, there are qualitative differences between the impacts of changing formal interest rates, fixed costs and collateral constraints. The key mechanism here is that interest rate, fixed costs and collateral constraint jointly determine the average borrowing and savings interest rate schedule facing households. These three policy dimensions have different impacts because they shift average interest rates differently. On the borrowing side, the presence of fixed costs means the average borrowing interest rate is downward sloping as households’ demand for loans increases. Reducing the formal borrowing fixed cost, therefore, significantly reduces the effective interest rate for households with low credit demand. Besides fixed costs, the formal borrowing collateral constraints could be thought of as generating a discontinuous jump on households’ formal interest rate schedule. Relaxing the collateral constraints, therefore, significantly influences previously constrained households but has no direct impact on most households’ average interest rates. Given the presence of fixed costs and collateral constraints, lowering the formal borrowing interest rate might have low impacts on households with low borrowing needs, but higher impacts on households with greater borrowing needs. On the savings side, given fixed costs, there is an upward-sloping average interest rate schedule as households’ savings needs increase. Reducing savings fixed costs could influence households with low saving needs significantly and increasing the savings interest rate could have larger impacts on households with greater saving needs.

### 6 Estimation Results and Counterfactual

#### 6.1 Estimation Results and Interpretations

Model estimates for credit market parameters are shown in Table 9 and other estimates are shown in Table 10. I first describe the estimated coefficients, and I then analyze what policies might have led to changes in estimated credit access coefficients. Estimation fit is shown in Figures 9 and 10.
**Estimated Coefficients**  Estimated parameters show that due to the policy changes there was a significant relaxation of the borrowing collateral constraint and a significant reduction in the fixed costs associated with formal credit market access, especially for formal borrowing.

Table 9 presents estimated fixed costs and collateral constraints for both the Northeast and the Central regions. The table shows how estimates changed from the first period between years 1999 and 2001 to the second period between years 2002 and 2009. The estimated coefficient for formal borrowing fixed costs decreased in the Northeast region from 6,975 Baht to 1,163 Baht. In the Central region, formal borrowing fixed costs also decreased from 7,350 to 2,327 Baht. Given median annualized loan size of approximately 30,000 Baht from the BAAC shown in Figure 4, the high fixed costs for formal borrowing in the 1999-2001 period meant that many borrowers faced very high average costs of loans. Reductions in these fixed costs help to explain increases in formal credit market participation rates over time.

Table 9 also presents fixed costs estimates for formal savings and informal borrowing and savings. The fixed costs for formal savings decreased, but these costs were initially lower to start with and the change was not large compared to the change in formal borrowing fixed costs. For informal activities, the fixed costs for informal borrowing is around 1400 Baht in the Northeast region and 1,900 Baht in the Central region in both periods. These correspond to average borrowing loan sizes that are around 13,000 baht for informal borrowing. Finally, the estimated fixed costs for informal saving is around 9,500 Baht for the Northeast region, and 8,000 Baht for the Central region. These estimates are high and reflect the fact that in every year, there is relatively a small proportion of households that lend informally despite the higher informal interest rate. These fixed costs correspond to median informal lending loan sizes of about 17,500 Baht.

The fixed costs parameters, especially the high fixed costs for informal lending, have to be interpreted with care. Estimated fixed costs do not represent only the pecuniary cost of credit access, but also non-pecuniary costs since the two are not separately identifiable. When the estimated cost coefficient is high, most households have a general aversion toward that credit category. High estimated informal savings fixed costs mean that households with low savings needs do not lend informally unless they receive a large positive utility shock for informal lending and households with higher savings needs lend informally if the informal interest rate is high.

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22 This utility shock for informal lending could be interpreted as random factors that reduced an individual’s high average fixed costs for informal lending in a particular period, or random factors that increases households’ preference for informal lending in a particular period.
In addition to changes in fixed costs parameters, table 9 also shows that formal borrowing collateral constraints changed significantly. In the Northeast region, the collateral constraint went from 14% of physical capital holding to 35%, and in the Central region, the collateral constraint went from 17% of physical capital holding to 32%. These changes mean that some households that previously chose to borrow informally due to limits on how much they could borrow formally might now be able to borrow formally up to their optimal choice. There can also be households that previously jointly borrowed from formal and informal sources, but which now only would need to borrow from formal sources.

Understanding Why Access to Formal Borrowing Improved  The large reduction in formal borrowing fixed costs was likely brought about mainly by the Million Baht Fund program. As discussed earlier, this program allowed lending to take place at the level of village committees. After the introduction of this program, households could acquire formal loans without leaving their own communities. I showed that this led to reductions in observed formal borrowing fees and transportation costs in Section 2.5. Borrowing from village committees also should have led to reductions in non-pecuniary costs of borrowing and reductions in other pecuniary costs in addition to reported fees and transportation costs. For example, non-pecuniary costs could go down because households find village committees less intimidating and foreign compared to bank managers. Besides the Million Baht Fund program, improvements in the efficiency of BAAC, construction of new roads and improvements in communication technologies could all have also contributed to the drop in fixed costs. The estimated change in the fixed costs for borrowing captures the aggregate impact of all of these pecuniary and non-pecuniary reductions.

The relaxation in collateral constraints might also have been mainly due to the introduction of the Million Baht Fund program. The fact that local committees administered formal loans means that formal lenders have local knowledge. Local knowledge about potential borrowers mean that Million Baht Fund loans are less likely to suffer from information problems and hence observable physical capital plays a smaller role in determining if households could acquire loans. Additionally, the Million Baht Fund brought large quantities of additional funds for formal lending to each village, increasing quantities available for lending to individuals. Besides the Million Baht Fund, other policies enacted in the initial years of Thaksin’s government could also have relaxed borrowing constraints. The BAAC, for example, was given more flexibility in approving loans, and BAAC and other state-sponsored banks were given greater state financial support to increase lending overall (Menkhoff, 2010; Boonperm, 2014).
6.2 Welfare Consequences of Thaksin’s Policies

Thai policies under Thaksin’s government reduced formal borrowing interest rates\textsuperscript{23}, lowered the fixed costs for formal borrowing, and relaxed the collateral constraints on formal borrowing. These policies promoted formal borrowing, and brought about a significant reduction in the size of the informal credit market. The impacts were especially large in the Northeast region, where the informal credit market had played a larger role than in the Central region. To understand the welfare gains and losses from this policy, I compare steady state welfare of households in the initial period, between 1999 and 2001, to the steady state welfare of households in the second period, between 2002 and 2009. Steady state comparison is based on observed interest rates in the two periods and estimated credit access and other parameters. Given the large impacts of policies in the Northeast region, I focus welfare analysis on credit access parameters in the Northeast. I present graphically the welfare impacts in Figure \textsuperscript{11}\textsuperscript{24}. The figure shows the welfare changes in terms of consumption equivalent variation (CEV) gains for households with different productivity level and cash-on-hand levels. Overall, conditional on productivity type, households with lower levels of cash-on-hand benefited from policies; and conditional on cash-on-hand, households with higher levels of productivity benefited from policies.

Specifically, five regions are shaded on the top panel of Figure \textsuperscript{11} showing the amount of consumption equivalent variation gains for five different subsets of households.

Starting from the top-left of the panel, there are two groups of households with larger gains. The first subset of households are those with productivity type 1 standard deviation above the mean and relatively low levels of cash-on-hand. They gain on the order of slightly more than 5% consumption equivalent variation. These are households who have high borrowing needs and who can now more cheaply borrow formally given both the drop in interest rate and fixed cost. Some households in this group chose to borrow informally previously because they were constrained in how much they could borrow formally, but now they are able to borrow formally at lower interest rates given relaxed

\textsuperscript{23} Formal borrowing interest rates could have moved down due to overall changes in international interest rates as well as government policies that shifted them.

\textsuperscript{24} Formal savings interest rate and formal savings fixed costs also changed after the initiation of Thaksin’s policies, to focus on the impacts of formal borrowing promotion policies, I leave the formal savings interest rate and fixed costs at their level in the pre 2001 period, and resolve for the equilibrium informal interest rate in the current period given other changes. Keeping the formal savings access dimensions at their original levels do not have large impacts on outcomes. This is because the changes in formal savings interest rate and fixed costs were relatively small, and this is also because the reduction in formal savings interest rate and the drop in formal savings fixed costs had countervailing impacts.
The second group of households includes those who have more than average productivity type and higher levels of cash-on-hand. These households gain on the order of 0.15% to 5% consumption equivalent variation. In this group, households with higher levels of cash-on-hand and higher productivity are gaining mostly due to the reduction in formal interest rate; households with lower levels of cash-on-hand and average productivity are gaining because the drop in fixed costs for formal borrowing reduces the average cost of loans sufficiently to allow them to borrow formally now.

The third group of households consists of large proportion of households who have average levels of productivity and cash-on-hand. The are shown in the central area of as shown in Figure 11. These households do not have high immediate need for formal borrowing, but they benefit from the possibility of borrowing formally in some future state. For these households, given the presence of the informal credit market, the relative gain of switching from informal to formal options is small given their relatively low level of credit market needs.

The last two groups of households have higher cash-on-hand and lower productivity levels. They are shown in the bottom right corner of Figure 11. These two groups of households suffered welfare losses up to 1% consumption equivalent variation due to the drop in informal interest rate. These households do not have high borrowing needs, but do use saving as investment and consumption smooth tools. They are hurt by the significant drops in the informal borrowing interest rate which diminishes their informal savings opportunities. Although a relatively small proportion of households save informally in any given year, but many households have the possibility of saving informally in some period in the future. The welfare losses are smaller for households with slightly higher productivity types and lower levels of cash-on-hand.

Finally, I look at consumption equivalent variation gains integrating over assets and productivity levels. Integrating over assets, the lower panel of Figure 11 show welfare gains and losses along the productivity dimension. The panel shows that the most productive households gain in expectation on the order of 2% consumption equivalent variation, and the least productive households have in expectation losses up to 1.5% consumption equivalent variation. The magnitude of welfare gains and losses along the cash-on-hand dimension with integration over productivity type is weaker at less than 1% for all cash-on-hand levels. This is because each cash-on-hand dimension is a weighted average

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25I showed that this is the case in the data in the data section, and in the model, credit category shocks mean that households have some probability of saving informally in the future.
of low productivity households with welfare losses and high productivity households with welfare gains.

6.3 Impacts of Interest Rates, Fixed Costs, and Collateral Constraints

In the previous section, I used the estimated model to evaluate the aggregate welfare impacts of Thaksin’s policies which focused on improving conditions for formal borrowing. Now I use the estimated model to address two sets of additional questions. First, the relative roles of changes in interest rates, fixed costs and collateral constraints on the overall impacts of Thaksin’s policies. Second, the differential welfare impacts of policies that improve each of the three dimensions of credit market access, both for borrowing and saving. For policy makers, changing interest rates, reducing the fixed costs of access, and relaxing collateral constraints are crucial components in their financial policy toolbox. Addressing these two sets of questions help policy makers to understand the impacts of these important dimensions of credit market policies.

Relative Roles of Three Dimensions of Credit Access in Aggregate Outcomes

To understand the relative roles played by the three dimensions of credit access, I run counterfactual policy experiments in which I shift each policy parameter from its value in the 2002-2009 period while holding unchanged other credit market access parameters at their observed and estimated values in the 2002-2009 period.

The results of these counterfactual simulations are in shown in these Figures: Figure 12 shows the impacts of changing formal borrowing interest rate holding other parameters at their 2002-2009 estimated values, Figure 13 shows the impacts of changing formal borrowing fixed costs, Figure 14 shows the impacts of changing formal saving interest rates, Figure 15 shows the impacts of changing formal savings fixed cost, and finally Figure 16 shows the impacts of changing formal borrowing collateral constraints. In each of the figures, I show on the left panel the impacts of changing each of the policy dimensions on formal and informal credit market participation rates. I show on the right panel the impacts of each of the policy dimensions on the informal interest rate. In each of the figures, I mark with two vertical dashed lines the observed or estimated parameter values for each of the policy parameter in the 2002-2009 period and in the 1999-2001 period.

To summarize, the main findings are that the reduction in formal borrowing fixed costs was mainly responsible for increasing the proportion of households using formal credit options. About 80% of the changes in the share of households participating in different credit categories could be attributed to this change. Second, I find that relaxing the
formal borrowing collateral constraint is mainly responsible for the reduction in informal interest rate. About 73% of the changes in informal interest rate could be attributed to this dimension of policy change. Third, I find that the reduction in formal borrowing interest rate only had limited effects on aggregate choices and the informal equilibrium.

Specifically, first, a drop in formal borrowing fixed costs significantly changes the average cost of formal loans for low cash-on-hand households, and changes credit market participation rates across households. Figure 13 shows that increasing the formal borrowing fixed costs parameter back to its 1999-2001 value while holding other parameters constant increases the proportion of households using only the informal credit market from about 11% to 23% and reduces the proportion of households using only the formal credit market from about 43% to 32%. Turning the value of the policy parameter back up would also have increased informal interest rate from slightly below 14% to 17%. The change in informal interest rate is relatively small because the impact from increased demand for informal loans would be attenuated on the one hand by reduced demand for informal loans from households who borrow jointly, and on the other hand by increased supply for informal saving as households’ desire for precautionary saving increases.

Second, the relaxation of formal borrowing collateral constraint lowers the average cost of formal loans mainly for formally constrained households. This brings about a large change in demand and supply for informal credit market as previously constrained households who borrowed informally switch to formal borrowing. Figure 16 shows that changing the collateral constraint strongly impacts the informal interest rate. Tightening the constraint from its estimated value in the 2002-2009 period back to its level in the 1999-2001 period would increase informal interest rate from 14% to 20.5%. The impacts on participation rates from this policy, however, is limited. Only about 2 percentage points of the changes in the proportion of households participating in the informal market, and 3 percentage points of the changes in the proportion of households participating in the formal market could be attributed to this policy change.

Third, the large change in formal borrowing interest rate from 14.8% to 6% had little impacts on participation rates. This is because given formal borrowing fixed costs and collateral constraint, changing formal borrowing interest rates only significantly impacts the average cost of formal loans for households with higher demand for loans. However, these households were already borrowing formally. Figure 12 shows that given other parameter values in 2002-2009, changing formal borrowing interest rates would have less than 3 percentage points impacts on participation rates. Shifting formal interest rate back to 14.8% would also only increase informal interest rate by 1.5%.
Finally, although the impacts of changes on formal savings fixed costs and interest rates were small in Thailand due to the relatively small amount of changes along these two policy dimensions, Figures 14 and 15 show that additional changes for both formal savings interest rate and fixed costs could have large impacts on credit market participation rates. For example, in strong contrast to the weak impact of changing formal borrowing interest rate on participation rates, increasing formal savings interest rate by 10 percentage points from its value in the 2002-2009 period would lead to a 13 percentage point increase in the proportion of households using only the formal credit market, and an 8 percentage point drop in the proportion of households using only the informal credit market.

Welfare Impacts of Shifting Three Dimensions of Credit Access

Given their impacts on the informal interest rates and credit market participation shares discussed in the section above, policies that change formal borrowing and savings interest rates and fixed costs have distinct welfare impacts on different segments of the population.

I show now the welfare impacts of some counterfactuals discussed in the previous section. Here, again, I change policy parameters one at a time holding other policy parameters at their 2002-2009 level. Specifically, I show in Figure 17 and Figure 18 the welfare impacts of lowering formal borrowing interest rates by 1 percentage point and lowering formal borrowing fixed costs by 10 percent. In Figure 19 and Figure 20, I show the welfare impacts of increasing formal saving interest rates by 1 percentage point and lowering formal saving fixed costs by 10%. In each of these figures, I show welfare gains and losses for households along cash-on-hand and ability type dimensions.

To summarize, the results are: Reducing formal borrowing interest rates benefits low cash-on-hand high-productivity households the most, and reducing formal borrowing fixed costs benefits medium-productivity and medium cash-on-hand households the most. Both formal borrowing policies tend to reduce the informal interest rate as shown in Figures 12 and 13 hence hurt low-productivity and high cash-on-hand households who suffer from diminished informal savings opportunities. For savings policies, increasing formal savings interest rates benefit low-productivity and high cash-on-hand households the most, and reducing formal savings fixed costs benefit low cash-on-hand and low- to medium-productivity households the most. Both formal savings policies tend to increase informal interest rates as shown in Figures 14 and 15 hence they tend to hurt households with higher productivities who rely partly on informal borrowing to finance their risky investments.
Here, I give some intuition for these differential impacts. First, a reduction in formal borrowing fixed costs represents a large reduction in average interest rates for households that have lower cash-on-hand and medium productivity. These households were on the verge of borrowing formally before the fixed costs reduction, and benefit the most from this policy. Households with higher level of productivity benefit less because their borrowing needs are large and are less impacted by fixed costs changes. Households with lower productivity benefit less because the fixed costs might still be too high for them to borrow formally. Households with higher cash-on-hand benefit less because they tend to save rather than borrow. Figure 18 shows this graphically. Second, a reduction in formal borrowing interest rates provides the most benefits for low cash-on-hand and very productive households. This policy has minimal impacts on the average cost of loan for most households due to the presence of fixed costs. The policy has smaller impacts for productive households with more cash-on-hand because they have lower need for formal borrowing. Figure 17 shows this graphically. Third, a reduction in formal savings fixed costs represents a large increase in average formal saving interest rates for households that have lower cash-on-hand and low productivity. These households would like to save due to the low return on their household firm, but could not easily save informally due to the high fixed costs for informal saving. They benefit the most from this policy. Figure 20 shows this graphically. Finally, an increase in formal savings interest rate benefits the most households that have high cash-on-hand but low levels of productivity. The impact on low cash and low productivity households, however, is small. Figure 19 shows this graphically.

7 Conclusion

In recent decades, formal financial services have expanded significantly in developing countries. The objective of this paper has been to evaluate welfare gains and losses for rural households as access to the formal credit market improves, taking into consideration the impacts of formal credit on the informal credit market. To achieve this objective, in this paper, I explored detailed data on formal and informal credit market interactions from Thai villages. I built an empirical dynamic equilibrium model with investment, borrowing and savings choices for formal and informal credit markets. I demonstrated that with fixed costs and collateral constraints, the model generates observed credit choice categories. I then estimated this model by simulated maximum likelihood using data from Thai villages.
Using the estimated model, I evaluated a range of counterfactuals that shift policies for formal borrowing and savings. I showed that policies that improve formal borrowing conditions tend to drive down informal interest rates, and could hurt less productive households who face diminished opportunities for saving. I also showed that policies that improve formal savings conditions tend to drive up informal interest rates, and could hurt more productive households who face higher costs of borrowing. Counterfactuals also showed that the policies that shift interest rates, fixed costs and collateral constraints have differential impacts on equilibrium informal interest rates, credit market participation rates and welfare. Specifically, I find that in the context of Thailand, the relaxation of the collateral constraints significantly helped to reduce the informal interest rates, and the reductions in fixed costs of formal borrowing significantly changed the proportion of households participating formally and informally in credit markets. Additionally, counterfactual welfare analysis showed that policies that lower fixed costs for formal borrowing or savings tend to benefit lower wealth and less productive households, and policies that change interest rates for formal borrowing might only have small impacts on outcomes in an environment with fixed costs and collateral constraints.

An important policy implication of this paper is that, given the prevalence of lending or savings-only development financial institutions (World Bank, 2012), governments should try to jointly promote both formal borrowing and savings services. In an environment where heterogeneous households have differential needs for borrowing and saving, unbalanced efforts that mainly improve formal access for either borrowing or saving could lead to more limited financial options for some households and their subsequent welfare losses.
References


A.1 Data: Village Locations

Figure 1: Townsend Thai Monthly Survey Village Locations

*Notes:* This paper uses panel data from 16 Thai villages collected between 1999 and 2009. The panel includes detailed credit market transactions information for more than 650 households. 8 of the 16 villages are located in the poorer Northeast region, and 8 villages are located in the wealthier Central region of Thailand. See Section 2 for details.
### A.2 Data: Channels for Borrowing from 1999 to 2009

Table 1: This table displays the percentage of households who have borrowed from different lenders (column 1) as well as the average number of years in which new loans were taken for borrowers (Column 2) between 1999 to 2009.

<table>
<thead>
<tr>
<th>Region</th>
<th>Lender</th>
<th>Percentage of Households who have Borrowed</th>
<th>Number of Years with New Loans (out of 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Northeast Region</strong></td>
<td>Million Baht Fund</td>
<td>78.0</td>
<td>7.13</td>
</tr>
<tr>
<td></td>
<td>BAAC</td>
<td>61.6</td>
<td>5.58</td>
</tr>
<tr>
<td></td>
<td>Village Coop</td>
<td>35.9</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>Friends and Neighbors</td>
<td>83.3</td>
<td>3.99</td>
</tr>
<tr>
<td></td>
<td>Village Moneylenders</td>
<td>37.5</td>
<td>1.93</td>
</tr>
<tr>
<td><strong>Central Region</strong></td>
<td>Million Baht Fund</td>
<td>74.5</td>
<td>6.73</td>
</tr>
<tr>
<td></td>
<td>BAAC</td>
<td>40.8</td>
<td>5.70</td>
</tr>
<tr>
<td></td>
<td>Village Coop</td>
<td>16.9</td>
<td>3.56</td>
</tr>
<tr>
<td></td>
<td>Friends and Neighbors</td>
<td>48.5</td>
<td>2.27</td>
</tr>
<tr>
<td></td>
<td>Village Moneylenders</td>
<td>12.9</td>
<td>1.50</td>
</tr>
</tbody>
</table>

**Notes:** To effectively model the variety of borrowing choices shown in Table 1, I group lenders into formal and informal categories. The Million Baht Fund and the Bank for Agriculture and Agricultural Cooperatives (BAAC) are formal lenders. Friends, neighbors, and village moneylenders are informal lenders. Village Coop include Production Cooperative Groups (PCG) and Village Agricultural Cooperatives, which are semi-formal organization that mostly intermediate credit among households within villages. This paper considers Village Coops as falling within the informal credit market. See Section 2.1 for detail.
A.3 Data: Channels for Saving from 1999 to 2009

Table 2: This table displays the percentage of households who have saved (lent) via different channels as well as the average number of years in which new savings (lending) were deposited by savers between 1999 to 2009.

<table>
<thead>
<tr>
<th>Percentage of Households who have Saved (out of 11)</th>
<th>Number of Years with New Deposits (out of 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Northeast Region (poorer)</strong></td>
<td></td>
</tr>
<tr>
<td>Commercial <em>formal</em></td>
<td>37.4</td>
</tr>
<tr>
<td>BAAC and GSB <em>formal</em></td>
<td>94.1</td>
</tr>
<tr>
<td>Village Coop <em>informal</em></td>
<td>64.1</td>
</tr>
<tr>
<td>Individual lending <em>informal</em></td>
<td>66.6</td>
</tr>
<tr>
<td><strong>Central Region (richer)</strong></td>
<td></td>
</tr>
<tr>
<td>Commercial <em>formal</em></td>
<td>77.9</td>
</tr>
<tr>
<td>BAAC and GSB <em>formal</em></td>
<td>85.6</td>
</tr>
<tr>
<td>Village Coop <em>informal</em></td>
<td>75.2</td>
</tr>
<tr>
<td>Individual lending <em>informal</em></td>
<td>33.1</td>
</tr>
</tbody>
</table>

**Notes:** To effectively model the variety of savings choices shown in Table 2, I group savings channels into formal and informal categories. Households could save formally at commercial banks, the BAAC, and the Government Savings Bank (GSB). Households can also save informally by lending to other individuals directly. When they save in village coops, I consider that households are saving informally. See Notes for Table 1 for what village coops are. See Section 2.1 for detail.
A.4 Data: Formal and Informal Credit Transaction Shares

Table 3: Credit Category Participation Shares

<table>
<thead>
<tr>
<th></th>
<th>Northeast Region (poorer)</th>
<th>Central Region (richer)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>percent percent</td>
<td>percent percent</td>
</tr>
<tr>
<td>Formal and Informal</td>
<td>31.5 40.3</td>
<td>6.7 18.1</td>
</tr>
<tr>
<td>Formal Only</td>
<td>21.1 44.0</td>
<td>51.5 58.3</td>
</tr>
<tr>
<td>Informal Only</td>
<td>32.0 11.1</td>
<td>12.1 9.9</td>
</tr>
<tr>
<td>Neither</td>
<td>15.5 5.6</td>
<td>29.7 13.8</td>
</tr>
</tbody>
</table>

Table 4: Credit Category Shares Across Seven Participation Types

<table>
<thead>
<tr>
<th></th>
<th>Northeast Region (poorer)</th>
<th>Central Region (richer)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>percent percent</td>
<td>percent percent</td>
</tr>
<tr>
<td>Formal Borrowing</td>
<td>14.9 29.0</td>
<td>21.5 24.2</td>
</tr>
<tr>
<td>Formal Saving</td>
<td>6.2 14.0</td>
<td>30.0 34.1</td>
</tr>
<tr>
<td>Informal Borrowing</td>
<td>25.0 6.2</td>
<td>9.2 6.1</td>
</tr>
<tr>
<td>Informal Saving</td>
<td>7.0 4.90</td>
<td>3.0 3.8</td>
</tr>
<tr>
<td>Formal+Informal Borrowing</td>
<td>24.1 32.5</td>
<td>5.0 14.3</td>
</tr>
<tr>
<td>Formal Borrow+Informal Saving</td>
<td>7.4 7.8</td>
<td>1.7 3.8</td>
</tr>
<tr>
<td>No Credit Transactions</td>
<td>15.5 5.6</td>
<td>29.7 13.8</td>
</tr>
</tbody>
</table>

Notes: Households’ credit market choices within a calendar year can be categorized as falling within one of the seven credit participation categories listed in Table 3. This table shows that after 2001, due to policies that promoted formal borrowing such as the Million Baht Fund Program (see Section 2), the proportion of households participating in the formal credit market increased significantly, especially in the Northeast region. See Section 2.2 for detail.
A.5 Data: Interest Rates

Figure 2: Village/Year Real Interest Rates for Different Lenders

Notes: Village/Year Interest rates are average interest rates for each lender type for each village in each calendar year. See Section 2.3 for detail.

Table 5: Annual Average Real Interest Rate (percent)

<table>
<thead>
<tr>
<th></th>
<th>1999-2001</th>
<th>2002-2009</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Northeast Region</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Informal Interest</em></td>
<td>27.9</td>
<td>13.9</td>
</tr>
<tr>
<td><em>Formal Borrowing Interest</em></td>
<td>14.8</td>
<td>6.1</td>
</tr>
<tr>
<td><em>Formal Saving Interest</em></td>
<td>3.3</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Central Region</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Informal Interest</em></td>
<td>17.6</td>
<td>9.4</td>
</tr>
<tr>
<td><em>Formal Borrowing Interest</em></td>
<td>13.0</td>
<td>5.4</td>
</tr>
<tr>
<td><em>Formal Saving Interest</em></td>
<td>3.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Notes: Table 5 and Figure 2 show that formal and informal interest rates decreased after 2001.
A.6 Data: Borrowing and Savings Amounts

Figure 3: Distribution of borrowing and savings Amount

![Box plots showing distribution of borrowing and savings Amount for households borrowing.]

Figure 4: Distribution of Borrowing Amount by Lenders

![Bar chart showing distribution of borrowing amount by lenders over two periods.]

Notes: Amount of borrowing and savings represents annualized sums for each lending and saving categories for each household. See Section 2.4 for detail.
A.7 Data: Reported Fees and Transport Costs for Formal Borrowing

Figure 5: Fees and Transport Cost for BAAC and Million Baht Fund

Notes: Million Baht Fund is administered by village committees, and hence require less fees and transport costs to access. Formal borrowing fees and transport costs decrease significantly after 2001 as Million Baht Fund became the main provider of formal loans. See Section 2.5 for detail.

Table 6: Fees and Transport Cost for Each Loan by Lender Types (Baht)

<table>
<thead>
<tr>
<th>Lender Types</th>
<th>Relatives mean(sd)</th>
<th>Neighbor mean(sd)</th>
<th>Moneylender mean(sd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fees and Transport Cost</td>
<td>25.8 (133.6)</td>
<td>4.0 (41.9)</td>
<td>22.1 (38.3)</td>
</tr>
<tr>
<td>Commercial-Bank</td>
<td>BAAC</td>
<td>Million Baht Fund</td>
<td></td>
</tr>
<tr>
<td>Fees and Transport Cost</td>
<td>379.7 (737.6)</td>
<td>51.6 (92.1)</td>
<td>11.3 (16.6)</td>
</tr>
</tbody>
</table>

Notes: Commercial bank loans are rare, likely due to the high fixed costs associated with getting them. Fees and Transport costs are only a proportion of the total pecuniary fixed costs associated with borrowing. There are also possibly non-pecuniary costs of borrowing. See Section 2.5 for detail.
### A.8 Data: Repayment Rate Based on Payment History

#### Table 7: Repayment of Loans

<table>
<thead>
<tr>
<th></th>
<th>Fully Repaid</th>
<th>Not Fully Paid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formal Loans</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of Loans</td>
<td>97.01</td>
<td>2.99</td>
</tr>
<tr>
<td><strong>Informal Loans</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of Loans</td>
<td>95.16</td>
<td>4.84</td>
</tr>
</tbody>
</table>

Notes: Every month, new loans that households take out are recorded and the month in which repayment should be completed is also recorded. Then every month, repayment of each loan is tracked until full repayment. Table 7 shows that most households repay their loans, and that repayment difference between formal and informal loans is small. Given these data, this paper does not model default. See Section 2.6 for detail.

#### Table 8: Repayment Percentage for Not Fully Paid Loans

<table>
<thead>
<tr>
<th></th>
<th>By Month 24</th>
<th>By Month 36</th>
<th>By Month 48</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formal Loans</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of Principal Repaid</td>
<td>30.3</td>
<td>36.7</td>
<td>39.1</td>
</tr>
<tr>
<td><strong>Informal Loans</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of Principal Repaid</td>
<td>32.4</td>
<td>39.9</td>
<td>44.0</td>
</tr>
</tbody>
</table>

Notes: For the 2.99 percent of formal loans that are not fully repaid, and 4.84 percent of informal loans that are not fully repaid, Table 8 shows that a significant proportion of the principal on these loans are repaid within 2 years of the start of the loans. Given these information and data shown in Table 7, the repayment gap between formal and informal loans is very small; hence, this paper does not model default. See Section 2.6 for detail.
B.1 Credit Choice Diagram 1

Figure 6: Choice Diagram for Productivity and Physical Capital

Notes: This choice diagram shows how productivity type and cash-on-hand holding—in the form of physical capital—jointly influence credit participation choices. Here, net financial asset position is held constant. Along the productivity dimension, households that are more productive are more likely to borrow because their household farm or business have sufficient return to pay for the cost of loans. Along the physical capital dimension, households that have more physical capital are more likely to jointly participate in formal and informal credit markets. See Section 5.1 for more detail.
B.2 Credit Choice Diagram 2

Figure 7: Choice Diagram for Cash-on-Hand and Physical Capital

Notes: This choice diagram shows how cash-on-hand and physical capital jointly influence credit participation choices. Here, productivity type is held constant. Along the cash-on-hand dimension, households with higher levels of cash-on-hand want to save, households with lower level of cash-on-hand want to borrow, and households with medium level cash-on-hand prefer to keep cash under the mattress because their borrowing and savings need do not justify paying for the fixed costs for formal or informal credit market activities. Along the physical capital dimension, households with lower levels of physical capital prefer to either participate in the formal credit market or the informal credit market, and households with higher levels of physical capital prefer to participate in both jointly. See Section 5.1 for detail.
B.3 Credit Choice Diagram 3

Figure 8: Credit Category Probabilities for Cash-on-Hand and Physical Capital

Notes: This probability diagram shows that households with more cash-on-hand prefer to save and less cash-on-hand prefer to borrow, holding productivity type constant. It also shows that households with more physical capital conditional on cash-on-hand are more likely to choose the credit categories that involve formal borrowing (formal borrowing, formal + informal borrowing, formal borrowing + informal saving). See Section 5.1 for detail.
C.1 Estimation: Estimated Coefficients

Table 9: Credit Access Estimates

<table>
<thead>
<tr>
<th></th>
<th>Northeast (poorer)</th>
<th>Central (richer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal Borrow Fixed Cost</td>
<td>6975</td>
<td>1163.85</td>
</tr>
<tr>
<td></td>
<td>(1110.9)</td>
<td>(338.5)</td>
</tr>
<tr>
<td>Formal Save Fixed Cost</td>
<td>1627.7</td>
<td>1296.65</td>
</tr>
<tr>
<td></td>
<td>(131.0)</td>
<td>(230.9)</td>
</tr>
<tr>
<td>Informal Borrow Fixed Cost</td>
<td>1396.65</td>
<td>1536.3</td>
</tr>
<tr>
<td></td>
<td>(145.4)</td>
<td>(270.4)</td>
</tr>
<tr>
<td>Informal Save Fixed Cost</td>
<td>9300</td>
<td>10242</td>
</tr>
<tr>
<td></td>
<td>(2253.1)</td>
<td>(3318.2)</td>
</tr>
<tr>
<td>Collateral Constraint</td>
<td>0.142</td>
<td>0.345</td>
</tr>
<tr>
<td></td>
<td>(0.0459)</td>
<td>(0.0321)</td>
</tr>
</tbody>
</table>

Notes: Estimated Fixed Costs represent the average of the sum of pecuniary and non-pecuniary cost. See Section 6.1 for detail.

Table 10: Production and Preference Estimates

<table>
<thead>
<tr>
<th></th>
<th>Production Parameters</th>
<th>Preference Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Northeast (poorer)</td>
<td>Central (richer)</td>
</tr>
<tr>
<td>Cobb-Douglas Capital Coefficient $\alpha_r$</td>
<td>0.29 (0.011)</td>
<td>0.28 (0.007)</td>
</tr>
<tr>
<td>Average Productivity Type $\mu_A$</td>
<td>11.10 (0.094)</td>
<td>12.38 (0.06)</td>
</tr>
<tr>
<td>SD of Productivity Type $\sigma_A$</td>
<td>1.36 (0.03)</td>
<td>1.56 (0.05)</td>
</tr>
<tr>
<td>SD of Productivity Shock $\sigma_{e_r}$</td>
<td>1.19 (0.010)</td>
<td>1.06 (0.013)</td>
</tr>
<tr>
<td>CRRA coefficient $\rho_{crra}$</td>
<td>1.25 (0.015)</td>
<td></td>
</tr>
</tbody>
</table>
C.2 Estimation: Fit of Estimated Model

Figure 9: Fit of Aggregate Credit Category Choice Probabilities

<table>
<thead>
<tr>
<th></th>
<th>Formal Borrow</th>
<th>Informal Borrow</th>
<th>Joint Borrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast 99-01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central 99-01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northeast 02-09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central 02-09</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model | Data
--- | ---
--- | ---
--- | ---
--- | ---
--- | ---

Figure 10: Fit of Continuous Borrowing and Savings Choices

Notes: See Section 6.1 for detail.
D.1 Results: Welfare Change in Northeast from 1999-2001 to 2002-2009

Figure 11: This figure shows the welfare impacts of Thaksin’s policies that lowered formal borrowing interest rates and fixed costs, and relaxed formal borrowing collateral constraints. I compare steady state welfare for households facing credit market access parameters from the 1999-2001 and the 2002-2009 periods. I present welfare changes in terms of consumption equivalent variation (CEV) percentage points changes. Credit market access parameters are observed or estimated. See Section 6.2 for detail.

Notes: CEV stands for consumption equivalent variation
D.2 Results: Formal Borrowing Counterfactuals

Figure 12: Shift Formal Borrowing Interest Rate
Keep Other Parameters at 2002-2009 level, move only Formal Borrowing Interest Rates

Figure 13: Shift Formal Borrowing Fixed Cost
Keep Other Parameters at 2002-2009 level, move only Formal Borrowing Fixed Cost

Notes: Figure 12 shows that changing formal borrowing interest rate has minimal impacts on credit participation choices. Figure 13 shows that reducing formal borrowing fixed costs has large nonlinear impacts on credit participation choices. Both Figures show improving formal borrowing conditions tend to reduce informal interest rate. See Section 6.3 for detail.
D.3 Results: Formal Saving Counterfactuals

Figure 14: Shift Formal Saving Interest Rate
Keep Other Parameters at 2002-2009 level, move only Formal Saving Interest Rates

Notes: Figure 14 shows that increasing formal saving interest rate could have large impacts on credit participation choices. Figure 15 shows that reducing formal saving fixed costs more could further reduce informal credit market size. Both Figures show improving formal saving conditions tend to increase informal interest rate. See Section 6.3 for detail.
D.4 Results: Formal Borrowing Collateral Constraint Counterfactuals

Figure 16: Shift Formal Borrowing Collateral Constraint

Notes: Figure 16 shows that the relaxation of collateral constraints between the two time periods contribute significantly to the change in informal credit market interest rates. This takes place as some previously formally-constrained households who borrowed informally switch to formal borrowing as formal borrowing collateral constraints are relaxed. This results in a large reduction in the demand for informal loans. However, since the change mainly impacts previously constrained households, the impact on participation rate is not as significant. See Section 6.3 for detail.
D.5 Results: Welfare Gains and Losses, Formal Borrowing Policies

Figure 17: Shift Formal Borrowing Interest Rate

Figure 18: Shift Formal Borrowing Fixed Cost

Notes: Figure 17 shows that decreasing formal borrowing interest rate improves welfare for households with low cash-on-hand and high productivity the most. Figure 18 shows that reducing formal borrowing fixed costs improves welfare for households with medium productivity and medium cash-on-hand the most. Both policies make less productive households worse off because they drive down the informal interest rate. See Section 6.3 for detail.
D.6 Results: Welfare Gains and Losses, Formal Saving Policies

Figure 19: Shift Formal Saving Interest Rate
Keep Other Parameters at 2002-2009 level
Increase Formal Savings Interest by 1 Percentage Point

Notes: Figure 19 shows that increasing formal saving interest rate improves welfare for households with high levels of cash-on-hand and low productivity the most. Figure 20 shows that reducing formal saving fixed costs improves welfare for households with medium to low productivity and lower levels of cash-on-hand the most. Both policies make more productive households worse off because they drive up the informal interest rate. See Section 6.3 for detail.
E.1 Solution Mechanism Detail: Feasible Choice Set for Borrowing

Figure 21: Borrowing Choice Set

For a particular individual i, the borrowing choice set

Figure 22: Joint Formal and Informal Borrowing Choice Set

For a particular individual i, Informal Borrowing Choice Set
If Doing Formal Borrowing Already (Maxed Out)

Notes: See Section 4.1
E.2 Solution Mechanism Detail: Feasible Choice Set for Saving

Figure 23: Saving Choice Set

For a particular individual i, the Saving choice set

Figure 24: Joint Formal and Informal Saving Choice Set

For a particular individual i, the Informal Saving/Lending Choice Set
If also doing formal borrowing already (Maxed Out)

Notes: See Section 4.1