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MASTER THESIS

Group lending with peer monitoring: A theoretical model of microcredit

Author: **Bc. Martin Štrobl**

Supervisor: **prof. Ing. Karel Janda, M.A., Dr., Ph.D.**

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Declaration of Authorship

I hereby proclaim that I wrote my diploma thesis on my own under the leadership of my supervisor and that the references include all resources and literature I have used.

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Signature

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Supervisor: prof. Ing. Karel Janda M.A., Dr., Ph.D.

Abstract

Over the years, the lending procedures of microcredit has evolved. The original joint liability group lending with simultaneous financing (loans released at once) has been replaced by sequential financing (loans released one by one). Moreover, recent studies suggest individual liability lending in groups to be the optimal choice. While numerous theoretical studies provide thorough models of each of these approaches, none presents a comparative analysis. In this study, we model these three schemes using the framework by Van Tassel (1999) and compare them. Further, we add exogenous peer monitoring costs and within-group heterogeneity of loan sizes to our models. Our findings prove that, in the presence of information asymmetry, group lending with joint liability dominates individual liability lending in groups. Furthermore, the interest rate of the sequential model is more sensitive to changes of monitoring costs or opportunity costs of capital than in the sequential model. On the contrary, sequential approach allows for higher degree of within-group heterogeneity of loan sizes. It is ambiguous which model achieves higher profit and lower interest rate. Our results confirm that the choice of optimal financing approach is determined by the characteristics of borrowers.

JEL Classificiation	G2
Keywords	group lending, microfinance, microcredit
Author's email	martin@martinstrobl.cz
Supervisor's email	Karel-Janda@seznam.cz

Abstrakt

Systém, jakým mikrokredit poskytuje půjčky, se během posledních let změnil. Původní systém sdílené odpovědnosti za dluhy ve skupině, kdy půjčky jsou uvolněny jejím členům najednou, byl nahrazen systémem, kdy jsou půjčky poskytovány postupně. Nejnovější studie navíc říkají, že nejvhodnějším způsobem je poskytovat půjčky ve skupině bez sdílené odpovědnosti. Přestože mnoho akademických prací tyto přístupy modeluje, žádný z nich je přímo nesrovnává. V této práci tyto tři varianty půjček ve skupině modelujeme pomocí přístupu z Van Tassel (1999) a následně je porovnáváme. Tyto modely zohledňují exogenní náklady na monitoring a rovněž umožňují různorodost velikosti půjček v rámci jedné skupiny. Naše výsledky ukazují, že v prostředí s asymetrickou informací o rizikovosti příjemce půjčky, půjčování ve skupině se sdílenou odpovědností dominuje nad půjčováním bez sdílené odpovědnost. Dále dokazují, že úrok z modelu s postupným financováním je více náchylný na výkyvy nákladů na monitoring a nákladů obětované příležitosti kapitálu, než ten z modelu s okamžitým financováním. Avšak model s postupným financováním dovoluje větší rozdíly ve výši půjček v rámci skupiny. Není jasné, který model dosahuje vyššího zisku a nižšího úroku. Naše výsledky tedy potvrzují, že volba optimálního modelu závisí především na charakteristice příjemců půjčky.

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Email autora	martin@martinstrobl.cz
Email vedoucího práce	Karel-Janda@seznam.cz

Master Thesis Proposal

Author	Bc. Martin Štrobl
Supervisor	prof. Ing. Karel Janda, M.A., Dr., Ph.D.
Proposed topic	Group lending with peer monitoring: A theoretical model of microcredit

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Motivation

The rise of microcredit in the developing countries has saved thousands of people from poverty. By introducing no collateral requirement and group liability, the lending scheme of microcredit denies the basic assumptions of common debt contracts. However, exactly thanks to these specificities, microcredit lending to the poor works where usual schemes fail. The providers of microcredit loans, most commonly NGOs and governmental agencies, differ in the way how they organize the group and structure the lending procedure. The loans may be provided simultaneously or sequentially within the group. In academia, the theorists initially inspected the joint liability feature to prove its positive impact on repayment rates (e.g., Besley and Coate, 1995). Later on, Ghatak (1999) and Van Tassel (1999) showed by modelling the group formation process that joint liability can induce peer selection of borrowers according to their types and, thus, help the lender screen the applicants. Unfortunately, none of these models deals with the possibility of moral hazard and the respective need for monitoring of the borrowers. This issue is raised by Ghatak and Guinnane (1999). Chowdhury (2005) formed a model with lender monitoring to conclude that traditional simultaneous financing is not feasible at all and, hence, it is dominated by sequential financing. Despite this result, microfinance institutions have operated the traditional scheme for several decades with moderate success. The model of Chowdhury (2005) may prove to be too restrictive as it takes the interest rate charged by the loan provider and the loan size as exogenous and homogeneous across groups. I aim to take the model of Van Tassel (1999), which does take these variables as endogenous and also allows for partial joint liability, and introduce costly state verification (monitoring) into the model.

Hypotheses

1. Lending is feasible (i.e. equilibrium exists) in the traditional group lending scheme with moral hazard.
2. Lending is feasible (i.e. equilibrium exists) in the sequential group lending scheme with moral hazard.
3. The sequential financing equilibrium provides higher social welfare than the traditional setup.

Methodology

I plan to build a model based on the foundations of Van Tassel (1999), which is the most comprehensive model of group lending, and introduce costly state verification of the borrower's project. This induces the need for monitoring the borrower as it is a typical example of ex-post moral hazard and agent-principal problem. I aim to solve the model and identify equilibria in this one period game. Firstly, in the perfect information environment (as a benchmark). Secondly, in the traditional simultaneous setting and, thirdly, in the scheme with sequential financing. Further, I am going to analyze and compare the social welfare in each setting to determine the most suitable model. As an ultimate objective, if applicable, I would like to add contingent renewal of the contract and social sanctions to my model as well and study its role and consequences.

Expected Contribution

All of the theoretical models of group lending with moral hazard assume the loan size and the interest rate to be exogenous and constant across groups. I am going to build the first model with moral hazard that takes them as endogenous and thus its results should be generally more valid. Moreover, I aim to inspect the behavior of the model with sequential financing and compare both setups. I also plan to comment on the role of partial joint liability extensively as it has not been analyzed with sequential financing at all. Altogether, this thesis should produce theoretical results which may have impact on the daily practice of microcredit intermediaries and the design of their products.

Outline

1. Motivation: I will introduce the background and the story of microcredit, its successes and failures. Also, I will introduce the difference between traditional group lending and sequential.
2. Microcredit in theory: I will review the theoretical models of group lending and their implications, further, I will confront these models with empirical evidence.
3. The model with moral hazard: In this section I will introduce the economic environment of the model, its setup with moral hazard.
4. Simultaneous financing: This section will analyze the one period game of simultaneous group lending.
5. Sequential financing: This section will analyze the one period game of sequential group lending.
6. Discussion: Here, I comment on the results and compare them to relevant literature.
7. Conclusion: I will summarize my findings and their implications for microcredit policies and possible future research.

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Author

Supervisor

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Acronyms

MFI Microfinance institution/intermediary

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1. Introduction

Throughout the past two decades, there has been a spate of interest in microfinance, one of the most notable financial innovations in the developing world. Microfinance was invented by Muhammad Yunus, who founded the Grameen Bank in Bangladesh in order to provide small loans to the poor in remote areas with absence of financial services. This provision of loans does not require any physical collateral on the part of the borrower, since borrowers are organized in groups whose members are jointly and mutually liable for all of the unpaid loans. In the twentieth century, though microfinance institutions (MFIs) are spread around the globe and offer new financial services like savings plans and insurance, group lending (microcredit) is still the main product of microfinance (Brau and Woller, 2004).

Over the years, MFIs have changed the way they provide loans as the original simultaneous method, where all loans are provided at once, was replaced by sequential financing (Morduch, 2000). In fact, initially, the Grameen Bank operated a semi-sequential scheme. However, the first wave of MFIs adopted it as simultaneous as empirical studies suggest (e.g. Paxton et al. (2000)). Subsequently, there has been a gradual shift towards sequential scheme.

Under sequential financing, a loan is provided only in case the previous loan was repaid. These changes of group lending design have spurred a new wave of theoretical studies on the benefits of this sequential scheme. Though these models analyze many aspects of these financing methods as well as of group lending in general, none of them offers a direct comparison of the simultaneous and sequential setup. In order to address this problem, we build both models in a single environment and provide an in-depth comparative analysis.

In the 20^{th} century, humanitarian aid and governmental subsidies for the poor were predominantly distributed through rural credit agencies. These governmental institutions were mostly unsuccessful (Gonzalez-Vega, 1994). Since microcredit achieves relatively high repayment rates, these traditional development initiatives were largely replaced by MFIs. Nevertheless, joint liability is not the only factor increasing the repayment rates and ensuring the sustainability of MFI's business. By imposing several requirements on participation in group lending, loans are provided only to responsible borrowers with high potential of repayment. Firstly, borrowers are asked to form the group themselves. Given the fact they usually know each other, borrowers with low abilities or low social capital are excluded from the group and do not receive any loan. Secondly, the participation is often restricted to women only as they empirically have more discipline in repaying debt. Thirdly, the funds are usually provided to business owners, since they are less susceptible to natural risks than farmers. Finally, if the borrower does not repay her debt, she will be rejected any further loans in the future. This way, an MFI screens borrowers and incorporates their social capital instead of physical collateral.

Unfortunately, these principles of microcredit are not universally applicable, since social ties have different forms and strength in different societies. Many MFIs did not adapt to local environments, establish sustainable practices, and as a result of that went bankrupt. Partially, the reason behind was ex-post moral hazard, resulting into strategic default of the whole group. Nowadays, this issue should be mitigated by sequential financing as the provision of loans is immediately stopped if a single loan defaults. However, there are only a few research papers investigating the role of strategic default.

In general, the theoretical literature on group lending has always lagged behind practice. Initially, theorists have investigated the benefits of group lending in comparison with traditional individual liability lending (e.g. Varian (1990), Stiglitz and Weiss (1981)). Later on, further studies modelled group lending in game theoretical models in order to analyze their equilibria (e.g. Van Tassel (1999), Ghatak (1999)). After the introduction of sequential financing, further models were built reflecting this new lending scheme (e.g. Chowdhury (2005)). Nevertheless, none of the papers offers a comprehensive comparison of simultaneous financing and sequential financing. Whilst Chowdhury (2005) models both methods, he concludes that there exists no equilibrium in the model with simultaneous financing and, therefore, provides no further comparisons. Given the fact that the traditional financing model has been used by MFIs for years with decent success, his result seems to be too strong.

Recently, the empirical evidence of Giné and Karlan (2014) has raised interest in the ongoing transition of MFIs from group lending with joint liability to individual lending in groups. A theoretical model of De Quidt et al. (2016) depicts these latest developments and identifies individual lending as a better choice. However, the authors do not model microcredit in an information asymmetry environment, i.e. in the presence of risky borrowers that harm the MFI's repayment rates. Given this heterogeneity of approaches and unsatisfactory theoretical evidence, there is still an ongoing lively debate about the benefits and drawbacks of particular designs of group lending. Consequently, policy makers and MFIs are not receiving any clear message and practice further remains ahead of theory.

After giving an overview of the relevant theoretical models available, we build models of individual liability lending in groups, joint liability group lending with simultaneous financing, and joint liability group lending with sequential financing. Since individual models from the mentioned literature can be hardly compared, we use a single environment with information asymmetry by Van Tassel (1999) for all of our models in order to guarantee comparability. Further, we reflect ex-post moral hazard risks and include exogenous monitoring costs into our models. By comparing various aspects of the models, we provide unique theoretical evidence and contribute to the discussion on the optimal microcredit lending design. In particular, we focus on the differences between individual liability lending in groups and group lending with simultaneous financing and between joint liability group lending with simultaneous financing and sequential financing. Additionally, we also model the within-group heterogeneity of loan sizes and analyze its limitations across the financing schemes. Such an analysis has also not been published yet.

The thesis is organized as follows. In the next chapter, we cover the evolution of microcredit, its challenges and successes. In Chapter 3, we review the relevant literature on group lending. We analyze theoretical research as well as empirical and experimental studies. In Chapter 4, we construct our models, analyze their individual properties, and identify equilibrium conditions. In Chapter 5, we compare our models from several perspectives. In the final chapter, we state our main findings and offer suggestions for further theoretical research on the topic of group lending.

2. The evolution of microcredit

Before the introduction of microfinance, governments in developing countries were struggling to eliminate poverty and to support the development of micro-enterprises. Their main instrument for poverty alleviation in those days was direct financing through social and agricultural programs. These subsidies proved to be rather unproductive and costly (Cull et al., 2009). In 1983, Muhammad Yunus founded the first microfinance institution, the Grameen Bank. The bank was established in Bangladesh. Its purpose was the provision of loans to the poor using group lending with joint liability, the pioneering service of microfinance Yunus had previously experimented with and developed. This approach was unique as it required no collateral on the part of the borrower. However, participation was usually restricted to women only.

According to Besley and Coate (1995), the key aspect of microfinance lending is the joint liability within the group which allowed loan provision even in small remote villages to borrowers with no credit record. The groups are formed by borrowers themselves such that, given the fact that the villagers know each other, the risky borrowers should be excluded from the group. Although the participants risk no collateral, default by one member can be followed by social sanctions by other group members, since they are obliged to cover her outstanding debt. In case the borrower defaults, she is banned from future loans as well.

The microcredit provision and repayment scheme has been further developing. Naturally, MFIs have adapted to local conditions of a given country. However most notably, there has been a shift toward sequential financing schemes (Morduch, 1999). Under this setup, the loan is provided to group members sequentially and its provision is conditional on the repayment of the previous loan. In case one borrower defaults, further lending is discontinued.

The focus on women (as more responsible borrowers than men) is not the only way an MFI increased repayment rates. Moreover, the funded projects are usually small enterprises that are not agricultural so that the MFI's credit portfolio cannot be suddenly harmed by unexpected natural events or disasters (Cull et al., 2009).

The introduction and the initial success of microcredit have led to the establishment of new MFIs in almost every developing country around the globe. Whilst the approach to group lending differs only slightly, the ways of funding MFIs are quite diverse (Brau and Woller, 2004). At the moment, there are two leading attitudes to MFI's funding and sustainability. From an institutional point of view, an MFI should generate enough profit such that it is entirely self-sufficient (Morduch, 2000). This condition originates from research on unsuccessful agricultural programs preceding microfinance (Gonzalez-Vega, 1994).

Welfarists, on the contrary, claim that an MFI can be sustainable even if it is not financially self-sufficient. The funding is then provided by governmental subsidies and external partners and donors. This polarization partially stems from an important trade-off between the depth of outreach (lending to the poorest) and financial self-sufficiency (Von Pischke, 1996). In practice, MFIs are usually not financially self-sufficient.

Although group lending (microcredit) still represents the main product of microfinance, the industry has also introduced new products such as microinsurance and savings (Nourse, 2001). As a result of this, the services of MFIs are more complex and offer the poor at least the necessary minimum of financial tools they need. An empirical study by Atkinson et al. (2013) has proved that binding a savings plan with a microcredit loan results in a better repayment morale.

There are several circumstances that can reduce the effectiveness of MFIs. One of the most dangerous situations is the competition of MFIs in a saturated market. Since this competition makes them provide loans to poorer and poorer borrowers, the presence of multiple MFIs is not optimal, since it harms their credit portfolio.

Under conditions of market saturation, it becomes too costly for the government to subsidize MFIs as their efficiency decreases (Sengupta et al., 2008). Furthermore, borrowers having the possibility to receive more than one loan, can borrow from multiple MFIs and have struggled to repay (McIntosh and Wydick, 2005). Such a situation is also likely to lead to an increase in interest rates due to lending to riskier borrowers (Guha and Chowdhury, 2013).

3. Literature review

In the literature review, we present and comment on the relevant academic literature dealing with group lending. Throughout the first section, we review the results of papers that have built theoretical models of group lending. In the subsequent section, we present empirical and experimental studies on group lending that illustrate several aspects of group lending that are yet to be modelled theoretically.

3.1 Microcredit in theory

Existing theoretical models of group lending are quite diverse in their assumptions. For example, some model group lending with a group of two (that can be generalized to group of any size n), while others use n explicitly. A clear pattern can be observed in the literature: In the 20^{th} century, research focused primarily on proving theoretically how group lending can improve repayment rates. Nowadays, most researchers study the design of group lending procedures (simultaneous vs. sequential financing).

Stiglitz (1990) and Varian (1990) initiated the (game) theoretical approach to microcredit group lending by investigating peer monitoring and its positive influence on repayment rates. Stiglitz (1990) argues that peer monitoring is the main reason why microcredit works. Further, he claims that the effect of peer monitoring among borrowers is the strongest in smaller groups. Increasing the group size raises the incentives to free ride and ignore other borrowers.

Varian (1990) comes to a similar conclusion. Although his rather descriptive microeconomic analysis does not have the form of a comprehensive model with equilibrium conditions, he formally describes all of the important features of microcredit lending, i.e. peer monitoring, group formation, sequential incentives, and contingent renewal.

Besley and Coate (1995) inspected the joint liability feature of group lending and proved its positive impact on repayment rates. They construct a simple model with social collateral, i.e. they use the social role of the borrower as a capital stock, he may lose replacing the classical physical collateral requirement. This provides the lender with a tool to punish the borrower in case he defaults. The authors also point to the case when all lending group members default (strategic default). They conclude by comparing to lending under individual contracts that, in this particular case, the group lending procedure has a negative effect.

Once the main features of microcredit were pointed out, researchers focused on building more comprehensive models to study the behaviour of borrowers (especially group formation). In this respect, the main research question was whether the given model leads to positive assortative matching, i.e. whether the formed groups contain only members of the same (high/low-ability) type. Based on this, the overall joint liability effect is evaluated as positive or negative. These models were pioneered by Ghatak (1999) and Van Tassel (1999) and usually consist of the following three stages: bank (MFI) offers contracts specified by interest rate and amount of joint liability, borrowers form groups and, if interested, agree on a contract, borrowers' outcomes are realized and respective transfers are made.

Ghatak (1999) built a model with joint liability based on Stiglitz and Weiss (1981). The degree of joint liability is considered as an endogenous variable, hence partial joint liability is also possible. The model assumes a general distribution of borrower types and varying group sizes. The main drawbacks of the model stem from the fact that it does not account for within-group heterogeneity of loan sizes as the project investment requirements are normalized to one. The model also ignores moral hazard risks. The authors provide evidence of positive assortative matching and conclude that this pooling of borrowers leads to better repayment rates and overall welfare.

The model of Van Tassel (1999) is one of the most complex models as it does not normalize loans to one. However, the author does not analyze the case of within-group heterogeneity of loans. The model features partial joint liability and allows for different (endogenous) interest rates across groups. It works with a group of two borrowers of two types. Nevertheless, the results can as usual be generalized up to any n. Again, the model induces positive assortative matching. Further, borrower types can be recognized by the lender according to the sensitivity to change of the degree of joint liability. This model does not reflect the possibility of moral hazard and the resulting need for monitoring borrowers.

Ghatak and Guinnane (1999) nicely sum up all of the important features of a group-based credit market. Furthermore, the paper describes the use of joint liability in practice, which illustrates several concepts that are yet to be modeled formally or have been incorporated in models only recently. Most notably, these are moral hazard risks.

The first author who introduced a model with ex-post moral hazard and borrower monitoring was Chowdhury (2005). The paper compares results in two regimes - under traditional simultaneous financing vs. sequential financing. The results show that lending is feasible only under sequential financing. That is a strong claim, since several microfinance institutions have operated the traditional scheme for several decades with decent success. One possible explanation might be that the model assumptions are too restrictive, as it takes the interest rate charged by the loan provider and the loan size as exogenous and homogeneous across groups. In practice, interest rates may vary across groups.

Allen (2016) built a model for the choice of strategic default of the group. His analysis shows that repayment rates can be significantly harmed by the motivation of borrowers to default strategically. After validating with empirical data, the author suggests that a decrease from full liability to partial liability of 50% would mitigate these risks.

A recent wave of theoretical literature has been triggered by the empirical paper of Giné and Karlan (2014). Theorists have begun discussing the shift from group lending to individual lending in groups and advocating why such a transition is beneficial. The paper concerning this shift by De Quidt et al. (2016) shows that joint liability can in the presence of high social capital be transformed into informal and independently arranged "insurance" among borrowers while making them better off than in the case of explicit joint liability. This case may apply from the point of view of the borrower, but it may not be in the best interest of the lender. Under asymmetric information, the lender uses group liability as a tool to pool borrowers by separating those who are risky from those who are not. De Quidt et al. (2016) ignore this purpose of microcredit and do not model the group formation stage. Given the presence of perfect information about the risk profile of the borrower, it is obvious that individual lending must be a better option than group lending. We remark on this approach in Section 5.1.

3.2 Experimental and empirical evidence

The empirical research and evidence from the field or laboratory experiments are very diverse. While many papers examine the group lending repayment rates and the role of social capital, there are only very few authors studying the differences in lending scheme design (simultaneous vs. sequential financing) - a vast majority of the papers are based on the traditional simultaneous financing scheme. A possible explanation is the ongoing focus of researchers on the defense of group lending as such. Initially, the reason for this advocacy was the appeal for a wider spread of group lending and elimination of state-funded development programs. Over the last decade, the academic papers have investigated new models that result from empirical practice of MFIs, including the shift from group lending to individual lending in groups.

A field experiment from Mongolia by Attanasio et al. (2014) provides a comparative analysis of individual lending and group lending (simultaneous financing). Their results show that the funds received by borrowers through group lending are usually used for investment, since these borrowers are more likely to be business owners than individual lending borrowers. This implies individual lending funds are predominantly used for consumption or other non-investment purposes. Furthermore, the repayment rates were higher in the case of group lending.

Cason et al. (2012) conducted a lab experiment investigating the role of monitoring costs in moral hazard alleviation. If peer monitoring costs are at the same level as lender monitoring costs (direct individual monitoring), group lending with peer monitoring does not provide any improvement over individual lending with direct monitoring. If peer monitoring costs are lower than those of individual monitoring, group lending is a more efficient way of lending. Additionally, the experiment examined the differences between the simultaneous and sequential designs. Surprisingly, both of the methods resulted in similar repayment rates.

Giné and Karlan (2014) organized a field experiment in the Phillippines and argue that a possible transition from group lending to individual lending through group meetings does not influence the repayment rates. However, the change from group lending to individual lending results in less groups being formed.

Beck and Behr (2017) have also studied the differences between individual and group lending. Their data from an MFI and an individual lending institution from Montenegro suggest that the probability of being in short-term arrears is higher for individual loans. However, in the longterm (more than 30 days), the loans of an MFI are more likely to be in arrears. The authors argue that this may be caused by the motivation of the group to default strategically.

Allen (2016) developed a theoretical framework to model this strategic default of microfinance borrowers. After fitting data from a Mexican MFI, the results show that a significant portion of defaults could be attributed as strategic. The author suggests that a reduction to a partial joint liability at the level of 50% would reduce the incentives for strategic default, resulting in higher repayment rates.

The drivers of strategic default were studied by Ahlin and Townsend (2007). Using data from a Thai MFI, the authors found that repayment rates are negatively correlated to social connections within the group as well as the level of joint liability. That implies a higher motivation for strategic default is present with a growing degree of joint liability and the ability to "convince" other group members to collude and default strategically. The role of social ties is very curious. On the one hand they can contribute to strategic default, while on the other hand, other researchers argue that social connections make group lending work. Karlan (2007) finds evidence from Peru that groups with more socially interconnected members achieve higher repayment rates. These relationships are affected if a member defaults. These results suggest the role of social ties is ambiguous. Though increasing the probability of repayment, they may backfire and facilitate strategic default if they become too strong.

A field experiment in India by Feigenberg et al. (2014) illustrates that social capital does not only substitute for physical collateral. The authors find evidence that more frequent meetings of the group induce the growth of social capital within the borrowing group. This is because borrowers get to know each other and build trust.

The results of the field experiments of Cassar and Wydick (2010) in India, Kenya, Guatemala, Armenia, and the Philippines show that trust among borrowers is of high importance. People are willing to take on joint liability if they trust the other group members. Moreover, participants who have been given a loan in this way already seem to trust their fellow borrowers more than borrowers who are new to microcredit.

4. Group lending model

In this chapter, we present three models. The first one models individual liability lending in groups. The second one simulates simultaneous financing procedure in group lending, and the third models the sequential setup. Since the model for simultaneous financing is a slight modification of the model of Van Tassel (1999) (we add peer monitoring and variability of loan sizes within the group), for the purpose of comparability, we follow the approach and framework from the original paper. For clarity and cross-referencing, we also choose to follow the notation of the original paper.

Let us start by defining the modelling environment, agents, and their payoffs. Let A be a set of fully rational agents (entrepreneurs) with reservation income of zero, since we assume borrowers lack any other income. Each of the agents has the possibility to realize a project (e.g., start a business) with an uncertain outcome. Such a project requires an initial investment of size L for funding. Those projects that turn out to be successful generate the outcome of $f(L)$, where $f()$ is a production function satisfying the following conditions (equivalent to Inada conditions from macroeconomic theory), i.e.

(i) $f(0) = 0$

(ii) $f()$ is continuously differentiable

(iii) $f'() > 0$

(iv) $f''() < 0$

(v) $\lim_{L \to \infty} f' = 0$

(vi) $\lim_{L \to 0} f' = +\infty$

Unsuccessful projects receive the outcome of zero. The probability of success is given by p_i, where i denotes agent's type. These probabilities are assumed to be common knowledge. There are two types of agents, high-ability (h) and low-ability (l). We assume $p_h > p_l > 0$. The share of low-ability entrepreneurs, $\phi \in (0, 1)$, is commonly known.

The main purpose of microcredit group lending is to pool borrowers into two groups - those who on average repay their loans and generate non-negative outcome for the lender and those who do not and whose default creates a loss for the lender. Therefore, we have two types of agents such that the lenders want to provide loans only to high-ability agents in order to sustain profitable (formally stated in Assumption (iii) in Subsection 4.3.3).

We assume agents are poor and lack any form of prior capital ownership; hence, the whole amount L for project funding must be obtained through the loan provided by the MFI. Since agents have no capital, they cannot provide collateral. The loans in our models are provided by MFIs with the opportunity cost of capital of γ. We assume these intermediaries are two identical lenders such that we can model competitive credit market on the supply side. We assume that these lenders maximize their profit individually, without any collaboration or collusion. Note that, in accordance to the original paper, γ includes the principal amount of investment resulting in $\gamma \geq 1$ whilst r reflects only the return on loan excluding the amount originally provided as a loan.

The provision of credit to borrowers is arranged in groups, where successful agents are liable for a portion of unpaid loans within the group. This portion is defined in the loan contract by joint liability parameter σ. These contracts are offered by lenders to borrowers. Such a loan contract is then described by the pair (r, σ), where r is the interest rate. Further, we assume $r \geq 0$ and $\sigma \geq 0$. Therefore, loans with no joint liability (individual liability loans) are feasible as well as loans with partial liability. By the contract of (r, σ, L), we refer to a contract (r, σ) accepted by an agent maximizing his profit through the choice of L.

We assume the group to be of size two throughout this thesis. See Section 4.1 for explanation how the results can be generalized to larger groups. We assume the optimal sorting property (Becker and Becker, 2009) to hold for the formed groups, i.e. formed groups are renegotiation proof - any of the agents cannot be better off by pairing with another agent he is currently not paired with. Given a contract (r, σ), an agent of type i will choose a loan size maximizing her expected income:

$$L(r) = \arg\max_{L} p_i \left[f(L) - (1+r)L \right]. \tag{4.1}$$

We can express the expected income of an agent of type i paired with an agent of type j as:

$$\begin{aligned} V^{i,j}(r, \sigma, \bar{L}) &= \max_{L} p_i p_j \left[f(L) - (1+r)L \right] \\ &+ p_i(1-p_j) \left\{ \max_{L} \left[f(L) - (1+r)L - \sigma \bar{L}, 0 \right] \right\} \end{aligned} \tag{4.2}$$

where by $\bar{L}$ denotes the amount provided to the other group member (agent j) as a loan.

We see that this income consists of incomes of two possible contingencies weighted by their probabilities. The first one covers the situation when both agents repay the loan, the other one captures the default of the partner and repayment of her own loan. The third possibility of group default is omitted in the formula as it generates income of zero for the agent. Moreover, this possibility of expected income of zero actually includes the fourth possibility: a failure of the agent i, a success of the agent j. Given the fact that borrowers face the alternative of reservation income of zero, we do not model their utility, risk aversion, and other behavioural aspects. For simplicity, we assume simple profit maximization.

Additionally, we must ensure the agents actually have type-specific preferences. These are given by the incentive compatibility constraints that must hold so that the agents choose the right contract. For individual liability ($\sigma = 0$) contracts $(r_1, 0, L_1)$

and $(r_2, 0, L_2)$, according to Van Tassel (1999) we have

$$p_h[f(L_1) - (1 + r_1)L_1] \geq p_h[f(L_2) - (1 + r_2)L_2] \tag{4.3}$$

$$p_l[f(L_2) - (1 + r_2)L_2] \geq p_l[f(L_1) - (1 + r_1)L_1]. \tag{4.4}$$

This way we ensure the preferences of agents of each type are behaving properly - each type's optimal contract is different. The above inequalities imply the following condition equalizing independent profits of agents

$$f(L_1) - (1 + r_1)L_1 = f(L_2) - (1 + r_2)L_2. \tag{4.5}$$

This is an important condition as it states that funded projects must yield the same profit for both agents. We will use this condition in our further analysis extensively.

Further, we assume borrowers prefer to accept a contract with the expected income of zero rather than abstaining from borrowing. Moreover, borrowers prefer a contract with lower joint liability if interest rates are equal. The similar holds for the lenders - they prefer to offer a contract if expected payoff equals reservation income. The borrower accepts a contract only if her expected income is non-negative.

The game is set in three stages. In the first stage, the lenders offer their loan contracts to borrowers. In the second stage, borrowers observe and evaluate lenders' offers, and each chooses at most one, lending groups are formed and funds are provided to borrowers. In the third stage, projects' outcomes are realized and loans are repaid.

4.1 Generalization of group size

Part of this thesis as well as several relevant academic papers model group lending only with two borrowers. In practice, for example, the groups of the Grameen Bank usually consist of five members (Abbink et al., 2006). This section explains how we can generalize this concept of two borrowers to any arbitrarily set number of actors.

Suppose we have two agents of the same type. Furthermore, assume that positive assortative matching holds, i.e. agents are willing to match only with counterparts that are of the same type. The agents are offered a contract (r, σ), they agree to accept it and form a group. Though we have two agents now, we can simplify the situation back to the point where we had only one agent initially. Since the original two agents are in fact homogeneous, their group can be considered by a third agent only as a single agent going for the contract of $(r, \sigma, 2L)$, who is looking for a counterpart to team up with. Consequently, this third agent can decide whether he joins this group of two or not.

Although we do not provide any formal proof, it can be seen that this aggregation principle works by induction ad infinitum. The only requirements are positive assortative matching property (will be proved in each model) and none of the variables in the model must be defined as size dependent. We violate the second requirement in our peer monitoring models because the monitoring cost does depend on size. However, we consider the group size n and the resulting monitoring cost to be exogenous in our models. Hence an MFI can optimize by setting the maximum size to n^* ex-ante such that the per unit monitoring cost is minimized. Agents are then willing to form groups up to size of n^*. This allows us to generalize our model and its results to any arbitrarily set group size.

4.2 Costly state verification and peer monitoring

We assume there exists ex-post moral hazard in the form of costly state verification of the success or failure of the funded project by the intermediary. In other words, successful agents may report their projects as unsuccessful to the lender and the lender is unable to verify this information. This is a common problem in microcredit practice as the lending usually takes place in remote areas where MFIs have no offices or delegates. Since, in such a case, the revenue is $f(L)$ instead of $f(L) - (1 + r)L$, this deception is a dominant strategy for a successful agent. In order to mitigate these moral hazard risks, the lender must monitor individual borrowers to observe the true state of the project. By monitoring we mean controlling the expenses and verifying the completion state of the project.

Given a group of n members, individual monitoring of all members would cost the lender $\sum_{i=1}^{n} mL_i$, where $m > 0$ is the per unit cost of individual monitoring. Although such practice increases repayment rates, this cost is non-negligible and makes the lender increase r in order to remain profitable. This raise of interest backfires at borrowers and might rule them completely out of the market; thus, it is beneficial for both sides to switch to peer monitoring as a more cost-efficient way.

Peer monitoring refers to a situation where each borrower observes the status of projects of other borrowers, her peers, within the group. This way, the lender can receive information about a particular project from all group members, not just its owner. Relevant academic papers (e.g. Varian (1990)) agree that peer monitoring is the key feature of microcredit as it motivates all agents to behave honestly. The rest of the group may sanction the misbehaving agent in his everyday activities, e.g. by the loss of business contacts, friends, social position.

This approach has two drawbacks that are usually ignored in theoretical models of microcredit. Firstly, the whole group can collude without punishment and report all projects as unsuccessful (strategic default). Such an outcome results in a huge loss for the MFI. In practice, the usual counter-measure of an MFI is to reject provision of any future loans to these borrowers. Secondly, borrowers are likely to report unsuccessful projects as successful not to be held responsible for the outstanding debt. However, such a situation can be easily noticed by the lender and agents punished.

These problems are in practice mitigated by using contingent renewal contracts and sequential financing. Theoretically, we assume to have exogenous monitoring costs that an MFI must pay in order to mitigate these practices. For example, these expenses can be assumed to be used in the following way: We assume the lender to monitor at least one borrower selected at random at the end of stage two. This controlling mechanism is assumed to be common knowledge (while not revealing the identity of the agent who is being monitored). Naturally, in order to make this threat credible, the lender must provide evidence for his commitment (e.g. part of monitoring costs paid in advance). Moreover, the lender announces punishments for insincere reporting - loss of any profit. That means the entire amount of $f(L)$ for successful agents. We assume unsuccessful agents to report always sincerely even in the absence of punishment threat as insincere reporting might hurt their social role. Under these measures, borrowers know that at least one of them is being monitored without being able to identify his identity. Given this situation, the dominant strategy for the borrower of any type is to report on others truthfully. Monitoring exactly one random borrower directly by the lender is sufficient and prevents group collusion. For our analysis, assuming the monitoring of one borrower at random is adequate as we do not model borrowers' decision whether to report sincerely or not.

Let us discuss, why the monitoring target must be chosen at random. It would be cost optimal to monitor the smallest loan. However, such behavior could be anticipated by borrowers, and thus would not be effective. Using the proposed mechanism, the expected monitoring cost decreases to $M = \dfrac{m(n)\sum_{i=1}^{n} L_i}{n}$, i.e. the cost of monitoring the average borrower. The function $m(n)$ is a marginal monitoring cost function such that:

$$m(1) = m \tag{4.6}$$

$$m > 0 \tag{4.7}$$

$$\frac{\partial m(n)}{\partial n} > 0 \tag{4.8}$$

$$\frac{\partial^2 m(n)}{\partial n^2} > 0. \tag{4.9}$$

These conditions ensure that it is not optimal for an MFI to increase the group size infinitely. Therefore, there exists an optimal group size of n^* minimizing $\frac{m(n)}{n}$. In order for peer monitoring to be more effective than individual monitoring, we assume the existence of at least one $\hat{n} > 1$ such that

$$\frac{m(\hat{n})}{\hat{n}} < m. \tag{4.10}$$

In other words, the average monitoring cost is lower for group lending. Given that the cost of monitoring is entirely borne by the bank, expected income of the borrower $V^{i,j}(r, \sigma, L)$ remains unchanged. We assume the lender knows this optimal group size beforehand and restricts the group formation to this group size. In our model for the group of two, we can then take the monitoring costs being equal to its optimal level of $\frac{m(n^*)}{n^*}$ as exogenously predetermined.

4.3 Simultaneous financing

In this section, we illustrate the benefits of peer monitoring in an environment with complete information. Then, we proceed to derive the models of individual liability lending and joint liability simultaneous financing group lending.

4.3.1 Complete information

Let us solve the model with complete information and individual monitoring as a benchmark to further results. In this setting, the lender is able to recognize the type of each borrower. Hence he is able to adjust r_i to the risk profile of each borrower. Given this knowledge, there is no incentive to initiate group lending in order to group borrowers by the lender. Also, borrowers are not be willing to group, since they would not be offered a lower interest rate and they prefer lower joint liability given the same level of interest rate. Thus, borrowers are provided individual liability contracts, where the equilibrium level of r_i for each type is given by the following formula.

Proposition 1. *In a situation, where lenders have access to complete information, agents will be in equilibrium offered individual liability contracts* $(r_i, 0)$, *where*

$$r_i = \frac{\gamma + m - p_i}{p_i}, i = h, l. \tag{4.11}$$

Proof. Since we have more than one lender, the competition on the lending market drives the offered interest rates as low as possible. That means the lender is offering a rate which matches his profit to the profit from investing L_i elsewhere. Otherwise, the other lender would be able to seize the market by reducing r_i by an arbitrarily small amount while still getting the same level of profit reduced only by an arbitrarily small amount. Thus, by using $\pi_i(r_i, L_i) = p_i(1 + r_i)L_i - L_i - mL_i$ in the break-even condition of an MFI equalizing its profit and yield on the capital market

$$\pi_i(r_i, L_i) \quad = \quad L_i(\gamma - 1),$$

we have

$$p_i(1 + r_i) - m \quad = \quad \gamma$$

and then

$$r_i = \frac{\gamma + m - p_i}{p_i}.$$

□

It cannot be completely ruled out that there exists a joint liability equilibrium. However, this equilibrium would always be dominated by individual liability lending. This is because the borrower out of two contracts with the same interest rate always prefers the one with less joint liability.

Also, it could be the case that borrowers would be willing to take a bit of joint liability in exchange for lower interest rate. However, it can be shown that the lender would not actually be willing to offer such a contract as borrowers' types are known to him. The grouping and pooling of borrowers would not provide the lender with any extra benefit. The lender cannot acquire any useful information by group lending, since agents' types are already known to him. Given this fact that each type is offered an individual loan with the lowest possible type-specific interest rate (while lender earns the lowest possible profit), the lender cannot decrease the interest rate in exchange for a bit of joint liability.

Nevertheless, the lender can choose to ignore this information, not to offer type-specific contracts, and offer one a single pooling individual liability contract reflecting uncertainty about agent's type instead. For the purposes of this simple analysis and for setting this complete information scenario as a benchmark, we assume the lender to offer type-specific contracts.

Proposition 2. *Under perfect information, there exists only one unique equilibrium if and only if* $m < \gamma$.

Proof. The rationale of the dominance of individual liability contracts has been outlined in the previous paragraph. Hence consider the case when the borrower of type i is offered an individual contract, $(r_i, 0)$. The borrower maximizes her profit through the choice of L, her loan size, given the conditions specified in the contract. This choice of L is given by the following optimization problem:

$$\begin{aligned} &\max_{L} \quad p_i[f(L) - (1 + r_i)L] \\ &s.t. \\ &\quad r_i = \frac{\gamma + m - p_i}{p_i}, \\ &\quad L \geq 0, \\ &\quad p_i[f(L) - (1 + r_i)L] \geq 0 \end{aligned}$$

Given the properties of $f()$, there must be some $L > 0$ satisfying

$$p_i[f(L) - (1 + r_i)L] \geq 0.$$

Hence solving the problem gives us the equilibrium condition

$$f'(L) = \frac{\gamma - m}{p_i}, \tag{4.12}$$

which proves the equilibrium existence and uniqueness as long as $\gamma - m > 0$. □

The above proposition illustrates how the lender evaluates the monitoring cost of the loan. If the cost is too high, there is no contract that could satisfy all of the required conditions and, therefore, lending is not feasible at all. This is exactly the case MFIs face in underdeveloped and remote areas. With no branch offices of the MFI in this area, monitoring of each individual borrower may be too costly for the loan provider. Then, in such circumstances, individual lending is not feasible at all.

4.3.2 Information asymmetry and individual liability

Now, suppose there exists an information asymmetry between the lenders and borrowers. By that we understand the situation such that lenders do not observe borrowers' types and must adjust offered contracts to reflect this uncertainty. In other words, lenders offer one contract for all types of borrowers. Offering type-specific contracts is not feasible, since the lender cannot tell the type of an agent to determine which contract he should offer her. The only possibility is to offer an individual liability contract reflecting this uncertainty about agents' types.

In the first part of this chapter, we analyze individual lending with uncertainty, a situation where each borrower is monitored separately. The second part highlights the benefits of peer monitoring by comparing individual lending from the first part to individual lending in groups with peer monitoring.

Individual lending

With information asymmetry, individual lending may still be feasible. To check this possibility, we assume only individual liability contracts are being offered. In such a situation, an MFI proposes a rate that reflects the share of each type of borrowers. This adjustment is implemented such that the interest rate is not determined by the risk profile of each individual borrower (her probability of success) but by weighted probabilities of both types, i.e. the probability of a randomly chosen borrower, $\phi p_l + (1-\phi)p_h$. Using that, the lender sets the interest rate to a level matching the risk profile of an average or random borrower.

Proposition 3. *Under imperfect information and individual lending, agents will be in equilibrium offered contracts* $(r, 0)$*, where*

$$r = \frac{\gamma + m}{\phi p_l + (1-\phi)p_h} - 1. \tag{4.13}$$

Proof. The logic is analogical to the proof of Proposition 1. Under imperfect information, the profit of an MFI changes to

$$\pi_i(r_i, L_i) = \phi[p_l(1+r_i)L_i] + (1-\phi)[p_h(1+r_i)L_i] - L_i - mL_i.$$

Hence the resulting condition of zero profit of an MFI is

$$\begin{aligned} \phi[p_l(1+r_i)L_i] + (1-\phi)[p_h(1+r_i)L_i] - L_i - mL_i &= L_i(\gamma - 1) \\ (1+r_i)[\phi p_l + (1-\phi)p_h] - m &= \gamma, \end{aligned}$$

which implies

$$r_i = \frac{\gamma + m}{\phi p_l + (1-\phi)p_h} - 1.$$

□

Note that r_i is the same irrespective of agent's type as the lender cannot distinguish agents! types. This fact implies that all agents will be offered the same interest rate r. Also, note that the following holds:

$$\frac{1}{r} = \phi\frac{1}{r_l} + (1-\phi)\frac{1}{r_h},$$

where r is an interest rate with information asymmetry and r_l and r_h are type-specific interest rates with complete information.

The derived level of interest rate does not mean there exists equilibrium in the lending market. As previously, we need to specify the conditions for equilibrium existence.

Proposition 4. *Under imperfect information and individual lending, there exists an equilibrium if and only if $m < \gamma$. In this equilibrium, all agents choose the same loan size irrespective of their type.*

Proof. The borrower chooses the size of the loan according to the following problem

$$\max_{L} \quad p_i[f(L) - (1 + r_i)L]$$

$$s.t.$$

$$r = \frac{\gamma + m}{\phi p_l + (1 - \phi)p_h} - 1,$$

$$L \geq 0,$$

$$p_i[f(L) - (1 + r_i)L] \geq 0$$

Given the properties of $f()$, there must be some $L > 0$ satisfying

$$p_i[f(L) - (1 + r_i)L] \geq 0.$$

Hence solving the problem gives us the equilibrium condition

$$f'(L) = \frac{\gamma - m}{\phi p_l + (1 - \phi)p_h}. \tag{4.14}$$

□

The above results are quite straightforward. Since the lender has no way of telling the borrower's type, he cannot exclude low type borrowers and must lend to all. By making no difference between types, he uses weighted probabilities in his optimization and all borrowers get the same rate. Since all borrowers have the same $f()$, they all choose the very same level of L_i. Interestingly, the equilibrium condition did not change, only the interest rate changed such that low-ability borrowers pay lower interest, whilst high-ability agents pay higher interest rate.

The results suggest that, for the existence of the market for loans, the presence of information asymmetry does not play any role. However, it does affect the interest rate the agents are charged.

Individual lending in groups with peer monitoring

In this subsection, we extend the concept from the previous one by grouping individual borrowers and assuming peer monitoring. The group size is set to n where $n \geq 2$. Further, we assume there are appropriate measures and incentives in place so that all borrowers are motivated to monitor each other and report observed states truthfully (details have been discussed before). This results in lower monitoring costs for an MFI, since it only monitors one of borrowers that is selected at random. The expected monitoring costs then total $M = \frac{m(n)\sum_{i=1}^{n} L_i}{n}$ per group.

Since the lender sets the interest rate individually, he must reflect the cost of overall monitoring of the group, M, while determining r_i. The share of this monitoring cost is assigned fairly to individual borrowers according to the proportion of their loan size to the sum of loans within the group. Every individual loan L_i is then expected to cover the expected costs of $M_i = \frac{m(n)L_i}{n}$ whose sums result in the desirable outcome of $M = \sum_{i=1}^{n} M_i$.

Proposition 5. *Under information asymmetry and individual lending with peer monitoring, agents will be in equilibrium offered contracts* $(r, 0)$*, where*

$$r = \frac{\gamma + \frac{m(n^*)}{n^*}}{\phi p_l + (1-\phi)p_h} - 1. \tag{4.15}$$

Proof. Again, the logic is analogical to the proof of Propositions 1 and 3. Under imperfect information with peer monitoring, the profit of an MFI changes to

$$\pi_i(r_i, L_i) = \phi[p_l(1+r_i)L_i] + (1-\phi)[p_h(1+r_i)L_i] - L_i - M_i.$$

Hence the resulting condition of zero profit of an MFI is

$$\begin{aligned} \phi[p_l(1+r_i)L_i] + (1-\phi)[p_h(1+r_i)L_i] - L_i - \frac{m(n)}{n}L_i &= L_i(\gamma - 1) \\ (1+r_i)[\phi p_l + (1-\phi)p_h] - \frac{m(n)}{n} &= \gamma, \end{aligned}$$

which implies

$$r_i = \frac{\gamma + \dfrac{m(n)}{n}}{\phi p_l + (1-\phi)p_h} - 1.$$

From (4.7),(4.9), and (4.10), there must exist $n^* > 1$ such that

$$n^* = \arg\min_n \left[\frac{m(n)}{n}\right], \tag{4.16}$$

that minimizes r_i as well. □

Apparently, as the monitoring cost is shared across the group, r is lower than in the case with individual monitoring. That improves the welfare of borrowers. As previously, we have the same r for all types of agents.

Proposition 6. *Under imperfect information and individual lending with peer monitoring, there exists an equilibrium if and only if* $\frac{m(n^*)}{n^*} < \gamma$. *In this equilibrium, all agents choose the same loan size irrespective of their type.*

Proof. The borrower chooses the size of the loan according to the following problem

$$\begin{aligned}
&\max_L \quad p_i[f(L) - (1+r_i)L] \\
&s.t. \\
&\quad r = \frac{\gamma + \dfrac{m(n^*)}{n^*}}{\phi p_l + (1-\phi)p_h} - 1, \\
&\quad L \geq 0, \\
&\quad p_i[f(L) - (1+r_i)L] \geq 0
\end{aligned}$$

Given the properties of $f()$, there must be some $L > 0$ satisfying

$$p_i[f(L) - (1+r_i)L] \geq 0.$$

Hence solving the problem gives us the equilibrium condition

$$f'(L) = \frac{\gamma - \dfrac{m(n^*)}{n^*}}{\phi p_l + (1-\phi)p_h}. \tag{4.17}$$

□

The previous result implies that the conditions for credit market equilibrium existence are less strict than in the case of individual monitoring. This increases the welfare of both the lender and the borrower. The lending market exists in more situations and the borrower is charged a lower interest rate. These improvements result from the decrease of monitoring expenses an MFI must cover. These results suggest that despite an MFI not being able to provide individual liability loans and monitor each borrower individually, it can still manage to provide them if the agents are able to monitor each other through the peer monitoring approach.

4.3.3 Information asymmetry, joint liability, and peer monitoring

Under joint liability contracts, we investigate analogically to Van Tassel (1999) whether positive assortative matching holds and what contracts are borrowers offered in equilibrium. By positive assortative matching, we understand the conditions when borrowers of each type are only willing to group with counterparts of the same type. The purpose of the following theoretical derivations is to build a model with simultaneous financing that we can compare to our sequential financing model from Section 4.4. In our analysis of simultaneous financing, we extend the original model by introducing the monitoring costs and within-group loan size heterogeneity.

Let us start from a state where everybody gets an individual liability contract $(\bar{r}, 0)$ which is specified in the previous section. Suppose the agents have the possibility to trade a bit of joint liability (increase in σ) in exchange for lower interest rate r. This relation is expressed by a continuous function $r(\sigma)$ satisfying the following conditions:

$$\frac{\partial r(\sigma)}{\partial \sigma}\Big|_{\sigma=0} < 0, \quad (4.18)$$

$$\frac{\partial^2 r(\sigma)}{\partial \sigma^2} > 0, \quad (4.19)$$

$$r(0) = \bar{r}. \quad (4.20)$$

Then, in a situation with no joint liability ($\sigma = 0$) we have

$$\frac{\partial V^{i,j}}{\partial \sigma}\Big|_{\sigma=0} = p_i p_j[-\frac{\partial r(\sigma)}{\partial \sigma}\Big|_{\sigma=0} L] + p_i(1-p_j)[-\frac{\partial r(\sigma)}{\partial \sigma}\Big|_{\sigma=0} L - \bar{L}]. \quad (4.21)$$

The above partial derivative expresses the marginal change of borrower's income with a marginal change in joint liability parameter at the point of $\sigma = 0$. If this expression were positive, the borrower would be better off by increasing the joint liability slightly and is willing to accept such a change. If it were negative, the borrower would not be willing to accept joint liability and would stick to the original individual liability loan. Suppose the function for change in the interest rate, $r(\sigma)$, has the specific form of

$$r(\sigma) = \bar{r} - \epsilon\sigma. \quad (4.22)$$

We proceed by testing whether there exists such a way of decreasing r through $r(\sigma)$ such that only high-ability borrowers would be willing to accept the resulting contract and group with each other (positive assortative matching property) whilst low-ability agents stick to the original contract.

Let us analyze whether there exists $\epsilon > 0$ such that the positive assortative matching is induced. For that, in accordance with our previous discussion, we need the following properties to hold:

$$\left.\frac{\partial V^{h,h}}{\partial \sigma}\right|_{\sigma=0} > 0 \tag{4.23}$$

$$\left.\frac{\partial V^{l,l}}{\partial \sigma}\right|_{\sigma=0} < 0 \tag{4.24}$$

$$\left.\frac{\partial V^{l,h}}{\partial \sigma}\right|_{\sigma=0} > 0 \tag{4.25}$$

$$\left.\frac{\partial V^{h,l}}{\partial \sigma}\right|_{\sigma=0} < 0. \tag{4.26}$$

Van Tassel (1999) provides this analysis for the case when $L = \bar{L}$, i.e. both potential borrowers choose the same size of their loan. This is a valid assumption to be made, since it is implied by the fact that both borrowers have the same production function $f()$. However, in practice, the production functions may differ slightly and it may be beneficial for an MFI to allow groups with heterogeneous loan sizes. We choose to investigate this possibility and relax the original assumption, analyze the possibility of within-group loan size heterogeneity, and specify the ratio by a parameter s such that $L = s\bar{L}$. For that, we need to assume there are two production functions $f_1()$ and $f_2()$ specific to h-type borrowers (predetermined randomly an they cannot be changed) satisfying all of the our preceding assumptions including the modification of (4.3) and (4.4): i.e. for contracts $(r_{1a}, 0, L_{1a})$, $(r_{1b}, 0, L_{1b})$, and $(r_2, 0, L_2)$

$$p_h[f_1(L_{1a}) - (1 + r_{1a})L_{1a}] \geq p_h[f_1(L_2) - (1 + r_2)L_2] \tag{4.27}$$

$$p_h[f_1(L_{1b}) - (1 + r_{1b})L_{1b}] \geq p_h[f_1(L_2) - (1 + r_2)L_2] \tag{4.28}$$

$$p_h[f_2(L_{1a}) - (1 + r_{1a})L_{1a}] \geq p_h[f_2(L_2) - (1 + r_2)L_2] \tag{4.29}$$

$$p_h[f_2(L_{1b}) - (1 + r_{1b})L_{1b}] \geq p_h[f_2(L_2) - (1 + r_2)L_2] \tag{4.30}$$

$$p_h[f_1(L_{1a}) - (1 + r_{1a})L_{1a}] \geq p_h[f_1(L_{1b}) - (1 + r_{1b})L_{1b}] \tag{4.31}$$

$$p_h[f_2(L_{1b}) - (1 + r_{1b})L_{1b}] \geq p_h[f_1(L_{1a}) - (1 + r_{1a})L_{1a}] \tag{4.32}$$

$$p_l[f(L_2) - (1 + r_2)L_2] \geq p_l[f(L_{1a}) - (1 + r_{1a})L_{1a}] \tag{4.33}$$

$$p_l[f(L_2) - (1 + r_2)L_2] \geq p_l[f(L_{1b}) - (1 + r_{1b})L_{1b}]. \tag{4.34}$$

Under these conditions, it is possible that two high-ability borrowers would have a different optimal level of loan size and we can proceed with our analysis of loan size heterogeneity and assortative matching. Therefore,

$$\left.\frac{\partial V^{i,j}}{\partial \sigma}\right|_{\sigma=0} = p_i p_j[\epsilon s\bar{L}] + p_i(1-p_j)[\epsilon s\bar{L} - \bar{L}]. \tag{4.35}$$

Using (4.35) in (4.23) and (4.25) gives us the first condition for ϵ, whereas (4.24) and (4.25) provide the second one:

$$\epsilon > \frac{1-p_h}{s} \tag{4.36}$$

$$\epsilon < \frac{1-p_l}{s}. \tag{4.37}$$

The result above proves that for $s = 1$ there always exists such ϵ ensuring positive assortative matching. For $s \neq 1$, we also need the following two conditions to hold as the above conditions apply to both potential members of the group (symmetry):

$$\epsilon > (1-p_h)s \tag{4.38}$$

$$\epsilon < (1-p_l)s. \tag{4.39}$$

As s deviates from one, the intervals for ϵ, $\left[\frac{1-p_h}{s}; \frac{1-p_l}{s}\right]$ and $[(1-p_h)s; (1-p_l)s]$, also deviate until they do not overlap at all. The cap on s can be derived based on the narrowing of the bounds of the interval of the intersection:

$$[s(1-p_h); \frac{1-p_l}{s}].$$

which implies

$$\sqrt{\frac{1-p_h}{1-p_l}} < s < \sqrt{\frac{1-p_l}{1-p_h}}. \tag{4.40}$$

The drift of intervals (conditions) on ϵ and their intersection is illustrated in the following interval plots:

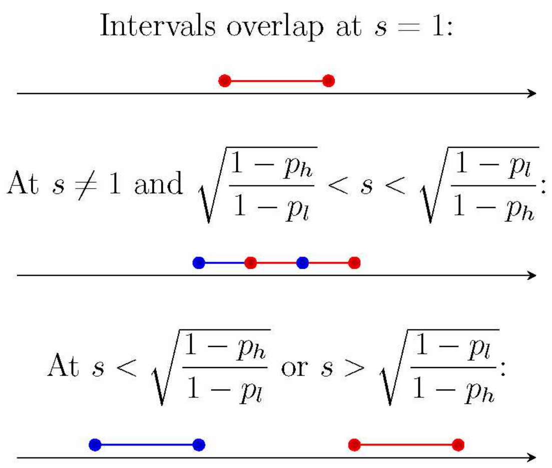

Figure 4.1: The intersection condition for ϵ.

By using the $r(\sigma)$ adjustment and specifying allowed s, the lender offers a contract that is only acceptable for high-ability borrowers. Type l borrowers are excluded from group lending (and MFIs can possibly lend them individually). Hence positive assortative matching is possible. Apparently, monitoring costs have no influence during the group formation stage. However, monitoring costs affect the equilibrium existence by moving the break-even interest rate of the lender upwards. From here on, we return to the original concept of a single production function for all borrowers.

In this setting, the lender makes a per one dollar profit of:

$$p_h^2(1+r) + p_h(1-p_h)(1+r+\sigma) - \gamma - \frac{m(n^*)}{n^*}. \tag{4.41}$$

In case of individual lending ($\sigma = 0$), the profit decreases to

$$p_h(1+\bar{r}) - \gamma - \frac{m(n^*)}{n^*}. \tag{4.42}$$

Since the lender can obtain a higher profit by increasing σ arbitrarily close to zero, group lending is a dominant strategy of the lender and there is no incentive to deviate and offer individual liability contract.

We have shown that there indeed exists a possible way of pooling borrowers according to their types by decreasing the interest rate and increasing joint liability at a specific rate. This is a result of the risk aversion of borrowers (through expected income), since high-ability borrowers are not willing to pair with riskier l-type as they minimize the costs resulting from the joint liability within the group. Consequently, homogeneous groups are formed. The lender can achieve this by using the fact that each of the types is willing to accept a different rate of substitution of an increase in joint liability for a decrease in the interest rate.

Equilibrium existence

Identifying the equilibrium is the main result of the original model of Van Tassel (1999). We show the equilibrium existence and the convergence using slightly different assumptions (adjusted to reflect monitoring costs) than in the original paper. However, the results are identical to the original paper.

We state the following assumptions:

(i) For all (r, σ) such that $V^{l,l}(r, \sigma; \bar{L}) = V^{l}(r_l)$ the following must hold

$$f(L(r)) - (1 + r)L(r) - \sigma\bar{L}(r) > 0$$

(ii) For σ such that $V^{l}(r_l) = V^{l,l}(0, \sigma; \bar{L})$ it must be that

$$p_h + p_h(1 - p_h)\sigma - \gamma - \tfrac{m(n^*)}{n^*} < 0$$

Assumption (i) is identical to (A1) of Van Tassel (1999). It states that the preferences of type l borrower towards group liability are monotonous in σ and ensures a proper behavior of preferences. The second assumption (ii) is slightly altered in comparison to the original paper due to peer monitoring costs. It guarantees that there is no possibility for lenders to offer negative interest rates. The result of positive assortative matching and competitive market are summarized in the following proposition. Besides its assumptions, this proposition and its proof is identical to Proposition 4.1 of Van Tassel (1999).

Proposition 7. *Suppose the assumptions above hold. In equilibrium high-ability borrowers are provided loans via group lending and low-ability borrowers are provided individual loans or excluded from lending entirely.*

Proof. See the proof of Proposition 4.1 in Van Tassel (1999). The slight modification of assumption (A2) from Van Tassel (1999), resulting in our assumption (ii) guarantees non-negativity of interest rates to our setup. Since this does not affect the logic and techniques of the original proof, this proof applies to our setup as well. □

For the existence of equilibrium, we introduce another assumption:

(iii) For all (r, σ) such that $\sigma < \hat{\sigma}$, $V^{h,h}(r, \sigma, \bar{L}) = V^{h,h}(\hat{r}, \hat{\sigma}, \bar{L})$, and $V^{l}(r_0) = V^{l,l}(r, \sigma, \bar{L})$ we have:

$$\phi[p_l(1+r_0)] + (1-\phi)[p_h(1+r) + p_h(1-p_h)\sigma] < \gamma + \tfrac{m(n^*)}{n^*}$$

Again, this assumption is a modified assumption (A3) from Van Tassel (1999). We alter it by adding peer monitoring costs to the inequality. This assumption restricts our analysis to the case when there is significant percentage of low-ability agents such that their inclusion in the lending process harms the lender. In other words, it is necessary for the lender to exclude low-ability borrowers from group lending in order to sustain in business (earning non-negative profit). Being this the particular scenario our study aims to analyze, there is no relevant loss by stating the above.

The following proposition proves the equilibrium existence in our model.

Proposition 8. *Suppose the assumptions (i)-(iii) hold. Then there exists an equilibrium.*

Proof. See the proof of Proposition 4.2 in Van Tassel (1999). Since we added peer monitoring costs to the original model, the definition of C_1 in the original proof must be altered as well to

$$C_1 \equiv \{(r,\sigma) \in C \mid p_h(1+r) + p_h(1-p_h)\sigma - \gamma - \frac{m(n^*)}{n^*} > 0,$$
$$\sigma < \hat{\sigma} \wedge V^{h,h}(r,\sigma;\bar{L}) \geq V^{h,h}(\hat{r},\sigma;\hat{L})\}. \quad (4.43)$$

After this adjustment, the original proof applies to our model. □

The above propositions show that there exists an equilibrium in the simultaneous group lending market and our previous findings are valid. Although it might seem that this equilibrium exists is general, we must bear in mind that it is limited by the assumptions (i)-(iii) we made. We will use the derived properties of this model in Chapter 5 for comparison with other group lending models.

4.4 Sequential financing

Sequential financing is a particular form of microcredit lending that has emerged throughout the last twenty years. It is based on a principle that has evolved from the traditional simultaneous financing scheme over the years. Under sequential financing, group size is usually limited to pairs. After the group is formed, the loan is provided to the first borrower and the other borrower's loan is provided conditionally on the repayment of the first loan. In other words, the second loan is not provided unless the first one was repaid.

As the first borrower receives the loan in any circumstance, being first may seem as a more favorable position of the two. However, this is not the case. The second borrower is provided the loan after the repayment of the first loan. Therefore, she cannot bear any costs resulting from the joint liability. The only way joint liability costs arise is the situation in which the first loan has been repaid, whilst the second has been provided and is not repaid. Then, the first borrower must cover the costs resulting from her partner's default.

Similarly to the previous model, the purpose of the above procedure is to screen the applicants with no credit history and identify groups of low-quality borrowers before the loan is provided to the entire group and more loans are at risk. This procedure decreases the losses of an MFI. Though it might occur that high-quality borrowers do not obtain the loan because their high-quality partner was simply unlucky, the procedure is still beneficial for the lender in general.

We analyze this lending procedure in a model similar to the previous one. For the purpose of comparability, the game environment, its stages, and agents remain unchanged. We compare both models in Section 5.2 in order to determine which is more appropriate for lending with asymmetric information.

The approach we follow to construct the model is similar to the simultaneous model. Nevertheless, we alter the expected income of the borrower in order to reflect the sequential financing scheme. We assume the order of borrowers is set by the lender at random. As a result of that, the probability of being given the first (or second) position is always equal to one half.

In case of sequential financing, the expected income of borrower of type i paired with type j is given by

$$\begin{aligned} V^{i,j}(r,\sigma,\bar{L}) &= \max_{L}\{0.5p_i[f(L)-(1+r)L-(1-p_j)\sigma\bar{L}] \\ &\quad +0.5p_ip_j[f(L)-(1+r)L]\}. \end{aligned} \tag{4.44}$$

Now, let us start the analysis by using the same approach as previously. Suppose we have the state where every borrower gets an individual liability ($\sigma = 0$) loan with $\bar{r}$. As previously, we assume the condition (4.5) to hold. The lender is, again, willing to decrease the interest rate in exchange for increasing the joint liability.

This approach is given by a continuous function $r(\sigma)$ satisfying

$$\left.\frac{\partial r(\sigma)}{\partial \sigma}\right|_{\sigma=0} < 0, \tag{4.45}$$
$$\frac{\partial^2 r(\sigma)}{\partial \sigma^2} > 0, \tag{4.46}$$
$$r(0) = \bar{r}. \tag{4.47}$$

At $\sigma = 0$ we have:

$$\left.\frac{\partial V^{i,j}}{\partial \sigma}\right|_{\sigma=0} = 0.5p_i \left[-\left.\frac{\partial r(\sigma)}{\partial \sigma}\right|_{\sigma=0} L + p_j \bar{L}\right] + 0.5p_i p_j \left[-\left.\frac{\partial r(\sigma)}{\partial \sigma}\right|_{\sigma=0} L\right]. \tag{4.48}$$

As in the previous model, we specify our $r(\sigma)$ as

$$r(\sigma) = \bar{r} - \epsilon\sigma \tag{4.49}$$

and analyze whether there exists $\epsilon > 0$ such that there is positive assortative matching. For that, we need the following properties to hold

$$\left.\frac{\partial V^{h,h}}{\partial \sigma}\right|_{\sigma=0} > 0 \tag{4.50}$$
$$\left.\frac{\partial V^{l,l}}{\partial \sigma}\right|_{\sigma=0} < 0 \tag{4.51}$$
$$\left.\frac{\partial V^{l,h}}{\partial \sigma}\right|_{\sigma=0} > 0 \tag{4.52}$$
$$\left.\frac{\partial V^{h,l}}{\partial \sigma}\right|_{\sigma=0} < 0. \tag{4.53}$$

By using $r(\sigma)$ function in (4.48), we get:

$$\left.\frac{\partial V^{i,j}}{\partial \sigma}\right|_{\sigma=0} = 0.5p_i \left[\epsilon L - (1 - p_j)\bar{L}\right] + 0.5p_i p_j \left[\epsilon L\right]. \tag{4.54}$$

As in the previous model, we relax the assumption of a universal production function temporarily in order to analyze the possibility of within-group heterogeneity of loan sizes. For that, we need to restate the assumptions on the production function, since we introduce heterogenous production functions specific to agent's types. As previously, we have randomly production functions $f_1()$ and $f_2()$ for high-ability agents (assigned ex-ante) and $f()$ for low ability agents such that it holds for contracts $(r_{1a}, 0, L_{1a})$, $(r_{1b}, 0, L_{1b})$, and $(r_2, 0, L_2)$ that

$$
\begin{aligned}
p_h[f_1(L_{1a}) - (1 + r_{1a})L_{1a}] &\geq p_h[f_1(L_2) - (1 + r_2)L_2] && (4.55)\\
p_h[f_1(L_{1b}) - (1 + r_{1b})L_{1b}] &\geq p_h[f_1(L_2) - (1 + r_2)L_2] && (4.56)\\
p_h[f_2(L_{1a}) - (1 + r_{1a})L_{1a}] &\geq p_h[f_2(L_2) - (1 + r_2)L_2] && (4.57)\\
p_h[f_2(L_{1b}) - (1 + r_{1b})L_{1b}] &\geq p_h[f_2(L_2) - (1 + r_2)L_2] && (4.58)\\
p_h[f_1(L_{1a}) - (1 + r_{1a})L_{1a}] &\geq p_h[f_1(L_{1b}) - (1 + r_{1b})L_{1b}] && (4.59)\\
p_h[f_2(L_{1b}) - (1 + r_{1b})L_{1b}] &\geq p_h[f_1(L_{1a}) - (1 + r_{1a})L_{1a}] && (4.60)\\
p_l[f(L_2) - (1 + r_2)L_2] &\geq p_l[f(L_{1a}) - (1 + r_{1a})L_{1a}] && (4.61)\\
p_l[f(L_2) - (1 + r_2)L_2] &\geq p_l[f(L_{1b}) - (1 + r_{1b})L_{1b}]. && (4.62)
\end{aligned}
$$

Then, we can analyze the heterogeneity in loan sizes, since the optimal levels of loan sizes maximizing the borrower's income may vary in a homogeneous group of two high-ability agents. The parametrization of relative loan size within the group using $L = s\bar{L}$ produces:

$$
\left.\frac{\partial V^{i,j}}{\partial \sigma}\right|_{\sigma=0} = 0.5p_i\left[\epsilon s\bar{L} - (1 - p_j)\bar{L}\right] + 0.5p_ip_j\left[\epsilon s\bar{L}\right]. \quad (4.63)
$$

Conditions (4.50)-(4.53) reduce to:

$$
\begin{aligned}
\epsilon &> \frac{1 - p_h}{(1 + p_h)s} && (4.64)\\
\epsilon &< \frac{1 - p_l}{(1 + p_l)s}. && (4.65)
\end{aligned}
$$

For $s = 1$, there always exists ϵ such that the conditions hold. For $s \neq 1$, we must ensure the following two conditions also hold due to the symmetry of group formation ($L = s\bar{L}$ vs. $sL = \bar{L}$):

$$\epsilon > \frac{(1-p_h)s}{1+p_h} \quad (4.66)$$

$$\epsilon < \frac{(1-p_l)s}{1+p_l}. \quad (4.67)$$

If s deviates from one, the intervals $[\frac{1-p_h}{(1+p_h)s}; \frac{1-p_l}{(1+p_l)s}]$ and $[\frac{(1-p_h)s}{1+p_h}; \frac{(1-p_l)s}{1+p_l}]$ also deviate until their intersection becomes an empty set. We can analyze the conditions on s based on the narrowing of the bounds of

$$\left[\frac{(1-p_h)s}{1+p_h}; \frac{1-p_l}{(1+p_l)s}\right]. \quad (4.68)$$

This gives us the solution of

$$\sqrt{\frac{(1+p_l)(1-p_h)}{(1-p_l)(1+p_h)}} < s < \sqrt{\frac{(1-p_l)(1+p_h)}{(1+p_l)(1-p_h)}}. \quad (4.69)$$

This result shows that for s satisfying the equation above, there always exists an ϵ such that the lender can reduce the interest rate in exchange for joint liability in a way that prevents low-ability agents to accept this offer. Therefore, positive assortative matching holds for such ϵ and high-ability agents are willing to match only with high-ability agents.

If the lender is able to achieve this pooling that provides joint liability loans only to high-ability borrowers, he gets the per dollar expected profit of

$$0.5[p_h^2(1+r) + p_h(1-p_h)(1+r+\sigma)] + 0.5[p_h^2(1+r) + (1-p_h)] - \gamma - \frac{m(n^*)}{n^*}. \quad (4.70)$$

The profit formula is based on the allocation of the dollar either to the first or the second group member. If the dollar is allocated (probability of one half) to the first in the pair and both borrowers repay their loans (p_h^2), the lender receives $(1+r)$ dollars. In case only the first member repays ($p_h(1-p_h)$), the lender gets $(1+r+\sigma)$.

If none repays, the profit equals zero.

Now, suppose the dollar is allocated to the second member (probability of one half). There are three possible outcomes. If the first loan defaulted $(1 - p_h)$, the second loan is not provided, i.e. the payoff for the lender is one dollar (the original investment). In case the first loan gets repaid, lender's profit is either $(1+r)$ (second loan repaid) or zero (second loan defaults). One might argue that in the latter case the profit is $(1 + r + \sigma)$ from the first member. However, this profit is a return on an investment on another dollar, not the one allocated to the second member.

At the point where $\sigma = 0$, the expected profit of group lending to high-ability borrowers is

$$p_h^2(1 + r) + 0.5p_h(1 - p_h)(1 + r) + 0.5(1 - p_h) - \gamma - \frac{m(n^*)}{n^*}. \tag{4.71}$$

It holds that this expected payoff is higher than the return on one dollar with individual lending $p_h(1 + \bar{r}) - \gamma - \frac{m(n^*)}{n^*}$ as long as

$$r > \frac{1}{p_h} - 1. \tag{4.72}$$

Hence if the condition is satisfied, the lenders are motivated to initiate group lending by allowing an arbitrarily small increase in joint liability while sustaining arbitrarily close the the initial level of the interest rate $(r = \bar{r})$. Since the initially offered interest rate, r, is an equilibrium interest rate for individual lending with information asymmetry, from Proposition 5 it equals

$$r = \frac{\gamma + m}{\phi p_l + (1 - \phi)p_h} - 1. \tag{4.73}$$

Using this, we can rewrite the condition from (4.72) as

$$\frac{\gamma + m}{\phi p_l + (1 - \phi)p_h} - 1 > \frac{1}{p_h} - 1. \tag{4.74}$$

By the definition of γ, it holds that $\gamma > 1$. Moreover, $\phi p_l + (1-\phi)p_h < p_h$ and $m > 0$. Then, the above inequality holds in any circumstances and the lender would be willing to switch to sequential group lending.

Equilibrium existence

Before we proceed to state further propositions, we need to state assumptions analogical to assumptions (i) and (ii) from the model with simultaneous financing:

(I) For all (r, σ) such that $V^{l,l}(r, \sigma; \bar{L}) = V^l(r_l)$, the following must hold

$$f(L(r)) - (1+r)L(r) - \sigma \bar{L}(r) > 0.$$

(II) For σ such that $V^l(r_l) = V^{l,l}(0, \sigma; \bar{L})$, it must be that

$$\frac{p_h(\sigma + p_h - \sigma p_h) + 1}{2} - \gamma - \frac{m(n^*)}{n^*} < 0.$$

The first assumption remains the same as (i), the second is adjusted to the new expected profit of the lender and guarantees that there are no negative interest rates. Based on these assumptions, we can state the proposition specifying the equilibrium conditions for the sequential model.

Proposition 9. *Suppose the assumptions (I) and (II) hold. In all equilibria, low-ability borrowers will get an individual contract* $(r_l, 0)$*, high-ability agents will receive a joint liability contract* $(\hat{r}_h, \hat{\sigma}_h)$*. The lenders expected profit is zero and* $V^{l,l}(\hat{r}, \hat{\sigma}, \bar{L}) = V^l(r_l)$*.*

Proof. In order to prove the proposition, let us cover all the possible states that might occur. From our previous analysis, we know that positive assortative matching holds and the agents form homogeneous groups. Say $\tilde{\sigma}_h = \hat{\sigma}$, i.e. h type lenders are at the equilibrium level of joint liability. Suppose low-ability agents are assigned a contract of $(\tilde{r}_l, \tilde{\sigma}_l)$ while the lender generates profit.

Suppose, $\tilde{\sigma}_l = 0$. Hence there is no joint liability. Then, the other lender can seize all low-ability borrowers by offering an interest rate decreased by a number arbitrarily close to zero, i.e. $(\tilde{r}_l - \epsilon, 0)$ where $\epsilon > 0$. This way the lender can receive a profit arbitrarily close to the original one. Thus, decreasing the interest rate to the point where the lender breaks even is the dominant strategy of the lender.

If we have $\tilde{\sigma}_l \neq 0$, the situation is quite different as the lenders can adjust the shared liability as well. Suppose low-ability borrower's profit is non-negative at $(\tilde{r}_l, \tilde{\sigma}_l)$, i.e. $f(L) - (1 + \tilde{r}_l)L - \tilde{\sigma}_l \bar{L} \geq 0$. At the point $(\tilde{r}_l, \tilde{\sigma}_l)$, it holds for the marginal rates of substitution that:

$$\left|\frac{-(1-p_l)L}{(1+p_l)L + (1-p_l)\tilde{\sigma}_l L'}\right| > \left|\frac{-(1-p_h)L}{(1+p_h)L + (1-p_h)\tilde{\sigma}_l L'}\right|. \tag{4.75}$$

A low-ability agent is willing to exchange σ for r at a higher rate than h type agent at $(\tilde{r}_l, \tilde{\sigma}_l)$. The lender can use this property and offer contract $(\tilde{r}_h, \tilde{\sigma}_h)$ together with another joint liability contract such that he starts with $(\tilde{r}_l, \tilde{\sigma}_l)$ arrives at the contract by an arbitrarily small decrease of the interest rate and increase of the joint liability according to the following rule:

$$\frac{-(1-p_l)L}{(1+p_l)L + (1-p_l)\tilde{\sigma}_h L'} < r'(\sigma) < \frac{-(1-p_h)L}{(1+p_h)L + (1-p_h)\tilde{\sigma}_h L'}. \tag{4.76}$$

Low-ability borrowers now choose the new contract rather than $(\tilde{r}_h, \tilde{\sigma}_h)$, whilst high-ability agents are not motivated to switch from $(\tilde{r}_h, \tilde{\sigma}_h)$. The change in the contract is arbitrarily small, keeping the profit arbitrarily close to the original one. Therefore, the lender will deviate this way.

Suppose $f(L) - (1 + \tilde{r}_l)L - \tilde{\sigma}_l \bar{L} < 0$, i.e. $(\tilde{r}_l, \tilde{\sigma}_l)$ is not profitable for l type agents and they might be willing to decrease the level of joint liability. Then it must be that $(\tilde{r}_l, \tilde{\sigma}_l) = (\tilde{r}_h, \tilde{\sigma}_h)$. The lender can attract all borrowers by setting $(\tilde{r}_l, \tilde{\sigma}_l - \epsilon)$ with arbitrarily small $\epsilon > 0$. Again, the lender will deviate this way.

Now, let us focus on the type h agent. Suppose, the lender makes positive profit on loans to high-ability agents with contract $(\tilde{r}_h, \tilde{\sigma}_h)$. Say the h type borrower is also having positive profit, i.e. $f(L) - (1 + \tilde{r}_h)L - \tilde{\sigma}_h \bar{L} > 0$. In this situation, since the marginal rates of substitution differ, the lender can offer $(\tilde{r}_l, \tilde{\sigma}_l)$ and adjusted $(\tilde{r}_h, \tilde{\sigma}_h)$ such that the interest rate decreases according to

$$\frac{-(1-p_l)L}{(1+p_l)L + (1-p_l)\tilde{\sigma}_h L'} < r'(\sigma) < \frac{-(1-p_h)L}{(1+p_h)L + (1-p_h)\tilde{\sigma}_h L'}. \tag{4.77}$$

This way, the new contract attracts all type h agents and none of type l. The lender will thus again deviate this way.

Suppose $f(L) - (1 + \tilde{r}_h)L - \tilde{\sigma}_h \bar{L} \leq 0$. Then it must be $\tilde{\sigma}_h > 0$, otherwise, the borrower would have to incur profits. Say the lender offers contracts $(\tilde{r'}_h, \tilde{\sigma'}_h)$ and $(\tilde{r'}_l, \tilde{\sigma'}_l)$ such that $\tilde{\sigma'}_h < \tilde{\sigma}_h$, $\tilde{\sigma'}_l < \tilde{\sigma}_l$, $V^{h,h}(\tilde{r'}_h, \tilde{\sigma'}_h, \bar{L}) = V^{h,h}(\tilde{r}_h, \tilde{\sigma}_h, \bar{L})$ and $V^{l,l}(\tilde{r'}_l, \tilde{\sigma'}_l, \bar{L}) = V^{l,l}(\tilde{r}_l, \tilde{\sigma}_l, \bar{L})$ while profiting no less than with the original contracts. The lender is motivated to deviate and will practice this until he reaches the break even point (zero profit).

Say $\tilde{\sigma}_l > 0$ and $f(L) - (1 + \tilde{r}_l)L - \tilde{\sigma}_l \bar{L} \geq 0$ at $(\tilde{r}_l, \tilde{\sigma}_l)$. As the marginal rate of substitution of l type agent is greater than that of h type agent as well as $(1 - p_l)$, the lender will deviate and raise the interest rate in this way:

$$\max\left[\frac{(1-p_l)}{(1+p_l)}, \frac{(1-p_h)L}{(1+p_h)L + (1-p_h)\tilde{\sigma}_l L'}\right] < r'(\sigma) < \frac{(1-p_l)L}{(1+p_l)L + (1-p_l)\tilde{\sigma}_l L'}.$$

While high-ability borrowers stick to $(\tilde{r}_h, \tilde{\sigma}_h)$, low-ability agents select the new contract.

Suppose $\tilde{\sigma}_l > 0$ and $f(L) - (1 + \tilde{r}_l)L - \tilde{\sigma}_l \bar{L} < 0$. The lender deviates by offering $(\tilde{r'}_l, \tilde{\sigma'}_l)$ such that $V^{l,l}(\tilde{r'}_l, \tilde{\sigma'}_l, \bar{L}) = V^{l,l}(\tilde{r}_h, \tilde{\sigma}_h, \bar{L})$ and $f(L) - (1 + \tilde{r}_l)L - \tilde{\sigma}_l \bar{L} = 0$. The lender decreases the joint liability and increases the interest rate such that

$$\max\left[\frac{(1-p_l)}{(1+p_l)}, \frac{(1-p_h)L}{(1+p_h)L + (1-p_h)\tilde{\sigma}_l L'}\right] < r'(\sigma) < \frac{(1-p_l)L}{(1+p_l)L + (1-p_l)\tilde{\sigma}_l L'}.$$

This generates the lender a profit and leads to $(\tilde{r}_l, \tilde{\sigma}_l) = (r_l, 0)$.

Say $\tilde{\sigma}_h < \hat{\sigma}_h$. Then it must be that $V^{l,l}(\tilde{r}_h, \tilde{\sigma}_h, \bar{L}) > V^l(\tilde{r}_l)$ which is a contradiction to previous results. Let $\tilde{\sigma}_h > \hat{\sigma}_h$. Suppose $f(L) - (1 + \tilde{r}_h)L - \tilde{\sigma}_h\bar{L} \geq 0$. The lender can deviate and reduce joint liability while raising interest rate with positive profit in the following way:

$$\frac{(1-p_h)}{(1+p_h)} < r'(\sigma) < \frac{(1-p_h)L}{(1+p_h)L + (1-p_h)\tilde{\sigma}_h L'}. \tag{4.78}$$

This causes type h agents to switch to the new contract while l type agents remain with the old one. Suppose $f(L) - (1 + \tilde{r}_h)L - \tilde{\sigma}_h\bar{L} < 0$. The lender can deviate by offering $(\tilde{r'}_h, \tilde{\sigma'}_h)$ such that $V^{h,h}(\tilde{r'}_h, \tilde{\sigma'}_h, \bar{L}) = V^{h,h}(\tilde{r}_h, \tilde{\sigma}_h, \bar{L})$ and $f(L) - (1 + \tilde{r}_h)L - \tilde{\sigma}_h\bar{L} = 0$. Earning a profit, the lender will decrease joint liability and raise the interest rate such that the following holds

$$\frac{(1-p_h)}{(1+p_h)} < r'(\sigma) < \frac{(1-p_h)L}{(1+p_h)L + (1-p_h)\tilde{\sigma}_h L'}. \tag{4.79}$$

That attracts all high-ability borrowers and no low-ability agents. That implies $(\tilde{r}_h, \tilde{\sigma}_h) = (\hat{r}_h, \hat{\sigma}_h)$. □

For the proof of existence, we need to state another assumption, just like we did in the previous model.

(III) For all (r, σ) such that $\sigma < \hat{\sigma}$, $V^{h,h}(r, \sigma, \bar{L}) = V^{h,h}(\hat{r}, \hat{\sigma}, \bar{L})$, and $V^l(r_0) = V^{l,l}(r, \sigma, \bar{L})$ we have:

$$\phi[p_l(1 + r_0)] + (1 - \phi)\{p_h^2(1 + r) + 0.5(1 - p_h)[p_h(1 + r + \sigma) + 1]\} < \gamma + \tfrac{m(n^*)}{n^*}.$$

In other words, individual lending to l type borrowers harms the lender such that he cannot sustain profitability.

Proposition 10. *Suppose the assumptions (I)-(III) hold. Then, there exists an equilibrium.*

Proof. See the proof of Proposition 4.2 in Van Tassel (1999). Since we changed the model to sequential financing, the per unit profit of an MFI differs from the original paper. The definition of C_1 in the original proof must be altered to

$$\begin{aligned} C_1 \equiv & \{(r,\sigma) \in C \mid p_h^2(1+r) + 0.5p_h(1-p_h)(1+r) + 0.5(1-p_h) - \gamma - \frac{m(n^*)}{n^*} > 0, \\ & \sigma < \hat{\sigma} \wedge V^{h,h}(r,\sigma;\bar{L}) \geq V^{h,h}(\hat{r},\sigma;\hat{L})\}. \end{aligned} \tag{4.80}$$

After this adjustment, the original proof applies to our model. □

5. Comparative analysis

In the following section, we present a short comparison of group lending with joint liability to individual lending in groups that serves as a remark to De Quidt et al. (2016). In the subsequent part, we compare the simultaneous and sequential financing models in several aspects and identify the advantages and disadvantages of each model.

5.1 Group lending vs. individual lending in groups

In the light of recent literature (De Quidt et al. (2016), Giné and Karlan (2014)) favouring the individual lending in groups to joint liability group lending, we present the comparison of these approaches in an environment with information asymmetry. By that, we aim to illustrate the principal benefits of group lending, since the paper of De Quidt et al. (2016) disregards the aspect of information asymmetry completely.

Suppose the condition $\dfrac{m(n^*)}{n^*} < \gamma$ from Proposition 6 holds. From Proposition 5, we had for the case of individual lending:

$$r_{IL} = \frac{\gamma + \frac{m(n^*)}{n^*}}{\phi p_l + (1-\phi)p_h} - 1. \tag{5.1}$$

Whereas for simultaneous group lending with joint liability, we have from the break-even condition (4.41):

$$r_{JL} = \frac{\gamma + \frac{m(n^*)}{n^*}}{p_h} - (1-p_h)\sigma - 1. \tag{5.2}$$

Apparently, it holds that

$$r_{JL} < r_{IL}. \tag{5.3}$$

The lender in group lending can afford to offer lower interest rate, since he knows there are only low-risk borrowers in the group thanks to positive assortative matching. As can be seen from (5.2), this group lending interest rate can decrease even further as the joint liability increases. When it comes to profits, the profit on one dollar invested in individual lending equals

$$\phi p_l(1 + r_{IL}) + (1 - \phi)p_h(1 + r_{IL}) - \gamma - \frac{m(n^*)}{n^*}.$$

That can be reformulated as

$$(1 + r_{IL})(\phi p_l + (1 - \phi)p_h) - \gamma - \frac{m(n^*)}{n^*}. \tag{5.4}$$

For simultaneous group lending, we have the per dollar profit to equal

$$p_h^2(1 + r_{JL}) + p_h(1 - p_h)(1 + r_{JL} + \sigma) - \gamma - \frac{m(n^*)}{n^*}.$$

This can be rewritten as

$$p_h(1 + r_{JL}) + p_h(1 - p_h)\sigma - \gamma - \frac{m(n^*)}{n^*}. \tag{5.5}$$

Equations (5.4) and (5.5) imply that in a situation when the lender offers an individual loan at the rate of r_{IL}, he can switch to group lending with $r_{JL} = r_{IL}$ while reaching higher profit. He can certainly do that, since we know that $r_{JL} = r_{IL}$ is available in group lending based on the fact that group lending break-even level of interest rate is lower (from equation (5.3)).

Therefore, group lending with joint liability dominates individual loans in group. The borrower is better off, since she can receive a lower interest rate. Nevertheless, this effect can be offset by the fact that the borrower may be held responsible for the unpaid loans of other group members. In any case, the decrase in interest rate increases the depth of outreach. For the lender, this is also a better setup as he can reach higher profits ceteris paribus. Note, that joint liability lending would still be dominant even if individual lending would be provided only to high-ability borrowers, since the lender benefits from joint liability. Hence, individual liability lending in groups is appropriate only if lenders have complete information about borrowers, borrowers are not willing to accept joint liability, and peer monitoring is feasible and effective.

5.2 Simultaneous financing vs. sequential financing

Determining the advantages and disadvantages of each model is the main result of this thesis. In the following paragraphs we compare the traditional simultaneous financing design and the relatively new sequential design. Unfortunately, in several respects, it is not possible to draw a clear conclusion and identify the better of the two models.

5.2.1 Within-group heterogeneity of loan sizes

Let us begin by focusing on the within-group heterogeneity of loan sizes. We analyze the possible span of s parameter specifying $L = s\bar{L}$. This variability is limited by assortative matching. The bounds on the relative sizes of loans were derived from the condition for positive assortative matching. In the model with simultaneous financing, we had the caps on s set as

$$\sqrt{\frac{1-p_h}{1-p_l}} < s < \sqrt{\frac{1-p_l}{1-p_h}}. \tag{5.6}$$

In the model with sequential financing, the derived interval was specified as

$$\sqrt{\frac{(1+p_l)(1-p_h)}{(1-p_l)(1+p_h)}} < s < \sqrt{\frac{(1-p_l)(1+p_h)}{(1+p_l)(1-p_h)}}. \tag{5.7}$$

As can be seen, the sequential model offers a wider interval for s; hence, sequential financing allows for higher variation of loan sizes within the group. This might, actually, influence the number of paired groups as the rule on the ratio of loans is looser. Then, the lender, as well as the borrower, is better off in the sequential scheme thanks to this increased variability. Having more potential group partners, the borrower is more likely to form a group. Since there is a possibility of more (or larger) groups, the lender can probably lend more funds through group lending.

5.2.2 Trading joint liability for lower interest rate

Another aspect relevant for the comparison is the rule used to initiate group lending together with positive assortative matching. In the model with sequential setup, the choice of ϵ is less restricted (for any fixed s), since we had:

$$\begin{aligned} \epsilon &> \frac{1-p_h}{(1+p_h)s} \\ \epsilon &< \frac{1-p_l}{(1+p_l)s}. \end{aligned}$$

For the simultaneous scheme, we derived:

$$\begin{aligned} \epsilon &> \frac{1-p_h}{s} \\ \epsilon &< \frac{1-p_l}{s}. \end{aligned}$$

That implies there are more applicable rates of this exchange in the sequential case. As a result of that, the lender can, in any case, in the sequential setup set the speed of adjustment higher or lower than in the simultaneous one. Of course, the lender will always choose the lowest possible level of ϵ in order not to decrease r in exchange for joint liability more than necessary.

5.2.3 Profit

Throughout this thesis, we have assumed perfect competition resulting in zero-profit condition for the lender. In practice, it might not be the case, since market frictions may arise (at least temporarily). Also, the lender would prefer to adopt the scheme with higher per dollar profit in case there is an unanticipated decline in the opportunity cost of capital resulting in strictly positive profit on loans which were provided but have not been repaid yet. Therefore,let us compare the per dollar unit profits of each of the models. In the simultaneous model, we had

$$p_h^2(1+r) + p_h(1-p_h)(1+r+\sigma) - \gamma - \frac{m(n^*)}{n^*}$$

and for the sequential case

$$p_h^2(1+r) + 0.5[p_h(1-p_h)(1+r+\sigma)] + 0.5(1-p_h) - \gamma - \frac{m(n^*)}{n^*}.$$

Using a bit of algebra, we derive that as long as

$$p_h(1+r+\sigma) > 1, \tag{5.8}$$

simultaneous financing achieves higher per dollar profit for the lender. If the opposite inequality holds, the sequential approach is a more profitable choice. For the case of group lending with full joint liability ($\sigma = 1$) with a very low r, we can generalize and state that simultaneous scheme is more profitable if the projects of high-ability borrowers are on average successful ($p_h > 0.5$). The sequential design is more appropriate if the probability of success of these projects is low and they turn out to be unsuccessful on average ($p_h < 0.5$).

The bounds of the intervals resulting from the inequality of (5.8) can be illustrated by the following plot where the area below the line corresponds to the optimal choice of the sequential design, whereas the area above the line depicts the optimal choice for simultaneous design.

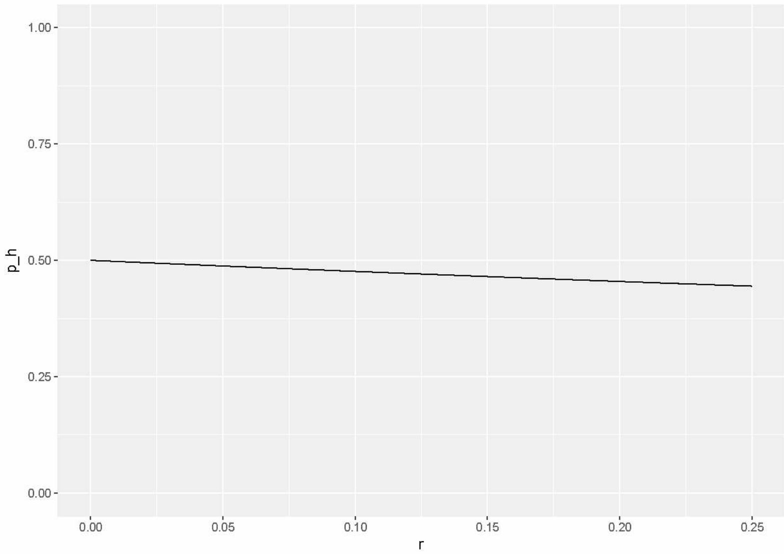

Figure 5.1: The threshold level of p_h equalizing profitability of models at $\sigma = 1$

In case we allow for partial liability, the relative profitability of the sequential model increases. For example, by reducing the joint liability to $\sigma = 0.5$ the indifference line shifts upwards widening the optimal choice area of the sequential model (below the line).

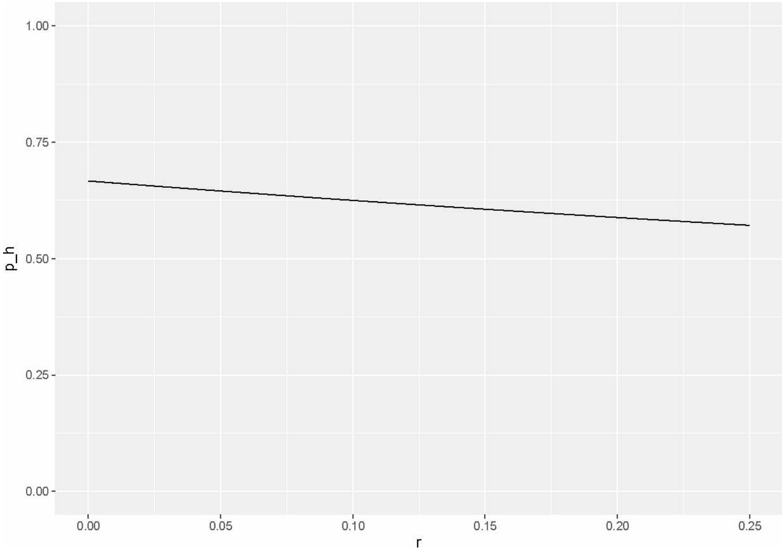

Figure 5.2: The threshold level of p_h equalizing profitability of models at $\sigma = 0.5$

Suppose we organize individual lending in groups ($\sigma = 0$) and we achieve to lend only to high-ability borrowers - as in Giné and Karlan (2014). Then, there is a strong dominance of sequential financing:

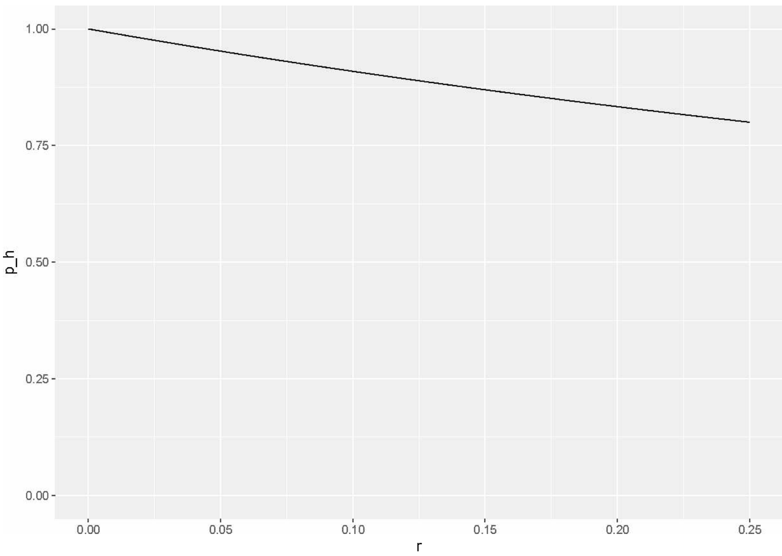

Figure 5.3: The threshold level of p_h equalizing profitability of models at $\sigma = 0$

5.2.4 Interest rate

Another important aspect when it comes to model comparison is the final interest rate $\hat{r}$ that is being offered to borrowers. We derive the following conditions for interest rates from the break-even conditions (equalizing profit to γ) for each model. In the simultaneous model, it must hold in competitive market equilibrium that

$$p_h^2(1+r) + p_h(1-p_h)(1+r+\sigma) - \frac{m(n^*)}{n^*} = \gamma.$$

From that, we derive

$$r = \frac{\gamma + \frac{m(n^*)}{n^*}}{p_h} - (1-p_h)\sigma - 1. \tag{5.9}$$

The expected profit function for high-ability borrowers set in the sequential model is

$$0.5[p_h^2(1+r) + p_h(1-p_h)(1+r+\sigma)] + 0.5[p_h^2(1+r) + (1-p_h)] - \frac{m(n^*)}{n^*} = \gamma.$$

The resulting expression for r is then

$$r = \frac{2(\gamma + \frac{m(n^*)}{n^*})}{p_h(1+p_h)} - \frac{\sigma(1-p_h)+2}{p_h+1}. \tag{5.10}$$

We cannot make any general conclusion on the difference of interest rates. There is no strict inequality that would hold for all possible combinations of parameters.

5.2.5 Marginal changes in interest rate

Although we do not determine the model with lower interest rate, we can analyze marginal changes in r with various factors. This way, we can assess the sensitivity of each model. For σ we have in the simultaneous case

$$\frac{\partial r}{\partial \sigma} = -(1 - p_h)$$

and for the sequential case

$$\frac{\partial r}{\partial \sigma} = -\frac{1 - p_h}{1 + p_h}.$$

We see that r is more sensitive to the changes in σ in the case of simultaneous financing. Then, in this case, a decrease in the liability parameter must be accompanied by a relatively slower increase in the interest rate.

Also, we can analyze marginal changes to r due to changes in the average monitoring cost. It could be the case that monitoring costs of the lender rise suddenly. For the simultaneous setup, we have

$$\frac{\partial r}{\partial \frac{m(n^*)}{n^*}} = \frac{1}{p_h}$$

and for the sequential setup

$$\frac{\partial r}{\partial \frac{m(n^*)}{n^*}} = \frac{2}{p_h(1 + p_h)}.$$

Obviously, the interest rate is slightly more sensitive to changes in monitoring costs (or any other fixed costs per unit) in the sequential case. This also holds for the opportunity cost of capital (as it is also per unit cost). Therefore, if γ rises, borrowers of sequential financing would be more negatively affected than those of simultaneous financing. However, for a decline in γ, the sequential scheme borrowers could enjoy a larger decrease of the interest rate.

6. Conclusion

Over the years, microcredit has evolved. Though the idea of joint liability among group members as a replacement for physical collateral has survived, the procedure of providing loans to borrowers has changed significantly. The traditional scheme under which the loans are provided simultaneously was replaced by a new sequential approach. The reception by researchers, who have always struggled to keep up with the innovations of MFIs, has been rather mixed. Whilst experimental economists are still using simultaneous financing approach to group lending in their field experiments, MFIs and theorists has already been advocating the newer scheme of sequential financing for several years. Moreover, recent papers suggest that group lending should evolve into individual lending in groups and eliminate the joint liability completely.

Given the absence of comparative studies, the aim of our present research was to analyze the three mentioned approaches theoretically and to provide theoretical evidence to the ongoing debate on the optimal organization of group lending. For this purpose, we have built three theoretical models, evaluated, and compared their properties and applications. For each of these models, we have specified the equilibrium level of interest rate and equilibrium existence. Furthermore, in the models with joint liability, we have analyzed the group formation stage and evaluated whether positive assortative matching holds, i.e. the ability to exclude risky borrowers from group lending. Since all of our models originate in the same environment introduced by Van Tassel (1999), the outcomes could be properly compared and analyzed. Moreover, this is the first study that compares the within-group heterogeneity of loan sizes.

The first model captured individual lending in groups with information asymmetry. Recent empirical evidence (Giné and Karlan, 2014) suggests that numerous

MFIs have begun to operate individual lending in groups with no joint liability. Although theoretical research (De Quidt et al., 2016) proved that such a transition could be beneficial for borrowers as well as MFIs, our comparison to simultaneous financing in an environment with information asymmetry does not support these conclusions and recommends group lending with simultaneous financing as a better model.

Since there is not much theoretical evidence, but a common belief among researchers, that the sequential model dominates the traditional one in many respects, we have devoted most of our study to the comparison of these two approaches. Although the sequential scheme is preferred by MFIs nowadays, it does not outperform simultaneous financing in all aspects. Our findings suggest that the interest rate in sequential financing is more sensitive to rises in monitoring costs or opportunity costs of capital. Consequently, an MFI offering sequential financing is relatively more susceptible to fluctuations of these costs. On the contrary, sequential lending design offers a larger scope of within-group loan size heterogeneity implying easier group formation. For the equilibrium level of interest rate and per unit profit of an MFI, the results are ambiguous, since the superior model is determined by the probability of borrower's success (his abilities). Thus, our research has confirmed that the suitability of either simultaneous or sequential approach is predominantly determined by local conditions. Therefore, there is no strict dominance of any of the models. Nevertheless, these findings have significant implications for the understanding of the behavior of borrowers as well as for the sustainability of MFI's business. Hopefully, the insights gained from this study will contribute to the debate on the optimal microfinance model and inspire further theoretical research.

As in every theoretical study, the most serious limitations are its assumptions. Besides that, our research did not allow for measuring the outreach of lending (number of financed projects). Moreover, we could not model the monitoring costs as endogenous, since the models do not capture the collusion of borrowers and their strategic default, the problems that sequential financing should mitigate. These limitation will be a subject to further research of the author.

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