Marketplace lending meets Diamond: A transaction cost-based analysis

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Abstract:

In a Diamond (1984) model setting extended by ex ante information asymmetry it is shown that MPL platforms are typically not superior to a financial intermediary solution with banks in terms of reduced transaction costs. Based on extensive numerical examples, it can be shown that only when simultaneously the default probabilities of the projects carried out by the debtors are low to medium and the number of creditors per project is small the MPL platform can dominate the bank. Only when a convenience yield of using an MPL platform interpreted as negative transaction costs relative to other institutional arrangements is introduced, can the dominance of the financial intermediary solution be broken. Furthermore, if the MPL platform has skin-in-the-game by taking the first loss tranche, this can have a substantial effect on the advantageousness of the MPL platform solution (depending on the additional services provided by the platform).

Key words: banking theory, information asymmetry, marketplace lending, transaction costs

JEL classification: G21, G23

1 Introduction

As part of the wave of digital financial innovations seen in the last two decades, so-called Marketplace Lending (MPL) platforms have emerged (formerly also referred to as ‘P2P lending’). Typical for these platforms is that the process of loaning money to individuals or (small) businesses is done through online services by which creditors and debtors are matched without employing banks acting as intermediaries in their traditional way.[1]

In the original form of MPL, the players on both sides of the platform were private individuals, and the volumes of the granted loans were comparatively small.[2] Lending via MPL requires capital investors and debtors to register on the platform. Both state the amount they intend to invest or borrow, respectively. The debtor describes its financial circumstances and explains the project for which the money is needed. The platform operator checks the identities and assesses the debtors' creditworthiness based on its screening procedures. If a debtor proves to be creditworthy, the platform expresses the creditworthiness in a risk classification and an individual, risk-related, and term-dependent interest rate. Loans are only granted if enough other investors support a project. For many customer segments, the loans granted are unsecured. The platform is typically not financed by access or membership fees but by closing fees, which investors and debtors only pay if a loan is granted. It has to be differentiated between on-balance sheet and off-balance sheet MPL. While in the case of on-balance sheet MPL, the platform grants loans itself, this obligation does not apply to the platform in the case of off-balance sheet MPL because, in the latter case, it is not the platform but an ‘intermediary’ bank (cooperation bank) that grants the loan. The cooperation bank's claim against the debtor for payment of the interest and repayment of the loan amount is divided into individual partial claims and then sold and assigned to the various investors who have decided in favor of the debtor and this loan in advance. With the assignment, the cooperation bank as the previous creditor is legally replaced by the (respective) capital investor as the new creditor of a (partial) repayment and interest payment claim.

During market development, the business model of MPL platforms has changed considerably. While the original business idea was to broker loans from private individuals to private individuals (‘peers’) and, by doing this, bypass traditional banks, there are now increasingly institutional investors such as banks, insurance companies, or hedge funds on the capital provider

[1] See Thakor (2020, p. 3).
[2] See Dinger et al. (2018) for this paragraph.

side.[3] These institutional players either buy up the loans granted or brokered by the platforms or acquire securitized loans generated by MPL platforms. Jenkins (2016) reports that, meanwhile, only 20% of the refinancing of U.S. MPL platforms comes from individuals. Accordingly, 50% of the funding comes from institutional investors who purchase the loans in packages and 30% from securitizing the loans generated on the platforms. Since 2016, the funding institutionalization rate for MPL platforms has even increased, but differs depending on the region and customer segment.[4] For example, for MPL platforms in Europe (including the UK) specialized on consumer lending, the rate of institutionalization was only one-third in 2020.[5] A second trend in the evolution of MPL platforms is the increasing (and meanwhile dominant) share of passive (retail and institutional) investors who automatically fund loans according to prespecified criteria, in contrast to active investors picking individual loans based on the information about the borrower provided by the platform.[6]

For banks, there is an extensive theoretical literature that, based on market imperfections (especially various types of information asymmetries), argues that the involvement of a bank as a financial intermediary can lead to a reduction in total transaction costs compared to direct financing relationships between creditors and debtors.[7] A seminal paper in this sense is Diamond (1984), in which it is shown that when banks act as delegated monitors in a world with ex post information asymmetry, this can reduce transaction costs compared to a market-like situation in which investors directly grant loans to debtors. In the Diamond (1984) setting, 'private' diversification (i.e., investors spread their investment amount over many loan-financed projects, as investors of MPL platforms could (and should) do) in a market-like situation has not have the same effect as diversification on the bank level and does not change the superiority of the intermediary solution in terms of transaction costs. Given these results from the banking theory literature, it is not apparent why an (at least partial) disintermediation by MPL platforms implying a substitution of banks by direct financing relationships between investors and debtors should provide efficient financing solutions. This paper deals with this question in a transaction costs-based framework. Doing this also allows to analyse which characteristics contribute to a (potential) superiority of MPL platforms.

[3] See Dinger et al. (2018) for this paragraph.
[4] See Ziegler et al. (2021, p. 140).
[5] See Ziegler et al. (2021, p. 84).
[6] See Balyuk and Davydenko (2024).
[7] See the overview in Hartmann-Wendels et al. (2019).

An extended Diamond (1984) model setting is employed to analyze this question. In the original model, the economic success of the projects financed from the loans taken out cannot be verified free of charge by the creditors after project completion (ex post information asymmetry). This incentivizes debtors to report the lowest possible project returns so that they do not have to make the contractually agreed payments in full. To mitigate this adverse incentive, monitoring costs must be incurred, or costs arise from an incentive-compatible contract design (transaction costs). In the model, there are two ways in which debtors' projects can be financed. First, a direct financing relationship between debtors and creditors can be established. Second, a financial intermediary (bank) can be set between debtors and creditors. However, the involvement of a financial intermediary implies that a one-step cooperation problem becomes a two-step cooperation problem.[8] Nevertheless, it can be shown in the model that, due to default risk diversification on the bank level, above a certain minimum number of debtors the solution with a bank can lead to lower overall transaction costs than if the creditors maintain direct financing relationships with the debtors. In this paper, the transaction costs that are caused by a two-sided cooperation problem with a bank as a delegated monitor (debtors-bank, bank-creditors) are compared with those that are caused by a direct lending relationship between debtors and creditors, which is informationally and operationally mediated by an MPL platform. It is analysed whether a better screening technology of the MPL platform can outweigh the advantages that a bank as an intermediary offers. For this, the original Diamond (1984) model is extended by additional ex ante information asymmetry, making screening procedures necessary. However, it also has to be taken into account that MPL platforms usually only act as informational and operational intermediaries without (monetary) skin-in-the-game.[9] Hence, with the MPL platform solution, creditors not only have to incentivize the debtors to report project results ex post correctly but also the MPL platform to ensure a sufficiently good screening of the debtors ex ante.

The main result of the model-based analysis in this paper is that MPL platforms are typically not superior to a financial intermediary solution with banks in terms of reduced transaction costs. Based on extensive numerical examples, it can be shown that only when simultaneously the default probabilities of the projects carried out by the debtors are low to medium and the number of creditors per project is small the MPL platform can dominate the bank. Only when a convenience yield of using an MPL platform interpreted as negative transaction costs rela-

[8] See Hartmann-Wendels et al. (2019).
[9] See Dinger et al. (2018).

tive to other institutional arrangements is introduced, can the dominance of the financial intermediary solution be broken. Private diversification of the creditors or alternative default rate distributions cannot shift the advantageousness in favor of the MPL platform solution. If the MPL platform has skin-in-the-game by taking the first loss tranche, this can have a substantial effect on the advantageousness of the MPL platform solution (depending on the additional services provided by the platform).

The paper is structured as follows: After sketching the related literature in Section 2, the modelling assumptions are introduced in Section 3. Furthermore, the incentive conditions of the stakeholders for all three considered institutional arrangements (market solution, financial intermediary solution, MPL platform solution) are derived, and a numerical example is presented. In Section 4, the effects of variations of modelling assumptions are discussed. Section 5 contains concluding remarks.

2 Related literature

This paper contributes to the theoretical literature on fintechs in general and MPL in particular.[10] Thakor and Merton (2018) differentiate between trust and reputation in a model with which the competitive interactions between banks and non-bank lenders (in particular, MPL platforms) are analysed. Trust ensures that lenders have assured access to funding, whereas a loss of trust makes this access conditional on market conditions and the lender's reputation. They show that banks endogenously have a stronger incentive to maintain trust than non-banks. In a game-theoretic model, Wei and Lin (2017) analyze the influence of the MPL platform's choice of market mechanisms to match the supply and demand of funds on transaction outcomes and social welfare. In particular, they differentiate between auctions, where the crowd of creditors determines the interest rate of a transaction through an auction process, and posted interest rates, where the MPL platform sets the interest rate. They find that under posted interest rates, which is market standard meanwhile, loans are funded with a higher probability, but interest rates tend to be higher than those resulting from auctions. Faia and Paiella (2017) compare returns and liquidity in a dynamic general equilibrium model, where creditors and debtors can choose between traditional banks (possessing a costly screening technology but which are subject to the risk of bank runs, implying an early liquidation of the debtors'

[10] See Thakor (2020) for an excellent literature review on fintechs in general, and Berg et al. (2022) for fintech lending in particular.

projects) and MPL platforms (providing costless public signals). Vallee and Zeng (2018) deal with the impact of pre-screening by the MPL platform and the provision of additional information to investors on the volume of loans originated by the platform. They differ between active ('sophisticated') and passive investors. While the former perform further verification of the debtor based on the additional information presented on the platform, the latter rely almost blindly on pre-screening. As a result, the active investors identify the better borrowers and can then offer them loans on more favorable terms, leaving the passive investors with a pool of borrowers who are, on average, worse. When unsophisticated investors are aware of this problem, they either charge higher interest rates, which reduces the amount of loan applications on the platform, or even exit the market. In both cases, the loan volume of the platform shrinks. Thus, to maximize the loan volume, the MPL platform has to choose an optimal pre-screening intensity and an optimal level of provision of additional information so that the advantage of the active investors does not become too large and unsophisticated investors are still willing to invest. In a model where banks and MPL platforms compete, de Roure et al. (2022) derive various testable predictions. First, MPL platform lending grows when some banks face an exogenous shock in the form of an unexpected increase in regulatory costs, and, simultaneously, the unaffected banks are not sufficiently capitalized. Second, the default risk of the loans attracted by the MPL platforms after this shock is larger than the average default risk of bank loans, and third, the risk-adjusted interest rate charged by MPL platforms is lower than that charged by banks. Similarly, Avramidis et al. (2022), also employing a model of competition between banks and MPL platforms, predict that MPL platforms can absorb unmet demand for consumer credit resulting from a reduction in the availability of bank credit after bank consolidations. However, in contrast to de Roure et al. (2022), they argue that MPL platforms mainly attract low-risk consumers. This results from their assumption that high-risk consumers benefit more from the lower screening costs implied by bank relationships and, therefore, are more reluctant to migrate to an MPL platform. Chu and Wei (2024) analyze the influence of a superior screening technology employed by the MPL platform in a lending competition model with two banks with different screening abilities and an MPL platform. They show that the MPL platform's superior screening technology can lead to a situation in which high-quality borrowers' access to credit is negatively affected. Chu and Wei (2024) argue that MPL platforms use big data analytics and non-traditional data, such as phone bills and shopping or Internet browsing history, to screen borrowers. In contrast, banks would rely on traditional credit scores and proprietary data they gather during the lending relationship. In a similar vein, He et al. (2023) show in a lending competition model with a traditional bank and an MPL platform that open banking initiatives, by which banks share customer data with MPL platforms, can have adverse effects on borrowers. The reason for this is that these initiatives widen the gap between the screening abilities of the two lenders. Finally, Braggion et al. (2023) propose and estimate a dynamic equilibrium model in which they analyze different specifications of MPL platforms. Besides classical peer-to-peer lending, they also consider the case that the platform sells diversified loan portfolios (similar to securitizations without the 'waterfall principle' and different tranches) characterized by maturity mismatch with the underlying loans. The loan portfolio shares can be sold on an internal secondary market run by the platform if the lenders do not want to roll over their portfolio investments. They empirically show that this specification raises lender surplus, platform profits, and credit provision. However, this comes at the price of liquidity risk for investors. If the platform additionally bears the liquidity risk, welfare is further increased when liquidity is low and the lenders' liquidity risk aversion is high.

Building on the seminal bank-theoretic approach of Diamond (1984), this paper extends the theoretic literature with respect to MPL. In a world with asymmetric information and resulting transaction costs, it shows under which circumstances which institutional arrangement (banks vs. MPL platforms vs. financial market) produces the lowest transaction costs while granting loans to entrepreneurs.

3 Model

Basically, the Diamond (1984) setting with ex post information asymmetry is employed that is extended by ex ante information asymmetry and off-balance sheet credit provision via MPL platforms as an additional institutional arrangement (besides credit provision by a financial intermediary or the financial market). A summary of the model assumptions is given in Figure 1.

3.1 Assumptions

In the following, first, general model assumptions are presented, and afterward, assumptions that are specific to one of the institutional arrangements are introduced.

3.1.1 General assumptions

All creditors, debtors, the bank, and the MPL platform are risk-neutral. It is assumed that n creditors each finance equally one out of m projects. Thus, in total, $n \cdot m$ creditors are needed to finance all m projects. All projects are homogeneous, but in contrast to the assumption in Diamond (1984), their results are not independent. Thus, even for a large number of projects in the portfolio, the resulting default rate $\tilde{d}$ of the portfolio of credits given to finance the projects will not converge to its mean with probability one. For each project, the required investment amount is I_0, and the projects' results $\tilde{y}$ in $t=1$ are identically Bernoulli distributed with $\tilde{y} \in \{0; y\}$ and $P(\tilde{y}=0) = PD^{true} = E^{true}\left[\tilde{d}\right]$ where PD^{true} is the true default probability of each project. It is assumed that the project result y in case of success is sufficiently large so that the debtors can always pay back their debt. In case of no success, the loss given default of the creditors equals 100%. Furthermore,

$$I_0 < E[\tilde{y}] = y \cdot \left(1 - PD^{true}\right) \tag{1}$$

is assumed. Without loss of generality, the risk-free interest rate r is set equal to zero. Thus, Equation (1) implies that a risk-neutral investor is willing to carry out the project, at least if the investor gets (parts of) the expected surplus of the project.

In $t=0$, all debtors carry out one project. They have no initial financial endowment. Thus, the whole investment amount I_0 has to be borrowed. For this, the debtors can either borrow from creditors directly via the (imperfect) capital market or borrow from a bank or via an MPL platform, respectively. All debtors know the true default probability PD^{true} of their project and the potential results of the project. However, this is private information to them.

3.1.2 Assumptions for the financial market solution

All creditors have an initial financial endowment of I_0/n which is invested in one project in $t=0$. Each creditor is equal in repayment. Due to an ex post information asymmetry, a creditor can observe the result $\tilde{y}$ of a project in $t=1$ only if he monitors the debtor which causes non-pecuniary costs $c_{creditor}^{monitoring}$. Alternatively, as assumed by Diamond (1984), a non-pecuniary penalty function for the debtors can be introduced that sanctions any incomplete repayment of the nominal amount R_{debtor}^{market} by the debtors. The non-pecuniary penalty equals the difference between the amount due and the amount that the debtors indeed pay. This penalty function incentivizes the debtors to report the result of their project in $t=1$ correctly. However, the penalty function is also applied when the debtor indeed cannot repay the credit because the project defaulted, which causes transaction costs. Furthermore, due to ex ante information asymmetry, a creditor has to spend non-pecuniary costs $c_{creditor}^{screening}$ for screening the debtor in $t=0$ to get some information about the debtor's project. By doing this, the creditor perfectly learns the two potential outcomes $\tilde{y} \in \{0; y\}$ of the project, but due to imperfect screening technologies or inferior data, the creditor only gets a biased estimate $PD^{creditor} \neq PD^{true}$ of the project's default probability with

$$PD^{creditor} = PD^{true} \cdot \left(1+\beta^{creditor}\right) \ \left(\beta^{creditor} \in \left[-1; 1/PD^{true} - 1\right]\right). \tag{2}$$

The bias factor $\beta^{creditor}$ determines how large the deviation between the true default probability PD^{true} and the default probability $PD^{creditor}$ estimated by the creditors is. The latter one is employed in $t=0$ to fix the nominal amount R_{debtor}^{market} that the debtors have to repay in $t=1$. The creditors are willing to finance a project, if and only if their expected net return is at least equal to zero. It is assumed that all creditors keep the result of their screening private so that each creditor has to do the screening by its own.

3.1.3 Assumptions for the financial intermediary solution

The bank, as a financial intermediary, has equity E invested in liquid non-risky assets. For financing the debtors' projects, the bank exclusively uses deposits of creditors. The bank can observe the result $\tilde{y}$ of a project in $t=1$ if and only if it monitors the debtor. This causes non-pecuniary costs $c_{bank}^{monitoring}$. The monitoring results are not publicly observed. Additionally, the bank has to spend non-pecuniary costs $c_{bank}^{screening}$ for screening the debtor in $t=0$ to get some information about the debtor's project. Doing this, as assumed for the creditors, the bank perfectly learns the two potential outcomes $\tilde{y} \in \{0; y\}$ of the project, but it only gets a biased estimate $PD^{bank} \neq PD^{true}$ of the project's default probability with

$$PD^{bank} = PD^{true} \cdot \left(1+\beta^{bank}\right) \quad \left(\beta^{bank} \in \left[-1; 1/PD^{true} - 1\right]\right). \tag{3}$$

It is assumed that, due to the bank's equity, the bank is incentivized to do the screening as well as possible, but the estimate of PD^{bank} is biased because the bank uses a non-perfect screening technology or inferior data. The bank employs the estimated default probability PD^{bank} in $t=0$ to fix the nominal amount R_{debtor}^{fi} that the debtors have to repay to the bank in $t=1$. The bank is willing to finance a project if and only if its expected net return is at least equal to zero. The bank provides the results of the debtors' screening to their creditors. Thus, the creditors do not have to do a screening on their own. In fact, it is assumed that the creditors even know the (biased) probability distribution (including the effects of stochastic dependencies between the projects) of the default rate $\tilde{d}$ of the bank's credit portfolio. The creditors use this to compute the nominal amount R_{bank}^{fi} the bank has to repay to them. Basically, each creditor (as the bank in its relationship to the debtors) has to spend non-pecuniary costs $c_{creditor}^{monitoring}$ to observe the bank's success in $t=1$. This ensures that the bank indeed pays back the nominal amount R_{bank}^{fi}, if possible, based on the repayments of the its debtors (being unobservable for the bank's creditors) and its equity. Another alternative to incentivize the bank to honest repayments is again the application of a non-pecuniary insolvency penalty for missing payments to the bank's creditors.

3.1.4 Assumptions for the MPL platform solution

The MPL platform is assumed to mediate only between debtors and creditors without granting credits itself (off-balance sheet MPL), but provides the screening of the debtors as a service to the creditors. However, as the MPL platform has no skin-in-the-game, it has to be incentivized to make efforts for a proper screening.[11] It is assumed that this is done by introducing a non-pecuniary penalty function that sanctions any quadratic deviations between the expected loss rate based on the MPL platform's estimate PD^{mpl} and the realized loss rate $\tilde{d}$ of the portfolio of loans mediated by the MPL platform.[12] The quadratic deviations are scaled by a

[11] See, for example, Balyuk and Davydenko (2024, p. 1999), Dinger et al. (2018), or Thakor (2020, p. 6).
[12] See Section 4.3 for non-quadratic penalty functions. As Thakor (2020, p. 6) points out, reputational concerns could basically be another disciplining mechanism. However, as he also points out, Thakor and Merton (2018) show that depository institutions endogenously have a stronger reputational incentive than MPL platforms and

penalty factor $\lambda \in \mathbb{R}_+$ that governs the degree of punishment, and the total amount of nominal repayments mR_{debtor}^{mpl}. Given this arrangement, the MPL platform has an incentive to do the screening as well as possible to reach $PD^{mpl} \approx PD^{true}$ and to minimize the expected penalty function

$$\lambda m R_{debtor}^{mpl} \left(PD^{mpl} - \tilde{d} \right)^2 . \tag{4}$$

It is assumed that due to superior screening technology or data, the MPL platform achieves $PD^{mpl} = PD^{true}$, and that $E^{mpl}[\cdot] = E^{true}[\cdot]$ is true.[13] The screening results are given to the creditors. For its services, the MPL platform gets a payment of $e_{creditor}^{mpl}$ percent of the nominal amount R_{debtor}^{mpl} from the creditors and a payment of e_{debtor}^{mpl} percent from the debtors. The MPL platform is willing to participate in the arrangement if and only if its expected net return is at least equal to zero. To overcome ex post information asymmetry, each creditor has to monitor the financed project. This causes non-pecuniary costs $c_{creditor}^{monitoring}$ for each creditor and project. Alternatively, as in Section 3.1.2, a non-pecuniary insolvency penalty for the debtors can be introduced, which incentivizes them to report the results of their project in $t = 1$ correctly.

3.1.5 Assumptions for the default rate distribution

For ease of computation, it is assumed that under the true probability measure, the default rate $\tilde{d}$ of the portfolio of credits given to finance all m projects is uniformly distributed on $\left[a^{true}; b^{true} \right]$ with $a^{true}, b^{true} \in [0;1]$.[14] This implies

$$PD^{true} = E^{true}\left[\tilde{d} \right] = \frac{a^{true} + b^{true}}{2} . \tag{5}$$

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other non-banks. Alternatively, Balyuk and Davydenko (2024) empirically argue that the co-existence of passive investors and those investors who actively pick loans based on the information provided by the MPL platform can reduce the platforms' moral hazard problem.

[13] See Di Maggio and Ratnadiwakara (2024), who find that screening outcomes produced by an MPL platform and a traditional credit scoring model employed by banks are different, where the difference is mainly driven by both the platform's algorithm and the employed alternative data. Furthermore, they find that banks tend to over-estimate the default risk of low credit score applicants. Chu and Wei (2024), He et al. (2023), and Serfes et al. (2024) analyse the consequences of screening ability gaps between MPL platforms and banks in lending competition models. However, it does not seem to be as clear that MPL platforms do indeed the better screening compared to banks, as the platforms themselves like to claim (see the discussion by Berg et al. (2022, pp. 194)).

[14] For an alternative, more realistic default rate distribution, see Section 4.1.

The creditors and the bank know that the default rate is uniformly distributed, but they only have a biased estimate of the individual default probability of a project (see Equations (2) and (3)). Thus, for computing the nominal repayment amounts, it is assumed that they work with the following biased boundaries of the support for the uniform distribution $\left(\beta^{bank}, \beta^{creditor} \in \left[-1; 1/PD^{true} - 1\right]\right)$:

$$a^{creditor} = a^{true} \cdot \left(1 + \beta^{creditor}\right) \text{ and } b^{creditor} = Min\left\{1; b^{true} \cdot \left(1 + \beta^{creditor}\right)\right\}, \tag{6}$$

$$a^{bank} = a^{true} \cdot \left(1 + \beta^{bank}\right) \text{ and } b^{bank} = Min\left\{1; b^{true} \cdot \left(1 + \beta^{bank}\right)\right\}. \tag{7}$$

The Min-term ensures that the upper boundary does not become larger than the maximum possible default rate. When the Min-term in Equations (6) and (7) yields $b^{creditor} = 1$ or $b^{bank} = 1$, respectively, this implies that the effective biased estimates of the project's default probability are somewhat smaller than $PD^{creditor}$ and PD^{bank}, respectively.

The timeline of the model is shown in Figure 1.

Figure 1: Timeline of the model

ex ante information asymmetry **interim information symmetry** **ex post information asymmetry**

$t = 0$

MPL platform screens all m projects at costs $c_{plat}^{screening}$ per project and obtains the (true) information about the potential outcomes, the marginal default probability and the joint default rate distribution for all projects. This perfect information is given to the creditors, who use it to compute their (subjectively) expected cash flows from the debtors.

Bank screens all m projects at costs $c_{bank}^{screening}$ per project and obtains the true information about the potential outcomes for all projects, but only blurred information concerning the marginal default probability and the joint default rate distribution.
This blurred information is given to the creditors of the bank, who use it for computing their (subjectively) expected cash flows from the bank.

Creditors giving money directly to the debtors via the financial market screen all m projects at costs $c_{creditor}^{screening}$ per project and obtain the true information about the potential outcomes for all projects, but only blurred information concerning the marginal default probability and the joint default rate distribution.

For all institutional arrangements: The nominal amounts that the debtors have to pay to the creditors or the bank, respectively, and that the bank has to pay to its depositors are fixed based on the information available for each party.

Projects are carried out by the debtors.

$t = 1$

All projects end with an outcome of y or 0.

Each creditor having financed a project via the MPL platform or the financial market either spends $c_{creditor}^{monitoring}$ per project to verify the reported project result, or an insolvency penalty is applied to the debtor in case of insufficient payment.

The bank always spends $c_{bank}^{monitoring}$ per project to verify the project result reported by the debtor.

Each creditor of the bank either spends $c_{creditor}^{monitoring}$ per project to verify the result reported by the bank, or an insolvency penalty is applied to the bank if the bank's payment to its creditors is insufficient.

3.3 Incentive conditions

Next, using the assumption of risk-neutrality, the incentive conditions under which the debtors, the creditors, the bank, and the MPL platform participate under the different institutional arrangements (project financing via the financial market, via a financial intermediary, and via an MPL platform, respectively) are derived. These are used to compute the required nominal repayment amounts for the granted loans. Furthermore, the total transaction costs for each institutional arrangement are determined.

3.3.1 Market solution

When the m projects are directly financed by $n \cdot m$ creditors via the financial market, the creditors are willing to participate if and only if the expected repayments from the granted loans are larger than the non-pecuniary screening costs for reducing ex ante information asymmetry and the initial investment sum:

$$\underbrace{E^{creditor}\left[mR_{debtor}^{market,\#1}(1-\tilde{d}) \right]}_{\substack{\text{expected repayments from} \\ \text{m loans granted by the creditors}}} - \underbrace{mnc_{creditor}^{screening}}_{\substack{\text{non-pecuniary screening costs} \\ \text{of the mn creditors for reducing} \\ \text{ex ante information asymmetry}}} \geq \underbrace{mI_0}_{\substack{\text{initial investment sum} \\ \text{of the mn creditors}}} . \tag{8}$$

Under the zero expected net return condition, Equation (8) yields for the nominal amount that the debtors have to pay to the creditors:

$$R_{debtor}^{market,\#1} = \frac{I_0 + nc_{creditor}^{screening}}{1 - PD^{creditor}} . \tag{9}$$

Obviously, $R_{debtor}^{market,\#1}$ increases in I_0, n, $c_{creditor}^{screening}$ and $PD^{creditor}$. The non-pecuniary monitoring costs $c_{creditor}^{monitoring}$ for reducing ex post information asymmetry do not appear in (8) because here it is assumed that the number of creditors n per financed project is sufficiently large so that the application of the non-pecuniary insolvency penalty to the debtors leads to minimal total transaction costs (case *market*,#1). Hence, the debtors participate if and only if the expected surplus from the project is larger than the expected insolvency penalty, which equals the expected loss of the m projects:

$$\underbrace{E^{true}\left[Max\left\{m\tilde{y}-mR_{debtor}^{market,\#1};0\right\}\right]}_{\text{expected surplus from m projects for the debtors}}-\underbrace{E^{true}\left[\tilde{d}mR_{debtor}^{market,\#1}\right]}_{\text{expected non-pecuniary insolvency penalty resulting from m granted loans for reducing ex post information asymmetry}}\geq 0. \tag{10}$$

This yields as prerequisite for the project's outcome y in case of success:

$$y\geq\frac{R_{debtor}^{market,\#1}}{1-PD^{true}}. \tag{11}$$

For the above calculation, it is assumed that $y\geq R_{debtor}^{market,\#1}$ is always true. The two expectations in Equation (10) are calculated under the true probability measure because it is assumed that the debtors (in contrast to the creditors) have private information about the true failure probability PD^{true} of their projects.

If the number of creditors n per financed project is small, the non-pecuniary monitoring costs for reducing ex post information asymmetry are smaller than the costs resulting from applying the non-pecuniary insolvency penalty to the debtors (case *market*,#2). In this case, the incentive conditions for the creditors and the debtors are:

$$\underbrace{E^{creditor}\left[mR_{debtor}^{market,\#2}(1-\tilde{d})\right]}_{\text{expected repayments from m loans granted by the creditors}}-\underbrace{mnc_{creditor}^{screening}}_{\text{non-pecuniary screening costs of the mn creditors for reducing ex ante information asymmetry}}-\underbrace{mnc_{creditor}^{monitoring}}_{\text{non-pecuniary monitoring costs of the mn creditors for reducing ex post information asymmetry}}\geq\underbrace{mI_0}_{\text{initial investment sum of the mn creditors}} \tag{12}$$

and

$$\underbrace{E^{true}\left[Max\left\{m\tilde{y}-mR_{debtor}^{market,\#2};0\right\}\right]}_{\text{expected surplus from m projects for the debtors}}\geq 0. \tag{13}$$

Under the zero expected net return condition for the creditors, Equation (12) yields for the nominal amount that the debtors have to pay to the creditors:

$$R_{debtor}^{market,\#2} = \frac{I_0 + n\left(c_{creditor}^{screening} + c_{creditor}^{monitoring}\right)}{1 - PD^{creditor}}. \quad (14)$$

Summarizing both cases, the total transaction costs (TTC) are given by:

$$TTC^{market} = Min\left\{TTC^{market,\#1}; TTC^{market,\#2}\right\}. \quad (15)$$

with

$$TTC^{market,\#1} = \underbrace{mR_{debtor}^{market,\#1} PD^{true}}_{\substack{\text{expected non-pecuniary insolvency penalty} \\ \text{resulting from m granted loans}}} + \underbrace{mnc_{creditor}^{screening}}_{\substack{\text{non-pecuniary screening costs} \\ \text{of the mn creditors}}}. \quad (16)$$

and

$$TTC^{market,\#2} = \underbrace{mnc_{creditor}^{monitoring}}_{\substack{\text{non-pecuniary monitoring costs} \\ \text{of the mn creditors}}} + \underbrace{mnc_{creditor}^{screening}}_{\substack{\text{non-pecuniary screening costs} \\ \text{of the mn creditors}}}. \quad (17)$$

Please note that the total transaction costs are always computed under the true probability measure. That is why PD^{true} appears in (16) instead of $PD^{creditor}$. In the case of the insolvency penalty being applied to the debtors (case *market*,#1), increasing values of PD^{true} have a directly increasing impact on the total transaction costs and, as $PD^{creditor}$ and, hence, $R_{debtor}^{market,\#1}$ increase in PD^{true}, an additional indirectly increasing effect. This latter effect is larger the larger the bias factor β^{market} is. An increase in n, $c_{creditor}^{screening}$ and $c_{creditor}^{monitoring}$ also has a directly and an indirectly increasing impact on the total transaction costs.

3.3.2 Financial intermediary solution

The involvement of a financial intermediary implies that the one-step cooperation problem is transformed into a two-step cooperation problem. The bank as a financial intermediary (or, more specifically, the bank equity holder) participates if and only if the invested bank equity is smaller than the expected surplus from financing the projects after subtracting the sum of the non-pecuniary monitoring and screening costs it has to bear with respect to its debtors and the non-pecuniary insolvency penalty it has to bear with respect to its creditors. The latter is applied whenever the nominal amount the bank has to pay to its creditors is larger than the sum of the actual repayments of the debtors to the bank and the bank equity:[15]

$$\begin{aligned}&\underbrace{E^{bank}\left[Max\left\{mR_{debtor}^{fi,\#1}(1-\tilde{d})-mR_{bank}^{fi,\#1};0\right\}\right]}_{\substack{\text{expected surplus of the bank from}\\ \text{financing m projects}}}-\underbrace{mc_{bank}^{monitoring}}_{\substack{\text{non-pecuniary monitoring costs of the bank}\\ \text{for m projects for reducing ex post}\\ \text{information asymmetry with respect}\\ \text{to the debtors}}}\\ &-\underbrace{mc_{bank}^{screening}}_{\substack{\text{non-pecuniary screening costs of the bank}\\ \text{for m projects for reducing ex ante information}\\ \text{asymmetry with respect to the debtors}}}\\ &-\underbrace{E^{bank}\left[Max\left\{mR_{bank}^{fi,\#1}-mR_{debtor}^{fi,\#1}(1-\tilde{d})-E;0\right\}\right]}_{\substack{\text{expected non-pecuniary insolvency penalty of the bank}\\ \text{resulting from m granted loans for reducing ex post}\\ \text{information asymmetry with respect to the bank}}}-\underbrace{E}_{\substack{\text{initial investment of}\\ \text{the bank equity holder}}}\geq 0.\end{aligned} \tag{18}$$

For Equation (18), it is assumed that the insolvency penalty of the debtors is always larger than the costs of the bank for monitoring the debtors.[16] Furthermore, it is assumed that the number of creditors of the bank is so large that the insolvency penalty of the bank leads to smaller transaction costs than the monitoring costs of the $n \cdot m$ creditors (case *fi*,#1).

Assuming that the creditors do not have to monitor the bank because the insolvency penalty is applied to motivate the bank to true reporting, the participation condition of the creditors is:

$$\underbrace{E^{bank}\left[Min\left\{mR_{bank}^{fi,\#1};mR_{debtor}^{fi,\#1}(1-\tilde{d})+E\right\}\right]}_{\text{expected repayments from the bank to the creditors}}\geq\underbrace{mI_0}_{\substack{\text{initial investment sum}\\ \text{of the mn creditors}}} \tag{19}$$

[15] In case of insufficient repayments of the debtors, the bank can first sell the risk-free liquid assets in which it has invested its equity to generate enough cash flow to fulfil its own repayment with respect to its creditors. Only when this additional cash flow is also insufficient is the non-pecuniary insolvency penalty applied to the bank.

[16] In the debtors-bank-relationship, the monitoring costs occur only once per project. In contrast, in the bank-creditors-relationship, the monitoring costs occur n times per project. Thus, only in the latter case, it depends on the number of creditors per project, whether monitoring the bank by the creditors or applying the insolvency penalty to the bank leads to smaller transaction costs.

$$\Leftrightarrow R_{bank}^{fi,\#1} - E^{bank}\left[Max\left\{ 0; R_{bank}^{fi,\#1} - R_{debtor}^{fi,\#1}(1-\tilde{d}) - \frac{E}{m} \right\} \right] \geq I_0. \tag{20}$$

The creditors either get the full repayment $mR_{bank}^{fi,\#1}$ from the bank or (if smaller) the sum of the repayments of the debtors to the bank $mR_{debtor}^{fi,\#1}(1-\tilde{d})$ and bank equity E. Screening costs of the creditors with respect to the bank do not exist because the credit risk of the bank directly results from the credit risk of the debtors, which is screened by the bank (per assumption reliably screened because of the bank's equity), and the screening results are given to the creditors. Under the zero expected net return condition, this yields as an incentive condition of the creditors:

$$R_{bank}^{fi,\#1} - I_0 - E^{bank}\left[Max\left\{ 0; R_{bank}^{fi,\#1} - R_{debtor}^{fi,\#1}(1-\tilde{d}) - \frac{E}{m} \right\} \right] = 0\,. \tag{21}$$

The nominal amounts $R_{debtor}^{fi,\#1}$ and $R_{creditor}^{fi,\#1}$ are computed based on solving Equations (18) (setting the LHS equal to zero) and (21) simultaneously.

When bank equity E in Equation (18) is neglected (as in Diamond (1984)), the participation condition (18) for the bank can be further simplified. However, without considering the insolvency-dampening and, hence, transaction costs-reducing effect of bank equity, the condition under which MPL platforms dominate banks in terms of smaller transaction costs stated in Section 3.4 is only a necessary condition for dominance. Due to

$$\begin{aligned} & Max\left\{ mR_{debtor}^{fi,\#1}(1-\tilde{d}) - mR_{bank}^{fi,\#1}; 0 \right\} \\ & = mR_{debtor}^{fi,\#1}\left(1-\tilde{d}\right) - mR_{bank}^{fi,\#1} + Max\left\{ mR_{bank}^{fi,\#1} - mR_{debtor}^{fi,\#1}(1-\tilde{d}); 0 \right\} \end{aligned} \tag{22}$$

and assuming $E = 0$, the participation condition (18) can be transformed to

$$R_{debtor}^{fi,\#1}\left(1 - E^{bank}\left[\tilde{d}\right]\right) - R_{bank}^{fi,\#1} - c_{bank}^{monitoring} - c_{bank}^{screening} \geq 0\,. \tag{23}$$

Under the zero expected net return condition for the bank, this yields for the nominal amount that the bank has to pay to its creditors:

$$R_{bank}^{fi,\#1} = R_{debtor}^{fi,\#1} \left(1 - PD^{bank}\right) - c_{bank}^{monitoring} - c_{bank}^{screening} . \tag{24}$$

Combining Equations (24) and (21) and again assuming $E = 0$ results in

$$\begin{aligned} & R_{debtor}^{fi,\#1} \left(1 - PD^{bank}\right) - c_{bank}^{monitoring} - c_{bank}^{screening} \\ & = I_0 + E^{bank} \left[Max \left\{ 0; R_{debtor}^{fi,\#1} \left(1 - PD^{bank}\right) - c_{bank}^{monitoring} - c_{bank}^{screening} - R_{debtor}^{fi,\#1} (1 - \tilde{d}) \right\} \right], \end{aligned}$$

which can be further simplified to

$$\begin{aligned} & R_{debtor}^{fi,\#1} \left(1 - PD^{bank}\right) - c_{bank}^{monitoring} - c_{bank}^{screening} \\ & = I_0 + E^{bank} \left[Max \left\{ 0; R_{debtor}^{fi,\#1} \left(\tilde{d} - PD^{bank}\right) - c_{bank}^{monitoring} - c_{bank}^{screening} \right\} \right]. \end{aligned} \tag{25}$$

Solving Equation (25) for $R_{debtor}^{fi,\#1}$ and finally inserting the result in Equation (26) yields the nominal amounts of repayment $R_{debtor}^{fi,\#1}$ and $R_{creditor}^{fi,\#1}$, respectively, in case of $E = 0$. Due to Equation (24) and PD^{bank}, $c_{bank}^{monitoring}$, $c_{bank}^{screening} \geq 0$, $R_{bank}^{fi,\#1} \leq R_{debtor}^{fi,\#1}$ always holds.

Assuming that no insolvency penalty is applied to the debtors because the bank monitors them, the debtors participate if and only if

$$\underbrace{E^{true} \left[Max \left\{ m\tilde{y} - mR_{debtor}^{fi,\#1}; 0 \right\} \right]}_{\substack{\text{expected surplus from m projects} \\ \text{for the debtors}}} \geq 0, \tag{26}$$

which is always true by assumption.

If the number of creditors of the bank is small so that the monitoring costs of the $n \cdot m$ creditors lead to smaller transaction costs than the insolvency penalty applied to the bank, the incentive conditions of the bank and the creditors are (case *fi*,#2):

$$\underbrace{E^{bank}\left[Max\left\{mR_{debtor}^{fi,\#2}(1-\tilde{d})-mR_{bank}^{fi,\#2};0\right\}\right]}_{\text{expected surplus of the bank from financing m projects}}-\underbrace{mc_{bank}^{monitoring}}_{\substack{\text{non-pecuniary monitoring costs of the bank}\\ \text{for m projects for reducing ex post}\\ \text{information asymmetry with respect}\\ \text{to the debtors}}}$$
$$-\underbrace{mc_{bank}^{screening}}_{\substack{\text{non-pecuniary screening costs of the bank}\\ \text{for m projects for reducing ex ante information}\\ \text{asymmetry with respect to the debtors}}}-\underbrace{E}_{\substack{\text{initial investment of}\\ \text{the bank equity holder}}}\geq 0. \quad (27)$$

and

$$\underbrace{E^{bank}\left[Min\left\{mR_{bank}^{fi,\#2};mR_{debtor}^{fi,\#2}(1-\tilde{d})+E\right\}\right]}_{\text{expected repayments from the bank to the creditors}}-\underbrace{mnc_{creditor}^{monitoring}}_{\substack{\text{non-pecuniary monitoring costs of the}\\ \text{mn creditors for reducing ex post}\\ \text{information asymmetry with respect}\\ \text{to the bank}}}\geq\underbrace{mI_0}_{\substack{\text{initial investment sum}\\ \text{of the mn creditors}}} \quad (28)$$

$$\Leftrightarrow R_{bank}^{fi,\#2}-E^{bank}\left[Max\left\{R_{bank}^{fi,\#2}-R_{debtor}^{fi,\#2}(1-\tilde{d})-\frac{E}{m};0\right\}\right]-nc_{creditor}^{monitoring}-I_0\geq 0. \quad (29)$$

Summarizing both cases, the total transaction costs (TTC) (in case of $E > 0$) are given by:

$$TTC^{fi}=Min\left\{TTC^{fi,\#1};TTC^{fi,\#2}\right\}. \quad (30)$$

with

$$TTC^{fi,\#1}=\underbrace{E^{true}\left[Max\left\{mR_{bank}^{fi,\#1}-mR_{debtor}^{fi,\#1}(1-\tilde{d})-E;0\right\}\right]}_{\substack{\text{expected non-pecuniary insolvency penalty of the bank}\\ \text{resulting from m granted loans}}}+\underbrace{mc_{bank}^{monitoring}}_{\substack{\text{non-pecuniary monitoring}\\ \text{costs of the bank}\\ \text{for m projects}}}+\underbrace{mc_{bank}^{screening}}_{\substack{\text{non-pecuniary screening}\\ \text{costs of the bank}\\ \text{for m projects}}} \quad (31)$$

and

$$TTC^{fi,\#2} = \underbrace{mnc_{creditor}^{monitoring}}_{\substack{\text{non-pecuniary monitoring costs of the}\\ \text{mn creditors for reducing ex post}\\ \text{information asymmetry with respect}\\ \text{to the bank}}} + \underbrace{mc_{bank}^{monitoring}}_{\substack{\text{non-pecuniary monitoring}\\ \text{costs of the bank}\\ \text{for m projects}}} + \underbrace{mc_{bank}^{screening}}_{\substack{\text{non-pecuniary screening}\\ \text{costs of the bank}\\ \text{for m projects}}}. \quad (32)$$

Please note that, again, the total transaction costs are computed under the true probability measure. Obviously, the total transaction costs per project in the case of the financial intermediary solution increase in $c_{bank}^{monitoring}$, $c_{bank}^{screening}$ and $c_{creditor}^{monitoring}$. Please additionally note that in the case of the financial intermediary solution, the complete probability distribution of the default rate $\tilde{d}$ is needed to compute the total transaction costs and the nominal repayment amounts. In contrast, for the financial market solution, only the marginal distribution of the projects is necessary.

3.3.3 MPL platform solution

In this setting, the MPL platform does not grant credits itself and is not responsible for the ex post monitoring of the debtors. Thus, the platform is willing to participate if and only if the sum of the non-pecuniary fees it gets from the debtors and the creditors is larger than the non-pecuniary screening costs and the non-pecuniary costs for doing a bad screening based on the assumed penalty function applied to the MPL platform:

$$\begin{aligned} &\underbrace{mne_{creditor}^{mpl} R_{debtor}^{mpl,\#1}}_{\substack{\text{volume-dependent fees}\\ \text{paid by the mn creditors}}} + \underbrace{me_{debtor}^{mpl} R_{debtor}^{mpl,\#1}}_{\substack{\text{volume-dependent fees}\\ \text{paid by the m debtors}}} - \underbrace{mc_{plat}^{screening}}_{\substack{\text{non-pecuniary screening costs}\\ \text{of the MPL platform}\\ \text{for m projects}}} \\ &\underbrace{-E^{mpl=true}\left[\lambda m R_{debtor}^{mpl,\#1}\left(\underbrace{PD^{mpl}}_{=PD^{true}} - \tilde{d}\right)^2\right]}_{\substack{\text{non-pecuniary penalty for inaccurate screening}\\ \text{applied to the MPL platform}}} \geq 0 \end{aligned} \quad (33)$$

$$\underset{\substack{\text{assuming}\\ ne_{creditor}^{mpl}+e_{debtor}^{mpl}>\lambda Var^{true}\left[\tilde{d}\right]}}{\Leftrightarrow} \quad R_{debtor}^{mpl,\#1} \geq \frac{c_{plat}^{screening}}{ne_{creditor}^{mpl} + e_{debtor}^{mpl} - \lambda Var^{true}\left[\tilde{d}\right]}. \quad (34)$$

It is assumed that the penalty function motivates the MPL platform to do the screening as well as possible and that the platform is capable of doing a perfect screening, implying

$PD^{mpl} = PD^{true}$ and $E^{mpl}\left[\cdot\right] = E^{true}\left[\cdot\right]$.[17] As a consequence of the structure of the penalty function applied to the MPL platform, the penalty which the platform has to bear increases, the more volatile the default rate $\tilde{d}$ is. Furthermore, $ne_{creditor}^{mpl} + e_{debtor}^{mpl} - \lambda Var^{true}\left[\tilde{d}\right] > 0$ is assumed meaning that the fees that the platform gets per unit of total nominal repayment amount to the creditors are larger than the non-pecuniary penalty per unit total nominal repayment amount it has to bear. Due to $c_{plat}^{screening} \geq 0$ this is a necessary prerequisite for the MPL platform to participate.

Assuming that the creditors do not have to monitor the debtors because the insolvency penalty is applied to the debtors to motivate them to true ex post reporting, the participation condition of the creditors is (case *mpl*,#1):

$$\underbrace{E^{mpl=true}\left[mR_{debtor}^{mpl,\#1}\left(1-\tilde{d}\right)\right]}_{\substack{\text{expected repayments from}\\ \text{m loans granted by the creditors}\\ \text{via the MPL platform}}} - \underbrace{mne_{creditor}^{mpl}R_{debtor}^{mpl,\#1}}_{\substack{\text{volume-dependent fees}\\ \text{paid by the mn creditors}}} \geq \underbrace{mI_0}_{\substack{\text{initial investment sum}\\ \text{of the mn creditors}}} \tag{35}$$

$$\underset{1-PD^{true} > ne_{creditor}^{mpl}}{\Leftrightarrow} R_{debtor}^{mpl,\#1} \geq \frac{I_0}{1-PD^{true} - ne_{creditor}^{mpl}}. \tag{36}$$

The creditors participate if and only if the expected repayments from the loans they granted via the MPL platform are larger than the sum of the fees they paid to the platform and their initial investment sum. For Equation (36), $1 - PD^{true} > ne_{creditor}^{mpl}$ is assumed. Under the zero expected net return condition for the MPL platform and the creditors, combining Equations (34) and (36), the nominal repayment amount of the debtors is:

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[17] In fact, the MPL platform could also have the idea to spend reduced screening costs $c_{plat}^{bad\ screening} < c_{plat}^{screening}$ to get a biased estimate $PD^{mpl} \neq PD^{true}$ of the default probability only (as in the case of banks). Because of $E^{mpl}\left[\left(PD^{mpl}-\tilde{d}\right)^2\right] = E^{true}\left[\left(PD^{true}-\tilde{d}\right)^2\right]$ the penalty subjectively expected by the MPL platform would not change. However, as the MPL platform knows that it only produces biased PD estimates with reduced screening costs $c_{plat}^{bad\ screening}$, it also knows the true expected penalty will be larger as $E^{true}\left[\left(PD^{mpl}-\tilde{d}\right)^2\right] = \Delta^2 + E^{true}\left[\left(PD^{true}-\tilde{d}\right)^2\right]$ with $\Delta = PD^{mpl} - PD^{true}$ holds. Thus, assuming that $c_{plat}^{screening} - c_{plat}^{bad\ screening} < \lambda R_{debtor}^{mpl,\#1}\Delta^2$ is given, the MPL platform will indeed spend the larger screening costs $c_{plat}^{screening}$ to get a perfect estimate with $PD^{mpl} = PD^{true}$.

$$R_{debtor}^{mpl,\#1} = Max\left\{\frac{I_0}{1-PD^{true}-ne_{creditor}^{mpl}};\frac{c_{plat}^{screening}}{ne_{creditor}^{mpl}+e_{debtor}^{mpl}-\lambda Var^{true}\left[\tilde{d}\right]}\right\}. \tag{37}$$

In most cases, Equation (36) rather than Equation (34) will be binding for $R_{debtor}^{mpl,\#1}$. Whenever this is the case, $R_{debtor}^{mpl,\#1}$ increases in I_0, n, $e_{creditor}^{mpl}$ and PD^{true}.

Finally, assuming that the insolvency penalty is applied to the debtors, the debtors participate if and only if

$$\begin{aligned} &\underbrace{E^{true}\left[Max\left\{m\tilde{y}-mR_{debtor}^{mpl,\#1};0\right\}\right]}_{\substack{\text{expected surplus from m projects}\\ \text{for the debtors}}} - \underbrace{E^{true}\left[mR_{debtor}^{mpl,\#1}\tilde{d}\right]}_{\substack{\text{expected non-pecuniary insolvency penalty}\\ \text{resulting from m granted loans for reducing}\\ \text{ex post information asymmetry}}} - \underbrace{me_{debtor}^{mpl}R_{debtor}^{mpl,\#1}}_{\substack{\text{volume-dependent fees}\\ \text{paid by the m debtors}}} \geq 0 \\ &\underset{y>R_{debtor}^{mpl,\#1}}{\Leftrightarrow} \frac{y\left(1-PD^{true}\right)}{1+e_{debtor}^{mpl}} \geq R_{debtor}^{mpl,\#1}, \end{aligned} \tag{38}$$

where $y > R_{debtor}^{mpl,\#1}$ is assumed. The debtors participate when the expected surplus from the projects is larger than the expected non-pecuniary insolvency penalty plus the fees paid to the MPL platform.

If the number of creditors n per financed project is small, the non-pecuniary monitoring costs for reducing ex post information asymmetry are smaller than the costs resulting from applying the non-pecuniary insolvency penalty to the debtors. In this case, the incentive conditions for the creditors and the debtors are (case *mpl*,#2):

$$\underbrace{E^{mpl=true}\left[mR_{debtor}^{mpl,\#2}\left(1-\tilde{d}\right)\right]}_{\substack{\text{expected repayments from}\\ \text{m loans granted by the creditors}\\ \text{via the MPL platform}}} - \underbrace{mnc_{creditor}^{monitoring}}_{\substack{\text{non-pecuniary monitoring costs}\\ \text{of the mn creditors for reducing}\\ \text{ex post information asymmetry}}} - \underbrace{mne_{creditor}^{mpl}R_{debtor}^{mpl,\#2}}_{\substack{\text{volume-dependent fees}\\ \text{paid by the mn creditors}}} \geq \underbrace{mI_0}_{\substack{\text{initial investment sum}\\ \text{of the mn creditors}}} \tag{39}$$

$$\underset{1-PD^{true}>ne_{creditor}^{mpl}}{\Leftrightarrow} R_{debtor}^{mpl,\#2} \geq \frac{I_0+nc_{creditor}^{monitoring}}{1-PD^{true}-ne_{creditor}^{mpl}}. \tag{40}$$

and

$$\underbrace{E^{true}\left[Max\left\{m\tilde{y}-mR_{debtor}^{mpl,\#2};0\right\}\right]}_{\text{expected surplus from m projects for the debtors}}-\underbrace{me_{debtor}^{mpl}R_{debtor}^{mpl,\#2}}_{\text{volume-dependent fees paid by the m debtors}}\geq 0\,. \tag{41}$$

Summarizing both cases, the total transaction costs (TTC) are given by:

$$TTC^{mpl}=Min\left\{TTC^{mpl,\#1};TTC^{mpl,\#2}\right\}. \tag{42}$$

with

$$TTC^{mpl,\#1}=\underbrace{mR_{debtor}^{mpl,\#1}PD^{true}}_{\text{expected non-pecuniary insolvency penalty applied to the debtors}}+\underbrace{mc_{plat}^{screening}}_{\text{non-pecuniary screening costs of the MPL platform for m projects}}+\underbrace{\lambda mR_{debtor}^{mpl,\#1}Var^{true}\left[\tilde{d}\right]}_{\text{non-pecuniary penalty for inaccurate screening applied to the MPL platform}} \tag{43}$$

and

$$TTC^{mpl,\#2}=\underbrace{mnc_{creditor}^{monitoring}}_{\text{non-pecuniary monitoring costs of the mn creditors}}+\underbrace{mc_{plat}^{screening}}_{\text{non-pecuniary screening costs of the MPL platform for m projects}}+\underbrace{\lambda mR_{debtor}^{mpl,\#2}Var^{true}\left[\tilde{d}\right]}_{\text{non-pecuniary penalty for inaccurate screening applied to the MPL platform}}\,. \tag{44}$$

Obviously, the total transaction costs per project for the MPL platform solution increase in $c_{plat}^{screening}$, λ, $Var^{true}\left[\tilde{d}\right]$ and PD^{true}. The latter parameter directly affects the total transaction costs only in case *mpl*,#1, but in both cases an indirect effect exists because $R_{debtor}^{mpl,\#1}$ as well as $R_{debtor}^{mpl,\#2}$ are also increasing in PD^{true}. In case *mpl*,#2, $c_{creditor}^{monitoring}$ also has a directly and indirectly increasing impact on the total transaction costs.

3.4 Results

Summarizing the results of the previous Section 3.3, the following main result is given.

PROPOSITION 1:

The MPL platform solution dominates the financial intermediary solution in terms of smaller total transaction costs if and only if

$$TTC^{mpl} < TTC^{fi} \tag{45}$$

with TTC^{mpl} defined as in Equation (42)and TTC^{fi} defined as in Equation (30).

The financial intermediary solution dominates the market solution in terms of smaller total transaction costs if and only if

$$TTC^{fi} < TTC^{market} \tag{46}$$

with TTC^{market} defined as in Equation (15).

The MPL platform solution dominates the market solution in terms of smaller total transaction costs if and only if

$$TTC^{mpl} < TTC^{market} . \tag{47}$$

As $R_{bank}^{fi,\#1(\#2)}$ and $R_{debtor}^{fi,\#1(\#2)}$ are only implicitly defined as numerical solutions of equations given in Section 3.3, it is difficult to derive general conditions under which a specific institutional arrangement is superior to others. Thus, numerical examples are considered in the following section to better understand the implications of the model.

3.5 Numerical examples

For the numerical examples, a default parameter setting is defined with $I_0 = 1$, $E = 0.12m$, $a^{true} = 0$, $b^{true} = 0.5$, $\beta^{bank} = 0.5$, $\beta^{market} = 1.5\beta^{bank} = 0.75$, $c_{bank}^{monitoring} = c_{creditor}^{monitoring} = 0.02$, $c_{bank}^{screening} = c_{creditor}^{screening} = 0.02$, $c_{mpl}^{screening} = 0.25c_{bank}^{screening} = 0.005$, $e_{creditor}^{mpl} = e_{debtor}^{mpl} = 0.01$ and $\lambda = 1$. This parameter setting implies a true default probability $PD^{true} = 0.25$. It is assumed that the bias factor β^{market} of the market is 50 percent larger than that one of the bank and that the market, as well as the bank, overestimates the true default probability. In addition, it is assumed that the MPL platform can carry out the screening to reduce ex ante informational asymmetry at a quarter of the bank's cost. For numerically computing R_{bank}^{fi} and R_{debtor}^{fi}, the *fsolve* order in MAPLE is used.

Financial intermediary solution:

As discussed in Sections 3.3.1 and 3.3.3, the nominal amount that the debtors have to pay the creditors increases with rising true default probability PD^{true}. As Table 1 shows this is also the case for the nominal amount the debtors have to pay to the bank in the financial intermediary solution, irrespective of whether the insolvency penalty is applied to the bank (case *fi*,#1) or the creditors monitor the bank (case *fi*,#2). Furthermore, it can be seen that $R_{debtor}^{fi} > R_{bank}^{fi}$ holds, which is also true in both cases. For $E = 0$, this relationship is generally proven in Section 3.3.2 for the case *fi*,#1. The difference between the nominal amounts R_{bank}^{fi} and R_{debtor}^{fi} increases with rising values for PD^{true}, which also holds in both cases. While $R_{bank}^{fi,\#1}$ and $R_{debtor}^{fi,\#1}$ are independent from the number n of creditors per project, both nominal amounts increase in n for the case *fi*,#2 in which the creditors monitor the bank.

Table 1:

Nominal amounts of debt and total transaction costs for the financial intermediary solution

The nominal credit amounts per project that the debtors have to pay to the bank and that the bank has to pay to its creditors, respectively, as well as the total transaction costs per project of the financial intermediary solution are shown for varying values of the bias factor, varying values of the number of creditors per project, and varying boundaries of the uniformly distributed default rate. The arithmetic mean of the two boundary values yields the true default probability. All other parameters correspond to the default setting. In bold, the lowest total transaction costs are marked.

$\left[a^{true};b^{true}\right]$	$[0;0.1]$	$[0;0.2]$	$[0;0.3]$	$[0;0.4]$	$[0;0.5]$	$[0;0.6]$
$\beta^{bank}=-0.5$						
$R_{bank}^{fi,\#1}$	1.000	1.000	1.000	1.000	1.000	1.000
$R_{debtor}^{fi,\#1}$	1.190	1.221	1.254	1.289	1.326	1.362
$R_{bank}^{fi,\#2}$ (n=10)	1.200	1.200	1.200	1.200	1.200	1.200
$R_{debtor}^{fi,\#2}$ (n=10)	1.395	1.432	1.470	1.511	1.552	1.591
$R_{bank}^{fi,\#2}$ (n=5)	1.100	1.100	1.100	1.100	1.100	1.100
$R_{debtor}^{fi,\#2}$ (n=5)	1.292	1.326	1.362	1.400	1.439	1.477
$R_{bank}^{fi,\#2}$ (n=1)	1.020	1.020	1.020	1.020	1.020	1.020
$R_{debtor}^{fi,\#2}$ (n=1)	1.210	1.242	1.276	1.311	1.348	1.385
$TTC^{fi,\#1}$	**0.040**	**0.040**	**0.040**	**0.051**	0.076	0.109
$TTC^{fi,\#2}$ (n=10)	0.240	0.240	0.240	0.240	0.240	0.240
$TTC^{fi,\#2}$ (n=5)	0.140	0.140	0.140	0.140	0.140	0.140
$TTC^{fi,\#2}$ (n=1)	0.060	0.060	0.060	0.060	**0.060**	**0.060**
$\beta^{bank}=0$						
$R_{bank}^{fi,\#1}$	1.000	1.000	1.000	1.001	1.011	1.032
$R_{debtor}^{fi,\#1}$	1.221	1.289	1.362	1.429	1.522	1.649
$R_{bank}^{fi,\#2}$ (n=10)	1.200	1.200	1.200	1.205	1.230	1.273
$R_{debtor}^{fi,\#2}$ (n=10)	1.432	1.511	1.591	1.667	1.761	1.872
$R_{bank}^{fi,\#2}$ (n=5)	1.100	1.100	1.100	1.102	1.121	1.157
$R_{debtor}^{fi,\#2}$ (n=5)	1.326	1.400	1.477	1.547	1.632	1.734
$R_{bank}^{fi,\#2}$ (n=1)	1.020	1.020	1.020	1.021	1.035	1.065
$R_{debtor}^{fi,\#2}$ (n=1)	1.242	1.311	1.385	1.452	1.529	1.623
$TTC^{fi,\#1}$	**0.040**	**0.040**	**0.040**	**0.041**	**0.051**	0.072
$TTC^{fi,\#2}$ (n=10)	0.240	0.240	0.240	0.240	0.240	0.240
$TTC^{fi,\#2}$ (n=5)	0.140	0.140	0.140	0.140	0.140	0.140
$TTC^{fi,\#2}$ (n=1)	0.060	0.060	0.060	0.060	0.060	**0.060**

Table 1 (continued):
Nominal amounts of debt and total transaction costs for the financial intermediary solution

$\left[a^{true};b^{true}\right]$	$[0;0.1]$	$[0;0.2]$	$[0;0.3]$	$[0;0.4]$	$[0;0.5]$	$[0;0.6]$
$\beta^{bank}=0.5$						
$R_{bank}^{fi,\#1}$	1.000	1.000	1.004	1.032	1.081	1.157
$R_{debtor}^{fi,\#1}$	1.254	1.362	1.471	1.649	1.913	2.303
$R_{bank}^{fi,\#2}$ (n=10)	1.200	1.200	1.215	1.273	1.372	1.524
$R_{debtor}^{fi,\#2}$ (n=10)	1.470	1.591	1.712	1.872	2.078	2.346
$R_{bank}^{fi,\#2}$ (n=5)	1.100	1.100	1.110	1.157	1.243	1.378
$R_{debtor}^{fi,\#2}$ (n=5)	1.362	1.477	1.588	1.734	1.922	2.168
$R_{bank}^{fi,\#2}$ (n=1)	1.020	1.020	1.026	1.065	1.141	1.262
$R_{debtor}^{fi,\#2}$ (n=1)	1.276	1.385	1.489	1.623	1.798	2.026
$TTC^{fi,\#1}$	**0.040**	**0.040**	**0.040**	**0.040**	**0.040**	**0.045**
$TTC^{fi,\#2}$ (n=10)	0.240	0.240	0.240	0.240	0.240	0.240
$TTC^{fi,\#2}$ (n=5)	0.140	0.140	0.140	0.140	0.140	0.140
$TTC^{fi,\#2}$ (n=1)	0.060	0.060	0.060	0.060	0.060	0.060

For both cases *fi*,#1 and *fi*,#2, Table 1 also shows the total transaction costs per project of the financial intermediary solution for varying values of the bias factor β^{bank}, varying values of the number of creditors per project n, and varying boundaries $\left[a^{true};b^{true}\right]$ of the uniformly distributed default rate $\tilde{d}$. The latter variation does not only imply varying true default probabilities $PD^{true}=0.5\left(a^{true}+b^{true}\right)$ but also a varying riskiness $Var^{true}\left[\tilde{d}\right]=1/12\left(b^{true}-a^{true}\right)^2$ of the default rate.

As it was assumed that always an institutional arrangement is chosen that leads to the minimal total transaction costs, the total transactions costs per project are given by the minimum of $TTC^{fi,\#1}$ and $TTC^{fi,\#2}$. As can be seen in Table 1, this minimum is more likely to be given by $TTC^{fi,\#2}$ (resulting from creditors monitoring the bank) the larger the true default probability PD^{true} is, the smaller the bias factor β^{bank} is, and the smaller the number n of creditors per project is. A smaller number n of creditors per project obviously leads to lower monitoring costs, making the monitoring solution relatively more favorable than the insolvency penalty solution. As the expectation term in Equation (31) for the total transaction costs $TTC^{fi,\#1}$ of the financial intermediary solution in case *fi*_#1 is computed under the true probability measure, the bias factor β^{bank} only can have an indirect effect on $TTC^{fi,\#1}$ via the absolute difference between $R^{fi,\#1}_{debtor}$ and $R^{fi,\#1}_{bank}$. As Table 1 shows, this difference is increasing in β^{bank}. This effect leads to decreasing transaction costs $TTC^{fi,\#1}$ for rising values of β^{bank} because $R^{fi,\#1}_{debtor}$ has a negative sign in the expectation term of Equation (31). Hence, the lower the bias factor β^{bank} is, the larger $TTC^{fi,\#1}$ is, so that the monitoring solution becomes relatively more favorable. The true default probability PD^{true} affects the probability distribution of the default rate $\tilde{d}$ in the expectation term in Equation (31) as well as on the nominal debt amounts $R^{fi,\#1}_{debtor}$ and $R^{fi,\#1}_{bank}$. On the one hand, increasing values of PD^{true} lead to larger differences between $R^{fi,\#1}_{debtor}$ and $R^{fi,\#1}_{bank}$ (see Table 1) and, hence, to smaller transaction costs $TTC^{fi,\#1}$. On the other hand, rising values of PD^{true} lead to a larger mean and variance of the default rate $\tilde{d}$ and, therefore, to higher transaction costs $TTC^{fi,\#1}$. In sum, the latter effect dominates so that the expected insolvency penalty and, thus, $TTC^{fi,\#1}$ increases with increasing values of PD^{true}, making the monitoring solution relatively more favorable.

Figure 2 shows the influence of the amount of bank equity E on the nominal credit amounts R^{fi}_{debtor} and R^{fi}_{bank} as well as on the total transaction costs per project. Under the default parameter setting, the insolvency penalty solution (case *fi,*#1) always yields the lowest total transaction costs. As can be seen, the effect of varying bank equity E is relatively small. As expected, there is a negative relationship, but the decline with rising E is not very pronounced.

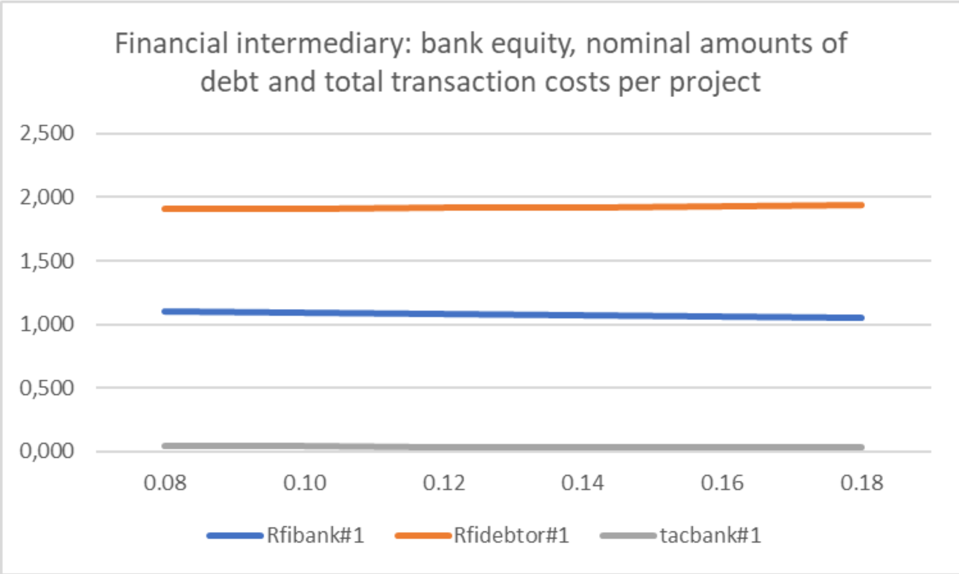

Figure 2: The nominal credit amounts per project that the debtors have to pay to the bank (Rfidebtor#1) and that the bank has to pay to its creditors (Rfibank#1), respectively, as well as the total transaction costs per project of the financial intermediary solution (tacbank#1) are shown. On the x-axis, varying values of bank equity are exhibited. All other parameters correspond to the default setting.

MPL platform solution:

For both cases *mpl*,#1 and *mpl*,#2, Table 2 shows the nominal credit amount per project that the debtors have to pay to the creditors and the total transaction costs per project of the MPL platform solution for varying values of the number of creditors per project n and varying boundaries $\left[a^{true};b^{true}\right]$ of the uniformly distributed default rate $\tilde{d}$. To ensure $ne^{mpl}_{creditor}+e^{mpl}_{debtor}>\lambda Var^{true}\left[\tilde{d}\right]$ which is necessary for the MPL platform to participate (see Section 3.3.3), b^{true} is restricted to a maximum value of 0.4.

For both cases *mpl*,#1 and *mpl,*#2, the nominal credit amount per project that the debtors getting a credit via the MPL platform have to pay to the creditors increases in PD^{true} and in n. Both influences are evident from the lower boundaries given in Equations (36) and (40), respectively, which are binding in the Max-condition (37). The influence of n on $R^{mpl,\#2}_{debtor}$ is more substantial than on $R^{mpl,\#1}_{debtor}$ because n additionally appears in the nominator of $R^{mpl,\#2}_{debtor}$.

Again, the total transaction costs per project are given by the minimum of $TTC^{mpl,\#1}$ and $TTC^{mpl,\#2}$ in each scenario. As seen in Table 2, this minimum is more likely to be given by $TTC^{mpl,\#2}$ (resulting from creditors monitoring the debtors) the larger the true default probability PD^{true} and the smaller the number n of creditors per project is. An increasing true default probability PD^{true} has a direct effect on $TTC^{mpl,\#1}$ due to an increasing expected insolvency penalty applied to the debtors. In contrast, it has only an indirect impact on $TTC^{mpl,\#2}$ due to an increasing nominal credit amount $R^{mpl,\#2}_{debtor}$ and, therefore, a rising penalty for inaccurate screening applied to the MPL platform (which is also the case for $R^{mpl,\#1}_{debtor}$).[18] That is why the monitoring solution becomes relatively more favorable for an increasing true default probability PD^{true}. A growing number n of creditors per project has a direct effect on $TTC^{mpl,\#2}$ due to increasing monitoring costs of the debtors. In contrast, it has only an indirect impact on $TTC^{mpl,\#1}$ due to an increasing nominal credit amount $R^{mpl,\#1}_{debtor}$, which leads to a larger expected insolvency penalty applied to the debtors and a larger penalty for inaccurate screening applied to the MPL platform. The latter effect also holds (even in a stronger way) for the monitoring solution. That is why the insolvency penalty solution becomes relatively more favorable for an increasing number n of creditors per project.

[18] Furthermore, in both cases *fi,*#1 and *fi,*#2, an increasing true default probability PD^{true} leads to a growing riskiness $Var^{true}\left[\tilde{d}\right]$ of the default rate, which also yields a growing penalty for inaccurate screening applied to the MPL platform.

Table 2:
Nominal amounts of debt and total transaction costs for the MPL platform solution

The nominal credit amounts per project that the debtors have to pay to the creditors and the total transaction costs per project of the MPL platform solution are shown for varying values of the number of creditors per project and varying boundaries of the uniformly distributed default rate. The arithmetic mean of the two boundary values yields the true default probability All other parameters correspond to the default setting. In bold, the lowest total transaction costs are marked.

$\left[a^{true};b^{true}\right]$	$[0;0.1]$	$[0;0.2]$	$[0;0.3]$	$[0;0.4]$
$R_{debtor}^{mpl,\#1}$ (n=10)	1.176	1.250	1.333	1.429
$R_{debtor}^{mpl,\#2}$ (n=10)	1.412	1.500	1.600	1.714
$R_{debtor}^{mpl,\#1}$ (n=5)	1.111	1.176	1.250	1.333
$R_{debtor}^{mpl,\#2}$ (n=5)	1.222	1.294	1.375	1.467
$R_{debtor}^{mpl,\#1}$ (n=1)	1.064	1.124	1.191	1.266
$R_{debtor}^{mpl,\#2}$ (n=1)	1.085	1.146	1.214	1.291
$TTC^{mpl,\#1}$ (n=10)	**0.065**	**0.134**	**0.215**	0.310
$TTC^{mpl,\#1}$ (n=5)	**0.061**	0.127	0.202	0.289
$TTC^{mpl,\#1}$ (n=1)	0.059	0.121	0.192	0.275
$TTC^{mpl,\#2}$ (n=10)	0.206	0.210	0.217	**0.228**
$TTC^{mpl,\#2}$ (n=5)	0.106	**0.109**	**0.115**	**0.125**
$TTC^{mpl,\#2}$ (n=1)	**0.026**	**0.029**	**0.034**	**0.042**

Financial market solution:

For both cases *market*,#1 and *market*,#2, Table 3 shows the nominal credit amount per project that the debtors have to pay to the creditors and the total transaction costs per project of the financial market solution for varying values of the number of creditors per project n and varying boundaries $\left[a^{true};b^{true}\right]$ of the uniformly distributed default rate $\tilde{d}$. As expected and already stated in Section 3.3.1, an increase in both parameters n and PD^{true} leads to a rise in the nominal credit amount per project (see Equations (9) and (14)). The minimum of the total transaction costs $TTC^{mpl,\#1}$ and $TTC^{mpl,\#2}$ is more likely to be given by $TTC^{mpl,\#2}$ (resulting from creditors monitoring the debtors) the larger the true default probability PD^{true} and the smaller the number n of creditors per project is. These are the same effects as observed before for the MPL platform solution. An increasing true default probability PD^{true} has a direct effect on $TTC^{market,\#1}$ due to an increasing expected insolvency penalty applied to the debtors, while it does not affect $TTC^{market,\#2}$. That is why the monitoring solution becomes relatively more favorable for an increasing true default probability PD^{true}. A growing number n of creditors per project is having a direct impact on both $TTC^{market,\#1}$ and $TTC^{market,\#2}$ due to increasing screening costs. However, it has an additional direct effect on the monitoring costs in $TTC^{market,\#2}$, while it has only an additional indirect effect on $TTC^{market,\#1}$ due to an increasing nominal credit amount $R_{debtor}^{market,\#1}$, which leads to a larger expected insolvency penalty applied to the debtors. That is why the insolvency penalty solution becomes relatively more favorable for a growing number n of creditors per project.

For both cases *market*,#1 and *market*,#2, Table 4 shows the nominal credit amount per project that the debtors have to pay to the creditors and the total transaction costs per project of the market solution for varying values of the number of creditors per project n and varying bias factors β^{market}. For both cases, the nominal credit amount per project is increasing in β^{market} because $PD^{creditor}$ in Equations (9) and (14), respectively, is increasing in β^{market}. In all parameter scenarios considered in Table 4, the monitoring solution leads to smaller total transaction costs than the insolvency penalty solution. Therefore, as $TTC^{market,\#2}$ is independent from β^{market}, the bias factor does not influence the total transaction costs in this numerical example. For $TTC^{market,\#1}$, there is an indirect effect via rising values of R_{debtor}^{market}. Remarkable is that for $TTC^{market,\#1}$ the impact of the bias factor β^{market} is opposite to that of the bias factor β^{bank} on $TTC^{fi,\#1}$ in the financial intermediary solution.

Table 3:
Nominal amounts of debt and total transaction costs for the financial market solution

The nominal credit amounts per project that the debtors have to pay to the creditors and the total transaction costs per project of the financial market solution are shown for varying values of the number of creditors per project and varying boundaries of the uniformly distributed default rate. The arithmetic mean of the two boundary values yields the true default probability. All other parameters correspond to the default setting. In bold, the lowest total transaction costs are marked.

$\left[a^{true};b^{true}\right]$	$[0;0.1]$	$[0;0.2]$	$[0;0.3]$	$[0;0.4]$	$[0;0.5]$	$[0;0.6]$
$R_{debtor}^{market,\#1}$ (n=10)	1.315	1.455	1.627	1.846	2.133	2.400
$R_{debtor}^{market,\#2}$ (n=10)	1.534	1.697	1.898	2.152	2.489	2.800
$R_{debtor}^{market,\#1}$ (n=5)	1.205	1.333	1.491	1.692	1.956	2.200
$R_{debtor}^{market,\#2}$ (n=5)	1.315	1.455	1.627	1.846	2.133	2.400
$R_{debtor}^{market,\#1}$ (n=1)	1.118	1.236	1.383	1.569	1.813	2.040
$R_{debtor}^{market,\#2}$ (n=1)	1.140	1.261	1.410	1.600	1.849	2.080
$TTC^{market,\#1}$ (n=10)	**0.266**	**0.345**	0.444	0.569	0.733	0.920
$TTC^{market,\#1}$ (n=5)	**0.160**	0.233	0.324	0.438	0.589	0.760
$TTC^{market,\#1}$ (n=1)	0.076	0.144	0.227	0.334	0.473	0.632
$TTC^{market,\#2}$ (n=10)	0.400	0.400	**0.400**	**0.400**	**0.400**	**0.400**
$TTC^{market,\#2}$ (n=5)	0.200	**0.200**	**0.200**	**0.200**	**0.200**	**0.200**
$TTC^{market,\#2}$ (n=1)	**0.040**	**0.040**	**0.040**	**0.040**	**0.040**	**0.040**

Table 4:
Nominal amounts of debt and total transaction costs for the financial market solution with varying bias factor

The nominal credit amounts per project that the debtors have to pay to the creditors and the total transaction costs per project of the financial market solution are shown for varying values of the number of creditors per project and varying bias factors. All other parameters correspond to the default setting. In bold, the lowest total transaction costs are marked.

β^{market}	–0.75	–0.25	0	0.25	0.5	0.75
$R_{debtor}^{market,\#1}$ (n=10)	1.280	1.477	1.600	1.745	1.920	2.133
$R_{debtor}^{market,\#2}$ (n=10)	1.493	1.723	1.867	2.036	2.240	2.489
$R_{debtor}^{market,\#1}$ (n=5)	1.173	1.354	1.467	1.600	1.760	1.966
$R_{debtor}^{market,\#2}$ (n=5)	1.280	1.477	1.600	1.745	1.920	2.133
$R_{debtor}^{market,\#1}$ (n=1)	1.088	1.255	1.360	1.484	1.632	1.813
$R_{debtor}^{market,\#2}$ (n=1)	1.109	1.280	1.387	1.513	1.664	1.849
$TTC^{market,\#1}$ (n=10)	0.520	0.569	0.600	0.636	0.680	0.733
$TTC^{market,\#1}$ (n=5)	0.393	0.438	0.467	0.500	0.540	0.589
$TTC^{market,\#1}$ (n=1)	0.292	0.334	0.360	0.391	0.428	0.473
$TTC^{market,\#2}$ (n=10)	**0.400**	**0.400**	**0.400**	**0.400**	**0.400**	**0.400**
$TTC^{market,\#2}$ (n=5)	**0.200**	**0.200**	**0.200**	**0.200**	**0.200**	**0.200**
$TTC^{market,\#2}$ (n=1)	**0.040**	**0.040**	**0.040**	**0.040**	**0.040**	**0.040**

Comparison of total transaction costs:

The main objective of the presented model is to compare the total transaction costs of MPL platforms relative to those of banks and the financial market. As Table 5 shows, in the numerical example, the MPL platform solution only yields the lowest total transaction costs out of all three considered institutional arrangements when simultaneously the true default probability is low to medium and the number of creditors per project is small. This is true for an under- as well as an overestimation of the true default probability by the bank and the creditors, respectively.[19]

In reality, it is not evident that MPL platforms indeed mainly serve debtors of high credit quality, instead the opposite seems to be true.[20] However, the results are ambiguous with respect to this result.[21] In contrast to this, there has actually been a trend towards MPL platforms moving away from peer-to-peer platforms to peer-to-institutional platforms, where the creditors are increasingly coming from the group of institutional investors.[22] Due to the capital strength of these investors, the number of creditors per project should actually tend to fall as a result. As can be seen by the transaction costs-based analysis, this development makes MPL platforms more likely to be the most favorable institutional arrangement.

For a medium or large number of creditors, the financial intermediary solution is always the transaction costs-minimal institutional arrangement, irrespective of the size of the true default probability and also irrespective of the sign of the bias factor. Obviously, the assumed superior screening ability of the MPL platform cannot change the dominance of the financial intermediary solution. Furthermore, Table 5 shows that only when simultaneously the true default probability is high and the number of creditors per project is small the financial market solution yields the lowest total transaction costs.

[19] The computations for Table 5 have been repeated for reduced monitoring and screening costs. For this, they are set to one-tenth of those values used in the default setting. The results for the ranking of the total transaction costs qualitatively do not change (results are available upon request from the author). If it all, the number of scenarios in which the MPL platform is dominant decreases because the MPL platform solution no longer yields the lowest total transaction costs when simultaneously the true default probability is medium and the number of creditors per project is small.

[20] See, e. g., Chava et al. (2021), de Roure et al. (2022), and Di Maggio and Yao (2021).

[21] For example, in contrast, Braggion et al. (2023, p. 15) find a relatively low default rate of 1% for a large Chinese MPL platform between 2010 and 2017. Furthermore, they observe a downward trend in default rates, which they interpret as a change in the composition of the group of MPL investors who tend to be more focused on limiting risk than seeking yields (see Braggion et al. (2023, p. 13)). In the US mortgage market, Fuster et al. (2019) find lower default rates for loans originated by fintechs in specific segments, while Buchak et al. (2018) find no differences in other segments.

[22] See Thakor (2020, p. 7).

Table 5:
Total transaction costs for different institutional arrangements

The total transaction costs per project for different institutional arrangements are shown for varying values of the bias factor, varying values of the number of creditors per project, and varying boundaries of the uniformly distributed default rate. The arithmetic mean of the two boundary values yields the true default probability. All other parameters correspond to the default setting. In bold, the lowest total transaction costs are marked.

$\left[a^{true};b^{true}\right]$	$[0;0.1]$	$[0;0.2]$	$[0;0.3]$	$[0;0.4]$
$\beta^{bank}=-0.5,\beta^{market}=-0.75$				
$n=10$				
TTC^{market}	0.261	0.323	0.387	0.400
$TTC^{mpl,\lambda=1}$	0.065	0.134	0.215	0.228
TTC^{fi}	**0.040**	**0.040**	**0.040**	**0.051**
$n=5$				
TTC^{market}	0.156	0.200	0.200	0.200
$TTC^{mpl,\lambda=1}$	0.061	0.109	0.115	0.125
TTC^{fi}	**0.040**	**0.040**	**0.040**	**0.051**
$n=1$				
TTC^{market}	0.040	0.040	0.040	**0.040**
$TTC^{mpl,\lambda=1}$	**0.026**	**0.029**	**0.034**	0.042
TTC^{fi}	0.040	0.040	0.040	0.051
$\beta^{bank}=0.5,\beta^{market}=0.75$				
$n=10$				
TTC^{market}	0.266	0.345	0.400	0.400
$TTC^{mpl,\lambda=1}$	0.065	0.134	0.215	0.228
TTC^{fi}	**0.040**	**0.040**	**0.040**	**0.040**
$n=5$				
TTC^{market}	0.160	0.200	0.200	0.200
$TTC^{mpl,\lambda=1}$	0.061	0.109	0.115	0.125
TTC^{fi}	**0.040**	**0.040**	**0.040**	**0.040**
$n=1$				
TTC^{market}	0.040	0.040	0.040	**0.040**
$TTC^{mpl,\lambda=1}$	**0.026**	**0.029**	**0.034**	0.042
TTC^{fi}	0.040	0.040	0.040	0.040

4 Discussion

In this section, various modifications of the default setting and their implications for the superiority of one of the institutional arrangements are discussed.

4.1 Effect of alternative default rate distribution

Up to now, it has been assumed that the results $\tilde{y} \in \{0; y\}$ of the m projects carried out by the debtors are marginally Bernoulli-distributed with $P\left(\tilde{y}=0\right)=PD^{true}$ and that a uniform distribution on $\left[a^{true};b^{true}\right]$ with $E^{true}\left[\tilde{d}\right]=PD^{true}$ can represent the default rate $\tilde{d}$ of the m dependent projects. This latter assumption has been used for ease of computation but without making explicit for which kind of joint default mechanism this probability distribution of the default rate could emerge. Furthermore, in contrast to Diamond (1984), the default rate distribution does not depend on the number m of projects carried out.[23]

In this section, the probability distribution of the default rate is explicitly derived based on the marginal default behavior of the projects, a specific joint default mechanism, and the assumption $m \to \infty$. This is basically the default modelling approach employed in the credit portfolio model CreditMetrics™ originally developed by JPMorgan and used in the context of credit portfolio risk management.[24] For further details of this approach, see Grundke (2005), Schönbucher (2003, pp. 305), and Vasicek (1987, 2002).

It is assumed that a project $k \in \{1,\ldots,m\}$ defaults if a latent credit quality variable R_k realized from $t=0$ to $t=1$ falls short of some threshold $c_k = c$. The latent variable R_k is modelled by:[25]

$$R_k = \sqrt{\rho}\cdot Z + \sqrt{1-\rho}\cdot \varepsilon_k \qquad (k \in \{1,\ldots,m\}) \tag{48}$$

where Z and $\varepsilon_1,\ldots,\varepsilon_m$ are mutually independent, standard normally distributed stochastic variables. The random variable Z represents systematic credit risk affecting all firms, where-

[23] For an increasing number of projects, the dispersion of the default rate should decrease due to diversification effects. As in Diamond (1984), this is only in favor of the financial intermediary solution because the insolvency penalty is less frequently applied to the bank and, hence, the transaction costs decrease for this institutional arrangement.
[24] See Gupton et al. (1997).
[25] See Vasicek (1987, 2002).

as the stochastic variables ε_k ($k \in \{1,\ldots,m\}$) represent idiosyncratic credit risk. The specification in Equation (48) implies that all latent variables R_k are standard normally distributed and that the correlation $Corr(R_k, R_l)$ ($k,l \in \{1,\ldots,m\}$, $k \neq l$) between the latent variables of two different projects is equal to ρ. This value is usually called asset return correlation. From $R_k \sim N(0,1)$ follows that the default barrier c is given by:

$$c = \Phi^{-1}(PD^{true}) \tag{49}$$

where $\Phi^{-1}(\cdot)$ is the inverse of the cumulative density function of the standard normal distribution. The probability that a project n defaults, conditional on the realization of the systematic credit risk factor Z, can easily be computed as:[26]

$$P\left(R_k \leq c \middle| Z = z\right) = \Phi\left(\frac{c - \sqrt{\rho} \cdot z}{\sqrt{1-\rho}}\right). \tag{50}$$

Conditional on the realization of the random variable Z, the latent credit quality variables and, hence, the projects' defaults are independent. On the one hand, this implies that the number of project defaults is conditionally binomially distributed.[27] On the other hand, conditional independence implies that the (strong) law of large numbers can be applied,[28] which ensures that with the number of projects approaching infinity, the fraction of projects that actually default equals almost surely the conditional default probability (50). Thus, provided that there are sufficiently many projects m, the default rate $\tilde{d}$ is approximated by:

$$\tilde{d} \approx \Phi\left(\frac{\Phi^{-1}(PD^{true}) - \sqrt{\rho} \cdot Z}{\sqrt{1-\rho}}\right) \tag{51}$$

[26] See Schönbucher (2003, p. 308).
[27] See Schönbucher (2003, p. 308).
[28] See Billingsley (1995, p. 282).

with $Z \sim N(0,1)$. A random variable $\tilde{d}$ with the representation given in Equation (51) is called Vasicek-distributed with parameters PD^{true} and ρ. It can be shown that the probability density function $f(x)$ of the default rate $\tilde{d}$ for $x \in [0,1]$ equals:[29]

$$f(x) = \sqrt{\frac{1-\rho}{\rho}} \exp\left\{ \frac{1}{2}\left(\Phi^{-1}(x)\right)^2 - \frac{1}{2\rho}\left(\Phi^{-1}(PD^{true}) - \sqrt{1-\rho}\,\Phi^{-1}(x)\right)^2 \right\}. \qquad (52)$$

The probability density function $f(x)$ is asymmetric on $[0,1]$ and yields $E^{true}\left[\tilde{d}\right] = PD^{true}$. The larger the asset return correlation ρ, the more probability mass is shifted to the distribution's tails. This is the distribution function for the default rate chosen in this section. However, in fact, this only affects the nominal amounts of debt and the total transaction costs in the financial intermediary solution and (via the penalty $\lambda m R_{debtor}^{mpl,\#1(\#2)} Var^{true}\left[\tilde{d}\right]$ for inaccurate screening applied to the MPL platform) in the MPL platform solution. In all other cases, only the marginal distribution of the project results is needed. As in Section 3.1 (see Equation (3)), the biased default probability estimated by the bank is related to the true default probability by $PD^{bank} = PD^{true} \cdot \left(1+\beta^{bank}\right)$ with $\beta^{bank} \in \left[-1; 1/PD^{true} - 1\right]$.[30]

For an asset return correlation of $\rho = 0.2$, Table 6 shows that, as before, the total transaction costs of the financial intermediary solution are lowest for most parameter scenarios.[31] Again, only when simultaneously the default probability is low to medium and the number of creditors per project is small, the MPL platform solution is dominant. Also, as before, when simultaneously the default probability is high and the number of creditors per project is small, the financial market solution yields the lowest total transaction costs. In all other cases, the financial intermediary solution is dominant.

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[29] See Schönbucher (2003, p. 311).

[30] To speed up the computations in Maple, the invertible approximation of the cumulative standard normal probability distribution function of Soranzo and Epure (2014) has been used instead of the corresponding Maple function. Furthermore, the expectation terms in Equations (18), (21), and (27), (28), respectively, and (31) are approximated by using the Simpson rule on [0.0001; 0.9999] with 100 subintervals.

[31] For the internal ratings-based approach of the Capital Requirement Regulation (CRR) for banks in the EU, the employed values for this parameter are all below 0.3. Thus, an assumption of 0.2 for the asset return correlation seems reasonable.

Table 6:
Total transaction costs for different institutional arrangements with Vasicek-distributed default rates

The total transaction costs per project for different institutional arrangements and Vasicek-distributed default rates are shown for varying values of the bias factor, varying values of the number of creditors per project, and varying default probabilities. The asset return correlation is $\rho = 0.2$. All other parameters correspond to the default setting. In bold, the lowest total transaction costs are marked.

PD^{true}	0.05	0.1	0.15	0.2
$\beta^{bank} = -0.5, \beta^{market} = -0.75$				
$n = 10$				
TTC^{market}	0.261	0.323	0.387	0.400
$TTC^{mpl,\lambda=1}$	0.067	0.139	0.221	0.234
TTC^{fi}	**0.041**	**0.044**	**0.052**	**0.064**
$n = 5$				
TTC^{market}	0.156	0.200	0.200	0.200
$TTC^{mpl,\lambda=1}$	0.064	0.114	0.122	0.130
TTC^{fi}	**0.041**	**0.044**	**0.052**	**0.064**
$n = 1$				
TTC^{market}	0.040	0.040	0.040	**0.040**
$TTC^{mpl,\lambda=1}$	**0.028**	**0.033**	**0.040**	0.051
TTC^{fi}	0.041	0.044	0.052	0.060
$\beta^{bank} = 0.5, \beta^{market} = 0.75$				
$n = 10$				
TTC^{market}	0.266	0.345	0.400	0.400
$TTC^{mpl,\lambda=1}$	0.067	0.139	0.221	0.234
TTC^{fi}	**0.040**	**0.041**	**0.043**	**0.046**
$n = 5$				
TTC^{market}	0.160	0.200	0.200	0.200
$TTC^{mpl,\lambda=1}$	0.064	0.114	0.122	0.130
TTC^{fi}	**0.040**	**0.041**	**0.043**	**0.046**
$n = 1$				
TTC^{market}	0.040	0.040	0.040	**0.040**
$TTC^{mpl,\lambda=1}$	**0.028**	**0.033**	**0.040**	0.051
TTC^{fi}	0.040	0.041	0.043	0.046

4.2 Effect of private diversification

Private Diversification means that each creditor does not invest his initial financial endowment I_0/n in one project but, to diversify default risks, splits it to invest it in k projects. Thus, each creditor gives an amount of I_0/kn to k projects. What does this imply for the transaction costs caused by the three institutional arrangements?

For the financial market solution, private diversification of the creditors directly increases the screening costs to reduce ex ante informational asymmetry and the monitoring costs to reduce ex post informational asymmetry in case *market*,#2 by factor k. In case *market*,#1, there is an indirect effect on the expected non-pecuniary insolvency penalty applied to the debtors. With rising k and, hence, rising ex ante screening costs, the nominal amount $R_{debtor}^{market,\#1}$ that the debtors have to pay to the creditors increases, which leads to an increase of the expected insolvency penalty in case *market*,#1.

For the MPL platform solution, the ex ante screening costs remain the same with private diversification because each project is still only screened once by the MPL platform (and not by the creditors). However, in case *market*,#2, the ex post monitoring costs increase with private diversification by a factor k, and, as a direct consequence, the total transaction costs $TTC^{mpl,\#2}$ increase. Furthermore, as an indirect effect in case *market*,#2, the nominal amount $R_{debtor}^{mpl,\#2}$ that the debtors have to pay to the creditors increases with rising ex post monitoring costs, which also leads to an increase of $TTC^{mpl,\#2}$ due to an increase of the non-pecuniary penalty for inaccurate screening applied to the MPL platform. The variance $Var^{true}\left[\tilde{d}\right]$ of the default rate of the portfolio of credits given to finance all m projects does not decrease because the private diversification of the creditors does not lead to more diversification on the level of the credit portfolio. The reason for this is that now, kn 'small' credits of size I_0/kn needed to fund one project are perfectly correlated, while before, this was the case for n 'large' credits of size I_0/n. Thus, there is no counter-effect that could lead to a reduction of total transaction costs. As a consequence, the total transaction costs of the MPL platform solution tend to increase with private diversification.

In case *fi*,#1 of the financial intermediary solution, private diversification should not influence the total transaction costs $TTC^{fi,\#1}$. On the one hand, this is because the ex ante screening costs and the ex post monitoring costs are incurred only once per project and are borne by the bank. This is also true in case *fi*,#2. On the other hand, the probability distribution of the default rate $\tilde{d}$ does not change because, for the financial intermediary solution, only the distribution of defaults on the bank level matters. As argued before for the MPL platform solution, this distribution does not change. Thus, private diversification neither affects the nominal amounts $R_{bank}^{fi,\#1}$ and $R_{debtor}^{fi,\#1}$ nor the non-pecuniary insolvency penalty applied to the bank. In case *fi*,#2 of the financial intermediary solution, private diversification also does not influence the total transaction costs $TTC^{fi,\#2}$ because the creditors still give their money to one bank and, hence, the ex post monitoring costs of the creditors with respect to the bank do not change.

To summarize, private diversification even increases the advantageousness of the financial intermediary solution relative to the two other institutional arrangements.

4.3 Asymmetric penalty for inaccurate screening by the MPL platform

In this section, it is tested how influential the choice of the non-pecuniary penalty function for inaccurate screening by the MPL platform for the results is. For this, as an alternative to the quadratic deviations penalty function (4), the following asymmetric penalty function is considered:

$$\lambda m R_{debtor}^{mpl} \max\left\{0; \tilde{d} - PD^{mpl}\right\}, \qquad (53)$$

where the MPL platform is punished whenever the default probability estimated by the platform is smaller than the realized default rate. It is assumed that the MPL platform is still incentivized to do the screening job as well as possible and achieves $PD^{mpl} = PD^{true}$, and that $E^{mpl}\left[\,\cdot\,\right] = E^{true}\left[\,\cdot\,\right]$ is true. Due to symmetry reasons, the results for this modification are the same as for the following asymmetric penalty function:

$$\lambda m R_{debtor}^{mpl} \max\left\{0; PD^{mpl} - \tilde{d}\right\}, \qquad (54)$$

where too large default probability estimates of the MPL platform are punished. Furthermore, the following absolute deviations penalty function is considered:

$$\lambda m R_{debtor}^{mpl} \left|\tilde{d} - PD^{mpl}\right|. \qquad (55)$$

As usually the lower boundary for the nominal repayment amount of the debtors resulting from the incentive condition for the creditors is binding in Equation (37), the above modifications usually do not influence the nominal repayment amount of the debtors but they directly impact the total transaction costs. The results can be seen in Table 7. For this, the penalty factor for unprecise screening of the MPL platform is set to $\lambda = 0.15$ to ensure that the sum of the fees earned by the platform is always larger than the penalty for unprecise screening of the MPL platform. As discussed in Section 3.3.3, this is a necessary prerequisite for the platform to participate. The total transaction costs resulting from the quadratic penalty function assumed before with $\lambda = 0.15$ are also shown for comparison. As the deviations between the default rate and the default probability estimated by the MPL platform are always smaller than one, the modified non-quadratic penalty functions yield larger total transaction costs than the quadratic penalty function. As expected, the absolute deviations penalty function (55) leads to higher total transaction costs than the asymmetric penalty function (53). However, in total, the influence of the choice of the penalty function is somewhat limited, particularly if one compares the results for the two modified versions. As Table 5 shows, the choice of the institutional arrangement is much more critical with respect to the magnitude of the differences in the total transaction costs. Thus, in general, it cannot be expected that the superiority of the financial intermediary solution can be reversed in favor of the MPL platform solution when modifying the penalty function for inaccurate screening by the MPL platform.

Table 7:
Total transaction costs of the MPL platform solution for different penalty functions

The total transaction costs per project of the MPL platform solution are shown for different penalty functions for deviations of the default rate from the default probability estimated by the platform, varying values of the number of creditors per project, and varying boundaries of the uniformly distributed default rate. The arithmetic mean of the two boundary values yields the true default probability. The penalty factor for unprecise screening of the MPL platform is set to $\lambda = 0.15$. All other parameters correspond to the default setting. In bold, the lowest total transaction costs are marked.

$\left[a^{true};b^{true}\right]$	$\left[0;0.1\right]$	$\left[0;0.2\right]$	$\left[0;0.3\right]$	$\left[0;0.4\right]$
Penalty for quadratic deviations				
$TTC^{mpl,\#1}$ (n=10)	**0.064**	**0.131**	**0.207**	0.294
$TTC^{mpl,\#1}$ (n=5)	**0.061**	0.123	0.194	0.274
$TTC^{mpl,\#1}$ (n=1)	0.058	0.118	0.185	0.261
$TTC^{mpl,\#2}$ (n=10)	0.205	0.206	0.207	**0.208**
$TTC^{mpl,\#2}$ (n=5)	0.105	**0.106**	**0.107**	**0.108**
$TTC^{mpl,\#2}$ (n=1)	**0.025**	**0.026**	**0.026**	**0.028**
Penalty for absolute deviations				
$TTC^{mpl,\#1}$ (n=10)	**0.068**	**0.139**	**0.220**	0.312
$TTC^{mpl,\#1}$ (n=5)	**0.065**	0.131	0.207	0.292
$TTC^{mpl,\#1}$ (n=1)	0.062	0.126	0.197	0.277
$TTC^{mpl,\#2}$ (n=10)	0.210	0.216	0.223	**0.231**
$TTC^{mpl,\#2}$ (n=5)	0.110	**0.115**	**0.120**	**0.127**
$TTC^{mpl,\#2}$ (n=1)	**0.029**	**0.034**	**0.039**	**0.044**
Penalty for asymmetric deviations				
$TTC^{mpl,\#1}$ (n=10)	**0.066**	**0.135**	**0.213**	0.301
$TTC^{mpl,\#1}$ (n=5)	**0.063**	0.127	0.200	0.282
$TTC^{mpl,\#1}$ (n=1)	0.060	0.122	0.190	0.268
$TTC^{mpl,\#2}$ (n=10)	0.208	0.211	0.214	**0.218**
$TTC^{mpl,\#2}$ (n=5)	0.107	**0.110**	**0.113**	**0.116**
$TTC^{mpl,\#2}$ (n=1)	**0.027**	**0.029**	**0.032**	**0.035**

4.4 How convenient MPL platforms must be to be favorable?

Anecdotal evidence suggests that the success of MPL platforms (and other fintechs) is partly driven by improved user experience and the ease of use that they offer their clients.[32] In this section, it is analyzed how large this convenience yield has to be to reverse the ranking of the

[32] See, for example, Berg et al. (2022, p. 193).

institutional arrangements in terms of total transaction costs. For this, the ease of use, for example, due to faster and more convenient application procedures or more transparent information provision of MPL platforms, is interpreted as a non-pecuniary utility increase $benefit_{creditor}^{mpl}$ ($benefit_{debtor}^{mpl}$) per unit of the total nominal loan repayment amount per project that creditors (debtors) of the MPL platform experience relative to the two other institutional arrangements.

In this case, assuming that the creditors do not have to monitor the debtors because the insolvency penalty is applied to the debtors to motivate them to true ex post reporting, the participation condition of the creditors is changed to (case *mpl*,#1):

$$\underbrace{E^{mpl=true}\left[mR_{debtor}^{mpl,\#1}\left(1-\tilde{d}\right)\right]}_{\substack{\text{expected repayments from}\\ \text{m loans granted by the creditors}\\ \text{via the MPL platform}}}+\underbrace{mnbenefit_{creditor}^{mpl}R_{debtor}^{mpl,\#1}}_{\substack{\text{non-pecuniary benefit of using the}\\ \text{MPL platform of the mn creditors}}}-\underbrace{mne_{creditor}^{mpl}R_{debtor}^{mpl,\#1}}_{\substack{\text{volume-dependent fees}\\ \text{paid by the mn creditors}}}\geq\underbrace{mI_0}_{\substack{\text{initial investment sum}\\ \text{of the mn creditors}}} \quad (56)$$

$$\underset{1-PD^{true}>ne_{creditor}^{mpl}}{\Leftrightarrow} R_{debtor}^{mpl,\#1}\geq\frac{I_0}{1-PD^{true}-ne_{creditor}^{mpl}+nbenefit_{creditor}^{mpl}}. \quad (57)$$

Combining Equations (34) and (57), the nominal repayment amount of the debtors now is:

$$R_{debtor}^{mpl,\#1}=Max\left\{\frac{I_0}{1-PD^{true}-ne_{creditor}^{mpl}+nbenefit_{creditor}^{mpl}};\frac{c_{plat}^{screening}}{ne_{creditor}^{mpl}+e_{debtor}^{mpl}-\lambda Var^{true}\left[\tilde{d}\right]}\right\}. \quad (58)$$

Depending on the size of $benefit_{creditor}^{mpl}$, now, the second term in Equation (58), which is the lower boundary for the nominal repayment amount resulting from the incentive condition for the MPL platform, can be binding.

Again, assuming that the insolvency penalty is applied to the debtors, the debtors participate if and only if

$$\underbrace{E^{true}\left[Max\left\{m\tilde{y}-mR_{debtor}^{mpl,\#1};0\right\}\right]}_{\substack{\text{expected surplus from m projects}\\ \text{for the debtors}}}+\underbrace{mbenefit_{debtor}^{mpl}R_{debtor}^{mpl,\#1}}_{\substack{\text{non-pecuniary benefit of using the}\\ \text{MPL platform of the m debtors}}}-\underbrace{E^{true}\left[mR_{debtor}^{mpl,\#1}\tilde{d}\right]}_{\substack{\text{expected non-pecuniary insolvency penalty}\\ \text{resulting from m granted loans for reducing}\\ \text{ex post information asymmetry}}}-\underbrace{me_{debtor}^{mpl}R_{debtor}^{mpl,\#1}}_{\substack{\text{volume-dependent fees}\\ \text{paid by the m debtors}}}\geq 0$$

$$\underset{y>R_{debtor}^{mpl,\#1}}{\Leftrightarrow}\frac{y\left(1-PD^{true}\right)}{1-benefit_{debtor}^{mpl}+e_{debtor}^{mpl}}\geq R_{debtor}^{mpl,\#1}, \tag{59}$$

where $y>R_{debtor}^{mpl,\#1}$ is assumed. As again, a sufficiently high project result y in case of success is assumed so that the Inequality (59) is always fulfilled, the introduction of $benefit_{debtor}^{mpl}$ does not influence the nominal repayment amount but only the total transaction costs.

If the number of creditors n per financed project is small, the non-pecuniary monitoring costs for reducing ex post information asymmetry are smaller than the costs resulting from applying the non-pecuniary insolvency penalty to the debtors. In this case, the incentive condition for the creditors is modified to (case *mpl*,#2):

$$\underbrace{E^{mpl=true}\left[mR_{debtor}^{mpl,\#2}\left(1-\tilde{d}\right)\right]}_{\substack{\text{expected repayments from}\\ \text{m loans granted by the creditors}\\ \text{via the MPL platform}}}+\underbrace{mnbenefit_{creditor}^{mpl}R_{debtor}^{mpl,\#2}}_{\substack{\text{non-pecuniary benefit of using the}\\ \text{MPL platform of the mn creditors}}}-\underbrace{mnc_{creditor}^{monitoring}}_{\substack{\text{non-pecuniary monitoring costs}\\ \text{of the mn creditors for reducing}\\ \text{ex post information asymmetry}}}-\underbrace{mne_{creditor}^{mpl}R_{debtor}^{mpl,\#2}}_{\substack{\text{volume-dependent fees}\\ \text{paid by the mn creditors}}}\geq\underbrace{mI_0}_{\substack{\text{initial investment sum}\\ \text{of the mn creditors}}} \tag{60}$$

$$\underset{1-PD^{true}>ne_{creditor}^{mpl}}{\Leftrightarrow}R_{debtor}^{mpl,\#2}\geq\frac{I_0+nc_{creditor}^{monitoring}}{1-PD^{true}-ne_{creditor}^{mpl}+nbenefit_{creditor}^{mpl}}. \tag{61}$$

In case *mpl*,#2, the above lower boundary for the nominal repayment amount has to be used to replace the first term in Equation (58).

Summarizing both cases, the total transaction costs (TTC) are now given by:

$$TTC^{mpl}=Min\left\{TTC^{mpl,\#1};TTC^{mpl,\#2}\right\}. \tag{62}$$

with

$$TTC^{mpl,\#1} = \underbrace{mR_{debtor}^{mpl,\#1} PD^{true}}_{\substack{\text{expected non-pecuniary insolvency penalty} \\ \text{applied to the debtors}}} + \underbrace{mc_{plat}^{screening}}_{\substack{\text{non-pecuniary screening costs} \\ \text{of the MPL platform for m projects}}} + \underbrace{\lambda mR_{debtor}^{mpl,\#1} Var^{true}\left[\tilde{d}\right]}_{\substack{\text{non-pecuniary penalty for inaccurate screening} \\ \text{applied to the MPL platform}}} - \underbrace{mnbenefit_{creditor}^{mpl} R_{debtor}^{mpl,\#1}}_{\substack{\text{non-pecuniary benefit of using the} \\ \text{MPL platform of the mn creditors}}} - \underbrace{mbenefit_{debtor}^{mpl} R_{debtor}^{mpl,\#1}}_{\substack{\text{non-pecuniary benefit of using the} \\ \text{MPL platform of the m debtors}}} \quad (63)$$

and

$$TTC^{mpl,\#2} = \underbrace{mnc_{creditor}^{monitoring}}_{\substack{\text{non-pecuniary monitoring costs} \\ \text{of the mn creditors}}} + \underbrace{mc_{plat}^{screening}}_{\substack{\text{non-pecuniary screening costs} \\ \text{of the MPL platform for m projects}}} + \underbrace{\lambda mR_{debtor}^{mpl,\#2} Var^{true}\left[\tilde{d}\right]}_{\substack{\text{non-pecuniary penalty for inaccurate screening} \\ \text{applied to the MPL platform}}} - \underbrace{mnbenefit_{creditor}^{mpl} R_{debtor}^{mpl,\#2}}_{\substack{\text{non-pecuniary benefit of using the} \\ \text{MPL platform of the mn creditors}}} - \underbrace{mbenefit_{debtor}^{mpl} R_{debtor}^{mpl,\#2}}_{\substack{\text{non-pecuniary benefit of using the} \\ \text{MPL platform of the m debtors}}} . \quad (64)$$

Assuming symmetric utility increases $benefit = benefit_{creditor}^{mpl} = benefit_{debtor}^{mpl}$ for the creditors and debtors, the results of this modification can be seen in Table 8. The variable $benefit$ is either set equal to 0.005 or 0.0075.[33] In total, introducing relative utility increases caused by using MPL platforms in the model has a strong effect. On the one hand, it has an indirect impact by reducing the nominal repayment amount and, hence, the total transaction costs for the MPL platform solution. On the other hand, it has a direct impact because the utility increases enter as negative terms in the total transaction costs. As a consequence, now, there are many more scenarios in which the MPL platform solution yields the institutional arrangement with the lowest total transaction costs. For low default probabilities and a large number of creditors per project, they can even get negative. Only when simultaneously the number of creditors per project is medium to large and the default probabilities are medium to large the financial in-

[33] The above definition of the relative utility increase caused by using MPL platforms as a percentage per unit of the total nominal loan repayment per project implies that the relative utility increase per unit investment sum of each creditor is equal to $n\, benefit_{creditor}^{mpl} R_{debtor}^{mpl} / I_0$ and, hence, increases with the number of creditors n per project. To check the robustness of the results concerning this choice, I repeated the computations for a relative utility increase per unit investment sum of each creditor that is independent of the number of creditors n per project. In this case, the term $mnbenefit_{creditor}^{mpl} R_{debtor}^{mpl}$ in Equations (56) and (60), respectively, is replaced by $mbenefit_{creditor}^{mpl}$ (analogously, this replacement is done in Equations (63) and (64) for the total transaction costs). Doing this, each creditor's relative utility increase per unit investment sum is equal to $benefit_{creditor}^{mpl} / n / I_0 / n = benefit_{creditor}^{mpl} / I_0$. In this case, the dominance of the financial intermediary solution for a medium to large number of creditors per project cannot be broken. For this, a much larger convenience yield $benefit$ would be necessary (results are available upon request from the author).

termediary solution can still be the financial arrangement with the lowest total transaction costs, depending on the size of the bias factor with which the financial intermediary estimates the default probability.

4.5 Effect of the MPL platform taking the first loss tranche

Next, it is analyzed which effect it has when the MPL platform has 'skin-in-the-game'. For this, it is assumed that the platform takes the first x percent loss tranche, i.e., the first x % of credit losses due to defaulting projects are borne by the MPL platform's equity E^{mpl}. If the loss exceeds the MPL platform's equity E^{mpl}, the platform defaults without further consequences.

A direct consequence of this assumption is that the MPL platform is incentivized to do an appropriate ex ante screening of the projects, at least as long as the additional effort to do an appropriate screening compared to the effort to do a bad screening is smaller than the additional expected credit loss that the MPL platform has to bear due to a bad screening. Given that this assumption is true, the penalty term in the total transaction costs given in Equations (43) and (44), respectively, would vanish.

Table 8:
Total transaction costs for different institutional arrangements with convenience yield caused by using the MPL platform

The total transaction costs per project for different institutional arrangements are shown for varying values of the bias factor, varying values of the convenience yield caused by using the MPL platform, varying values of the number of creditors per project, and varying boundaries of the uniformly distributed default rate. The arithmetic mean of the two boundary values yields the true default probability. All other parameters correspond to the default setting. The total transaction costs resulting from the financial intermediary solution and the financial market solution are reproduced from Table 5. In bold, the lowest total transaction costs are marked.

$\left[a^{true};b^{true}\right]$	$[0;0.1]$	$[0;0.2]$	$[0;0.3]$	$[0;0.4]$	$[0;0.5]$	$[0;0.6]$
$\beta^{bank}=-0.5, \beta^{market}=-0.75$						
$n=10$						
TTC^{market}	0.261	0.323	0.387	0.400	0.400	0.400
$TTC^{mpl,\lambda=1,benefit=0.005}$	0.0004	0.062	0.133	0.138	0.146	0.159
$TTC^{mpl,\lambda=1,benefit=0.0075}$	**-0.029**	**0.029**	0.096	0.098	0.103	0.112
TTC^{fi}	0.040	0.040	**0.040**	**0.051**	**0.076**	**0.109**
$n=5$						
TTC^{market}	0.156	0.200	0.200	0.200	0.200	0.200
$TTC^{mpl,\lambda=1,benefit=0.005}$	0.028	0.072	0.075	0.081	0.091	0.105
$TTC^{mpl,\lambda=1,benefit=0.0075}$	**0.011**	0.053	0.056	0.061	**0.069**	**0.081**
TTC^{fi}	0.040	**0.040**	**0.040**	**0.051**	0.076	0.109
$n=1$						
TTC^{market}	0.040	0.040	0.040	0.040	0.040	**0.040**
$TTC^{mpl,\lambda=1,benefit=0.005}$	0.015	0.017	0.022	0.029	0.040	0.054
$TTC^{mpl,\lambda=1,benefit=0.0075}$	**0.010**	**0.012**	**0.016**	**0.023**	**0.033**	0.047
TTC^{fi}	0.040	0.040	0.040	0.051	0.060	0.060
$\beta^{bank}=0.5, \beta^{market}=0.75$						
$n=10$						
TTC^{market}	0.266	0.345	0.400	0.400	0.400	0.400
$TTC^{mpl,\lambda=1,benefit=0.005}$	0.0004	0.062	0.133	0.138	0.146	0.159
$TTC^{mpl,\lambda=1,benefit=0.0075}$	**-0.029**	**0.029**	0.096	0.098	0.103	0.112
TTC^{fi}	0.040	0.040	**0.040**	**0.040**	**0.040**	**0.045**
$n=5$						
TTC^{market}	0.160	0.200	0.200	0.200	0.200	0.200
$TTC^{mpl,\lambda=1,benefit=0.005}$	0.028	0.072	0.075	0.081	0.091	0.105
$TTC^{mpl,\lambda=1,benefit=0.0075}$	**0.011**	0.053	0.056	0.061	0.069	0.081
TTC^{fi}	0.040	**0.040**	**0.040**	**0.040**	**0.040**	**0.045**
$n=1$						
TTC^{market}	0.040	0.040	0.040	0.040	0.040	**0.040**
$TTC^{mpl,\lambda=1,benefit=0.005}$	0.015	0.017	0.022	0.029	0.040	0.054
$TTC^{mpl,\lambda=1,benefit=0.0075}$	**0.010**	**0.012**	**0.016**	**0.023**	**0.033**	0.047
TTC^{fi}	0.040	0.040	0.040	0.040	0.040	0.045

As a further consequence of the self-retention, the MPL platform is incentivized to reduce ex post information asymmetry between the debtors and itself. This can be done either by spending non-pecuniary monitoring costs $c_{plat}^{monitoring}$ or by arranging a non-pecuniary insolvency penalty with the debtors for the losses resulting from the first loss tranche. In the latter case, the sum of the expected insolvency penalties as part of the total transaction costs of the MPL platform solution in case *mpl*,#1 does not change.[34] In case *mpl*,#2, the total transaction costs increase by the non-pecuniary insolvency penalty applied to the debtors $E^{true}\left[\tilde{d}mR_{debtor}^{mpl}\middle|\tilde{d}mR_{debtor}^{mpl}\leq xmR_{debtor}^{mpl}\right]$ for the losses resulting from the first loss tranche. In the former case, the total transaction costs in case *mpl*,#1 increase if and only if $c_{plat}^{monitoring}>E^{true}\left[\tilde{d}R_{debtor}^{mpl}\middle|\tilde{d}R_{debtor}^{mpl}\leq xR_{debtor}^{mpl}\right]$.[35] In case *mpl*,#2, the total transaction costs increase by $c_{plat}^{monitoring}$. Thus, combined with the omission of the penalty term for inaccurate screening in the total transaction costs given in Equations (43) and (44), respectively, opposing effects on the total transaction costs of the MPL platform solution tend to result, and it is à priori not clear which effect dominates.

In the former case, when the MPL platform chooses to monitor the debtors, a substantial decrease in the total transaction costs could be achieved if the MPL platform, as part of their paid service, gives the result of its ex post monitoring to the creditors and, hence, performs a delegated monitoring for them. Because of the self-retention, the platform is incentivized to do the ex post monitoring carefully. Furthermore, in contrast to the bank, the platform has no incentive to cheat the creditors, i.e., to report that the debtors have not paid although they did, because the platform is not the legal owner of the receivables from the debtors and, hence, cheating causes no extra profit for the platform. Thus, no two-stage cooperation problem would result. As a consequence, the total transaction costs for the MPL platform solution would be simplified to

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[34] As the incentive condition of the MPL platform changes to

$$\underbrace{mne_{creditor}^{mpl}R_{debtor}^{mpl}}_{\substack{\text{volume-dependent fees}\\\text{paid by the mn creditors}}}+\underbrace{me_{debtor}^{mpl}R_{debtor}^{mpl}}_{\substack{\text{volume-dependent fees}\\\text{paid by the m debtors}}}\underbrace{-E^{true}\left[\tilde{d}mR_{debtor}^{mpl}\middle|\tilde{d}mR_{debtor}^{mpl}\leq xmR_{debtor}^{mpl}\right]}_{\substack{\text{expected loss the MPL platform}\\\text{has to bear for m projects}}}-\underbrace{mc_{plat}^{screening}}_{\substack{\text{non-pecuniary screening costs}\\\text{of the MPL platform for m projects}}}\geq E^{mpl},$$

this is only true if the lower boundary for R_{debtor}^{mpl} that is implicitly defined by this new incentive condition does not become binding in Equation (37).

[35] The expected insolvency penalty applied to the debtors as part of the total transaction costs decreases by the loss self-retention of the MPL platform.

$$\underbrace{mc_{plat}^{monitoring}}_{\substack{\text{non-pecuniary monitoring costs} \\ \text{of the MPL platform for m projects}}} + \underbrace{mc_{plat}^{screening}}_{\substack{\text{non-pecuniary screening costs} \\ \text{of the MPL platform for m projects}}}. \tag{65}$$

Assuming $c_{plat}^{monitoring} = c_{bank}^{monitoring}$ and $c_{plat}^{screening} \leq c_{bank}^{screening}$, this would imply that the MPL transaction solution would always dominate the financial intermediary solution (see Equations (31) and (32), respectively). However, typically, MPL platforms offer dunning and enforcement measures as a paid additional service to the creditors. In this case, the platform would have an incentive to cheat after all, i.e., to report that the debtors have not paid although they did, to retain the cash flow it has gathered during the enforcement measures. Thus, a two-stage cooperation problem would again result, and the general advantageousness of the MPL platform solution would disappear again.

5 Conclusion

In a Diamond (1984) model setting extended by ex ante information asymmetry, it is shown that MPL platforms can typically not provide lending services at lower transaction costs than those resulting from a financial intermediary solution with banks. Based on extensive numerical examples, it can be demonstrated that only when simultaneously the default probabilities of the projects carried out by the debtors are low to medium and the number of creditors per project is small the MPL platform can dominate the bank. Comparing this with reality, the results are mixed. On the one hand, the empirical results mainly seem to contradict the idea that MPL platforms predominantly serve low-risk debtors. However, the results found in the literature are ambiguous. On the other hand, the trend observed in the last decade that institutional investors replace peers as creditors (see Section 1), which reduces the average number of creditors per project, is consistent with the model's result.

Private diversification of the creditors, alternative default rate distributions, or alternative 'bad screening' penalties for the MPL platform cannot shift the advantageousness in favor of the MPL platform solution. Only when a convenience yield of using an MPL platform interpreted as negative transaction costs relative to other institutional arrangements is introduced, can the dominance of the financial intermediary solution be broken. Furthermore, if the MPL platform has skin-in-the-game by taking the first loss tranche of the credit portfolio, this can substantially affect the advantageousness of the MPL platform solution. However, this depends on the additional services provided by the platform to the creditors and whether a two-stage cooperation problem results from these services.

To check the robustness of this result, in future research, it could be analyzed whether other arguments of the theoretical banking literature (e.g., concerning relationship lending, insurance against liquidity risk, or reputational effects in multi-period models) might be more in favor to MPL platforms than to banks.

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