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Group Lending with Peer Selection and Moral Hazard*

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Abstract

The theory on group lending suggests that joint liability induces borrowers to form homogeneous groups based on their risk types, which alleviates adverse selection and contributes to the success of microcredit schemes. We extend this theory by allowing individuals to differ both in their exogenous risk type and in their endogenous effort level. We find that joint liability leads to positive assortative matching in both a non-cooperative and cooperative game setting. Groups of safe borrowers additionally exhibit higher effort levels, which reinforces their likelihood of repayment as opposed to risky groups.

Keywords

Group Lending, Peer Selection, Moral Hazard, Microfinance

1. Introduction

In recent decades, microfinance has grown rapidly as a tool to reduce poverty by relaxing the liquidity constraints faced by poor populations, who often lack appropriate financial collateral. A common practice among many microfinance programs is group lending schemes with joint liability in which borrowers form groups to obtain a loan and are then held liable for each other.

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The seminal work of Ghatak (1999), van Tassel (1999), and Ghatak (2000) provides an appealing explanation of how group lending with joint liability can rely on information advantages among group members (peers) to overcome adverse selection, which is one of the main factors that typically prevent financial institutions from serving the poor in conventional credit markets. The authors show that in a context of individuals with heterogeneous risk types and asymmetric information (where borrowers know each other's type but lenders do not), joint liability will lead to the formation of relatively homogeneous groups of either safe or risky borrowers (i.e., positive assortative matching). The intuition behind this scenario is that while a borrower of any type prefers a safe partner because of lower expected joint liability payments, safe borrowers value safe partners more than risky partners because safe partners repay more often. For the same reason, agents in a safe group face lower effective borrowing costs than those in a risky group when facing the same loan terms, which allows financial institutions to screen off risky agents. This process is often called peer screening or peer selection in the literature.

We extend Ghatak (1999)'s base model by taking into account both peer selection and moral hazard. More specifically, we allow individuals to differ in their exogenous risk type or creditworthiness as well as in their endogenous effort level. Following Stiglitz (1990), we assume that the individuals' effort level is a hidden action that is unobserved by lenders but observed among peers. We find positive assortative matching based on risk type in both a non-cooperative and a cooperative game setting. By allowing the probability of an individual's success to depend on her inherent probability of success determined by her risk type (either safe or risky) and her level of effort, a borrower's optimal effort level is higher if her partner is a safe type and is the highest when both are safe types. Introducing endogenous effort thus strengthens positive assortative matching. Groups of safe borrowers exhibit higher effort levels, further increasing their likelihood of repayment, while the opposite holds true for groups of risky borrowers.

Our study adds to the theoretical literature on group lending by incorporating a hidden action to Ghatak (1999)'s base model and analyzing its implications for group formation and loan repayment. One strand of the literature focuses on hidden information (Ghatak, 1999; van Tassel, 1999; Ghatak, 2000). Another strand has investigated how group lending helps alleviate moral hazard behavior (hidden action) and enforce repayment because members can more closely monitor each other's use of loans and exert pressure to prevent deliberate default (Stiglitz, 1990; Varian, 1990; Banerjee, Besley, & Guinnane, 1994; Armendariz de Aghion & Gollier, 2000; Chowdury, 2005). A recent study by Ahlin (2020) derives positive assortative matching in a framework that extends Ghatak (1999)'s model by including an additional dimension of hidden information (correlated risk). To our knowledge, our study provides the first theoretical model that considers both hidden information and hidden action in group formation and loan repayment.

Our results have important policy implications. For example, we find that borrowers in a safe group can monitor each other more effectively than those in a risky group. It is thus plausible for lenders to foresee different monitoring efforts depending on the group type. Gan, Hernandez and Liu (2018) show that a mixture model can help microcredit providers to empirically identify different group types and then implement varying monitoring policies to different groups that can improve both efficiency and repayment.

The remainder of the paper is organized as follows. Section 2 reviews the literature on group formation in the context of group lending with joint liability. Section 3 presents the model setup introducing endogenous effort. Section 4 discusses the model predictions in both a non-cooperative and a cooperative game setting. Section 5 concludes.

2. Literature Review

The seminal model of Ghatak (1999) assumes that borrowers differ in their risk types, and they know each other's risk types, but the lender does not. It shows that joint liability will induce borrowers of the same risk type to match with each other. This positive assortative matching pattern implies that safer borrowers face lower expected borrowing costs than riskier borrowers under the same loan terms, because they have safer partners. Group lending schemes with joint liability are consequently more attractive to safer than riskier borrowers. The self-selection process, also called peer selection or peer screening, helps reduce adverse selection in credit markets and improves both efficiency and equity. Van Tassel (1999) derives alike results in a similar model setup, while considering ability types instead of risk types. We refer to risk types throughout the paper for simplicity, but the types could refer to other factors associated with the creditworthiness of borrowers such as ability, entrepreneurial spirit, or level of responsibility.

A more recent study by Ahlin (2020) extends the model in Ghatak (1999) by considering another dimension of hidden information—correlated risk, assessing whether borrowers will match with other borrowers exposed to similar or different types of risks. The model results in positive assortative matching across both dimensions: borrowers match with partners of similar risk level and exposed to similar types of risk.

The literature also shows that positive assortative matching may not hold under assumptions deviating from joint liability and common information on the agents' type among peers. For example, Armendariz de Aghion and Gollier (2000) suggest that non-assortative matching equilibrium can exist in the case where a borrower knows her own type but has no ex-ante information about other borrowers' types. Guttman (2008) demonstrates that positive assortative matching does not necessarily hold when side-payments are feasible and if members of the group are subject to a refinancing threat.

Although theoretical models suggest positive assortative matching plays a central role in alleviating adverse selection in microcredit markets, empirical work testing matching patterns among microcredit groups is relatively scant. To our knowledge, Gan, Hernandez and Liu (2018) and Ahlin (2020) are the only studies that empirically test for group matching patterns. Gan, Hernandez and Liu (2018) use data from women self-help groups promoted by The World Bank in the state of Andhra Pradesh in India. Ahlin (2020) uses data on borrowing groups from the Bank for Agriculture and Agricultural Cooperatives, which is the predominant rural lender in Thailand. Both studies provide empirical evidence supporting positive assortative matching in group formation along a number of dimensions.

Another set of theoretical studies focus on group lending schemes' ability to mitigate moral hazard behavior (i.e., hidden actions) and enforce repayment because members can monitor each other's use of loans and exert pressure to prevent deliberate default at a lower cost than the lender (Stiglitz, 1990; Varian, 1990; Banerjee, Besley, & Guinnane, 1994; Armendariz de Aghion & Gollier, 2000; Chowdury, 2005).[1] This strand of the literature takes group formation as given when investigating borrowers' efforts in implementing their projects and/or making repayments. However, borrowers' effort level, which is unobservable by the lender, may interact with peer selection and group formation. This is because individuals who team up with safe borrowers may exert different effort levels than those who team up with risky borrowers.

3. Model Setup

Similar to Ghatak (1999), we consider a setting where borrowers differ in their risk type and form groups voluntarily under a joint liability contract. We extend the model in Ghatak (1999) by endogenizing borrowers' effort levels in their group formation process. That is, we incorporate both hidden information (risk type) and hidden action (effort level) in our model in which the success probability of a borrower's project depends on both her inherent risk type and effort level.

Assume that borrowers are risk-neutral and endowed with one risky project, which requires one unit of capital. Individuals have no initial wealth and must borrow the required amount of capital. Further assume that there are two types of borrowers: risky individuals of type a and safe individuals of type b. The probability of success of borrower i's project (k_i) depends on her inherent probability of success ($p_i > 0$) determined by her risk type and her endogenous effort level ($e_i > 0$), where $i = a, b$. A risky borrower has a success probability of $k_a = p_a + e_a$ and a safe borrower has a success rate of $k_b = p_b + e_b$, with $p_a < p_b$ and $0 < k_a, k_b \le 1$. Without loss of generality, the output takes the value of Y if the project is successful and zero otherwise.

In the presence of local information, all borrowers know each other's risk

[1] Ghatak and Guinnane (1999) also examine how joint liability lending can promote peer monitoring.

type, but the outside lender (bank) does not. Following Ghatak (1999), in the absence of financial collateral, the bank requires potential borrowers to form groups of two in which both members are jointly liable for each other. The bank offers to each group the joint liability contract (r,q), where $r>0$ is the gross interest and $q>0$ is the liability payment. Hence, *r* is the payment made by the individual who succeeds and $q>0$ is the additional payment made by the individual when she succeeds and her partner fails. A borrower who fails does not make any payment to the bank. We assume $Y>r+q$ so that a borrower's payoff is positive if she succeeds.

The expected payoff for type *i* borrower matched with type *j* borrower is given by

$$E\pi_{ij}=(p_i+e_i)Y-(p_i+e_i)r-q(p_i+e_i)(1-p_j-e_j)-1/2\gamma e_i^2, \tag{1}$$

where the effort disutility is captured by $-1/2\gamma e_i^2$. Following Stiglitz (1990), we assume $\gamma>0$ to characterize increasing marginal effort costs.

4. Results

In this section, we first solve the model in a non-cooperative game setting and then in a cooperative setting.

4.1. Non-Cooperative Game

In the non-cooperative game setting, each borrower *i* matched with partner *j* maximizes her own expected payoff $E\pi_{ij}$ with respect to her effort e_i. The maximization problems of the matched borrowers are given by

$$\max_{e_i} E\pi_{ij}=(p_i+e_i)(Y-r)-q(p_i+e_i)(1-p_j-e_j)-1/2\gamma e_i^2 \tag{2}$$

$$\max_{e_j} E\pi_{ji}=(p_j+e_j)(Y-r)-q(p_j+e_j)(1-p_i-e_i)-1/2\gamma e_j^2 \tag{3}$$

$$\text{s.t. } e_i\geq 0,\ e_j\geq 0. \tag{4}$$

The main results are summarized in Propositions 1 to 3. See **Appendix A** for the proof of the results.

Proposition 1: A borrower's optimal effort level is higher if her partner is a safe type and is the highest when she and her partner are both safe types; a risky borrower matched with a safe partner has a higher optimal effort level than a safe borrower matched with a risky partner. That is, denoting borrower *i*'s optimal effort level with partner *j* as e_{ij}^* ($i=a,b$), we have

$$e_{bb}^*>e_{ab}^*>e_{ba}^*>e_{aa}^*. \tag{5}$$

Note that we change the subindex for effort from *i* to *ij* because the optimal effort of borrower *i* depends both on her own type *i* and on the type of her partner *j*.

Proposition 2: A borrower prefers a safe partner to a risky partner, despite her own type. That is, $E\pi_{bb}^*>E\pi_{ba}^*$ and $E\pi_{ab}^*>E\pi_{aa}^*$.

Proposition 3: Joint liability with varying risk types and effort levels leads to a single equilibrium of positive assortative matching in group formation. More specifically, $E\pi_{bb}^{*} - E\pi_{ba}^{*} > E\pi_{ab}^{*} - E\pi_{aa}^{*}$.

The equilibrium stated in Proposition 3 suggests that the net expected loss for a safe borrower of having a risky partner compared to having a safe partner is higher than the net expected gain for a risky borrower of having a safe partner compared to having a risky partner. As noted by Ghatak (1999), this equilibrium condition is similar to the optimal sorting property in Becker (1993), such that borrowers who are not in the same group should not be able to form a group without making one or both worse off.

Propositions 2 and 3 are consistent with the results from Ghatak (1999). The intuition behind is that while a borrower of any type prefers a safe partner because of lower expected joint liability payments, safe borrowers value safe partners more than risky borrowers because safe partners repay their loans more often and are more likely to realize the gains of having a safe partner. By allowing the probability of success to also depend on the borrowers' effort level, we additionally find that groups of safe partners will exhibit a higher effort (as shown in Proposition 1), which translates into further higher repayment probabilities. This result reinforces the notion that safe pairs will show a higher likelihood of repayment than risky pairs.

4.2. Cooperative Game

We next consider the cooperative game setting in which each borrower maximizes the expected total payoff of her group (formed by borrowers *i* and *j*) with respect to her effort:

$$\begin{aligned}\max_{e_i,e_j}\left(E\pi_{ij}+E\pi_{ji}\right) &= \left(p_i+e_i\right)\left(Y-r\right)-q\left(p_i+e_i\right)\left(1-p_j-e_j\right)-1/2\,\gamma e_i^2 \\ &\quad +\left(p_j+e_j\right)\left(Y-r\right)-q\left(p_j+e_j\right)\left(1-p_i-e_i\right)-1/2\,\gamma e_j^2\end{aligned} \tag{6}$$

$$\text{s.t. } e_i \ge 0,\ e_j \ge 0 \tag{7}$$

We obtain the same key results as those of the non-cooperative game: a single equilibrium with positive assortative matching in which groups of safe partners exhibit a higher effort than groups of risky partners. Specifically, Propositions 1 and 3 denoted above hold in the cooperative game setting as well as the following Proposition 2b (see Appendix B for the proof of the results).

Proposition 2b: A safe borrower will prefer a safe to a risky partner in the cooperative game setting, that is, $2E\pi_{bb}^{*} - \left(E\pi_{ab}^{*} + E\pi_{ba}^{*}\right) > 0$.

To summarize, we obtain two main results, which are consistent in both the non-cooperative and cooperative settings. First, a borrower's optimal effort level is higher if her partner is a safe type and is the highest when both are safe types. Second, a safe partner is preferred over a risky partner and a safe partner is more valued by a safe borrower than by a risky borrower. Consequently, joint liability with varying risk types and effort levels leads to a single equilibrium of positive assortative matching in group formation.

5. Conclusion

We propose a model that extends Ghatak (1999)'s base group lending model by accounting for both peer selection and moral hazard. In particular, we allow individuals to differ in their exogenous risk type or creditworthiness and in their endogenous effort level, which jointly affect the likelihood of their projects' success. To our knowledge, our model is the first study that endogenizes borrower's effort level in investigating matching patterns in the context of group lending under joint liability.

We find that, in equilibrium, borrowers form homogeneous groups based on their risk type, corroborating the theoretical findings in Ghatak (1999), Ghatak (2000) and van Tassel (1999). This finding is also supported by the recent empirical work of Gan, Hernandez and Liu (2018) and Ahlin (2020). We further find that borrowers in safe groups exert higher effort levels than those in risky groups, suggesting that lenders' optimal monitoring level may differ by group type. Our research highlights the usefulness of incorporating endogenous effort levels in models studying matching patterns in group lending.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

Appendix A: Proof of Propositions 1 - 3 in the Non-Cooperative Game

A1. Proof of Proposition 1

The first order conditions (FOCs) of the maximization problem described in (2)-(4) are

$$
\begin{gathered}
Y-r-q\left(1-p_j-e_j\right)-\gamma e_i \le 0, \\
Y-r-q\left(1-p_i-e_i\right)-\gamma e_j \le 0, \\
e_i \ge 0, \\
e_j \ge 0, \\
e_i\left[Y-r-q\left(1-p_j-e_j\right)-\gamma e_i\right]=0, \\
e_j\left[Y-r-q\left(1-p_i-e_i\right)-\gamma e_j\right]=0.
\end{gathered}
$$

Solving the FOCs, we have

$$
e_{ij}^{*}=\begin{cases} 0 & \text{if } \gamma \le q, \\ \dfrac{(\gamma+q)(Y-r)-q\left[q\left(1-p_i\right)+\gamma\left(1-p_j\right)\right]}{\gamma^2-q^2} & \text{if } \gamma > q. \end{cases}
$$

If we fix $\gamma > q$, we can discard the corner solution under which the second order condition (SOC) is violated. We only consider the interior solution. The SOC of the interior solution is satisfied and we have (5).

A2. Proof of Proposition 2

Substituting e_{ij}^{*} into $E\pi_{ij}$ in (1) and denoting M, A, and B as

$$
\begin{gathered}
M=Y-r-q, \\
A=e_{bb}^{*}-e_{ba}^{*}=e_{ab}^{*}-e_{aa}^{*}=\left[\gamma q\left(p_b-p_a\right)\right]/\left(\gamma^2-q^2\right), \\
B=e_{ba}^{*}-e_{aa}^{*}=e_{bb}^{*}-e_{ab}^{*}=\left[q^2\left(p_b-p_a\right)\right]/\left(\gamma^2-q^2\right),
\end{gathered}
$$

we obtain

$$
\begin{aligned}
E\pi_{bb}^{*}-E\pi_{ba}^{*} &= AM+qp_b\left(p_b-p_a\right)+qp_bB+q\left(e_{bb}^{*}p_b-e_{ba}^{*}p_a+e_{bb}^{*2}-e_{ba}^{*}e_{ab}^{*}\right) \\
&\quad -0.5\gamma A\left(e_{bb}^{*}+e_{ba}^{*}\right) \\
&> AM+qp_b\left(p_b-p_a\right)+qp_bB+qe_{bb}^{*}\left(p_b-p_a\right)-\left(\gamma-q\right)Ae_{bb}^{*} \\
&= AM+qp_b\left(p_b-p_a\right)+qp_bB+q^2\left(p_b-p_a\right)e_{bb}^{*}/\left(\gamma+q\right) \\
&> 0,
\end{aligned}
$$

where the first inequality is implied by (5). Similarly,

$$
\begin{aligned}
E\pi_{ab}^{*}-E\pi_{aa}^{*} &= AM+qp_a\left(p_b-p_a\right)+qp_aB+q\left(e_{ab}^{*}p_b-e_{aa}^{*}p_a-e_{aa}^{*2}+e_{ba}^{*}e_{ab}^{*}\right) \\
&\quad -0.5\gamma A\left(e_{ab}^{*}+e_{aa}^{*}\right) \\
&> AM+qp_a\left(p_b-p_a\right)+qp_aB+qe_{ab}^{*}\left(p_b-p_a\right)-\left(\gamma A-qB\right)e_{ab}^{*} \\
&= AM+qp_b\left(p_b-p_a\right)+qp_bB \\
&> 0.
\end{aligned}
$$

A3. Proof of Proposition 3

From the proof of Proposition 2, we have

$$\begin{aligned}&\left(E\pi_{bb}^{*}-E\pi_{ba}^{*}\right)-\left(E\pi_{ab}^{*}-E\pi_{aa}^{*}\right)\\&=q\left(p_b-p_a\right)^2+2q\left(p_b-p_a\right)B-\gamma AB+q\left(e_{bb}^{*2}+e_{aa}^{*2}-2e_{ba}^{*}e_{ab}^{*}\right)\\&=q\gamma^4\left(p_b-p_a\right)^2\Big/\left(\gamma^2-q^2\right)^2\\&>0.\end{aligned}$$

Appendix B: Proof of Propositions 1, 2b, and 3 in the Cooperative Game

B1. Proof of Proposition 1

The FOCs of the maximization problem described in (6) and (7) are

$$Y-r-q+2q\left(p_j+e_j\right)-\gamma e_i\le 0,$$

$$Y-r-q+2q\left(p_i+e_i\right)-\gamma e_j\le 0,$$

$$e_i\ge 0,$$

$$e_j\ge 0,$$

$$e_i\left[Y-r-q+2q\left(p_j+e_j\right)-\gamma e_i\right]=0,$$

$$e_j\left[Y-r-q+2q\left(p_i+e_i\right)-\gamma e_j\right]=0.$$

Solving the FOCs, we have

$$e_{ij}^{*}=\begin{cases}0 & \text{if } \gamma\le 2q,\\ \dfrac{(\gamma+2q)(Y-r-q)+2q\left(2qp_i+\gamma p_j\right)}{\gamma^2-4q^2} & \text{if } \gamma>2q.\end{cases}$$

Imposing $\gamma>2q$ to eliminate the corner solution ($e_{ij}=0$), we have the interior solution under which the SOC is satisfied and obtain (5).

B2. Proof of Proposition 2b

Plugging e_{ij}^{*} into $E\pi_{ij}$, we have

$$\begin{aligned}E\pi_{bb}^{*}-E\pi_{ba}^{*}&=A'M+qp_b\left(p_b-p_a\right)+qp_bB'+q\left(e_{bb}^{*}p_b-e_{ba}^{*}p_a\right)\\&\quad+q\left(e_{bb}^{*2}-e_{ba}^{*}e_{ab}^{*}\right)-0.5\gamma\left(e_{bb}^{*2}-e_{ba}^{*2}\right),\end{aligned}$$

$$\begin{aligned}E\pi_{bb}^{*}-E\pi_{ab}^{*}&=B'M+\left(p_b-p_a\right)M+qp_b\left(p_b-p_a\right)+q\left(2p_be_{bb}^{*}-p_ae_{ba}^{*}-p_ae_{ab}^{*}\right)\\&\quad+q\left(e_{bb}^{*2}-e_{ab}^{*}e_{ba}^{*}\right)-0.5\gamma\left(e_{bb}^{*2}-e_{ab}^{*2}\right),\end{aligned}$$

where

$$A'=e_{bb}^{*}-e_{ba}^{*}=e_{ab}^{*}-e_{aa}^{*}=\left[2\gamma q\left(p_b-p_a\right)\right]\Big/\left(\gamma^2-4q^2\right),$$

$$B'=e_{bb}^{*}-e_{ab}^{*}=e_{ba}^{*}-e_{aa}^{*}=\left[4q^2\left(p_b-p_a\right)\right]\Big/\left(\gamma^2-4q^2\right).$$

We note

$$
\begin{aligned}
& q\left(e_{bb}^{*2}-e_{ba}^{*}e_{ab}^{*}\right)-0.5\gamma\left(e_{bb}^{*2}-e_{ba}^{*2}\right)+q\left(e_{bb}^{*2}-e_{ba}^{*}e_{ab}^{*}\right)-0.5\gamma\left(e_{bb}^{*2}-e_{ab}^{*2}\right) \\
& >2q\left(e_{bb}^{*2}-e_{ba}^{*2}-e_{ab}^{*2}\right)-\gamma e_{bb}^{*2}+0.5\gamma\left(e_{ab}^{*2}+e_{ba}^{*2}\right) \\
& =-0.5(\gamma-2q)A'\left(e_{bb}^{*}+e_{ba}^{*}\right)-0.5(\gamma-2q)B'\left(e_{bb}^{*}+e_{ab}^{*}\right) \\
& >-(\gamma-2q)(A'+B')e_{bb}^{*} \\
& =-(A'+B')M-2qp_b(A'+B'),
\end{aligned}
$$

where the inequalities are implied by (5). Then

$$
\begin{aligned}
& 2E\pi_{bb}^{*}-\left(E\pi_{ab}^{*}+E\pi_{ba}^{*}\right) \\
& >(A'+B')M+2qp_b(p_b-p_a)+(p_b-p_a)M+qp_bB'+q\left(e_{bb}^{*}p_b-e_{ba}^{*}p_a\right) \\
& \quad +q\left(2p_be_{bb}^{*}-p_ae_{ba}^{*}-p_ae_{ab}^{*}\right)-(A'+B')M-2qp_b(A'+B') \\
& =(2qp_b+M)(p_b-p_a)+q\left(e_{bb}^{*}p_b-e_{ba}^{*}p_a\right)+q\left(2p_be_{bb}^{*}-p_ae_{ba}^{*}-p_ae_{ab}^{*}\right) \\
& \quad -2qp_bA'-qp_bB' \\
& >(2qp_b+M)(p_b-p_a)+qp_bA'+qp_bA'+qp_bB'-2qp_bA'-qp_bB' \\
& =(2qp_b+M)(p_b-p_a) \\
& >0,
\end{aligned}
$$

where the second inequality is implied by $p_b > p_a$.

B3. Proof of Proposition 3

Finally, we examine if positive assortative matching is the only equilibrium, which is implied by $2E\pi_{bb}^{*}-\left(E\pi_{ba}^{*}+E\pi_{ab}^{*}\right)>\left(E\pi_{ba}^{*}+E\pi_{ab}^{*}\right)-2E\pi_{aa}^{*}$. That is, the net expected gain of a risky borrower to have a safe instead of a risky partner would be higher than the net expected loss of a safe borrower to have a risky instead of a safe partner.

Plugging e_{ij}^{*} into $E\pi_{ij}$, we have

$$
\begin{aligned}
& \left(E\pi_{bb}^{*}-E\pi_{ba}^{*}\right)-\left(E\pi_{ab}^{*}-E\pi_{aa}^{*}\right) \\
& =q(p_b-p_a)^2+2q(p_b-p_a)B'-\gamma A'B'+q\left(e_{bb}^{*2}+e_{aa}^{*2}-2e_{ba}^{*}e_{ab}^{*}\right) \\
& =q(p_b-p_a)^2+B'\left[2q(p_b-p_a)-\gamma A'\right]+\frac{4q^5\left(\gamma^2+4q^2\right)(p_b-p_a)^2}{\left(\gamma^2-4q^2\right)^2} \\
& =q(p_b-p_a)^2-\frac{32q^5(p_b-p_a)^2}{\left(\gamma^2-4q^2\right)^2}+\frac{4q^5\left(\gamma^2+4q^2\right)(p_b-p_a)^2}{\left(\gamma^2-4q^2\right)^2} \\
& =q(p_b-p_a)^2\left[1+\frac{-32q^4+\left(\gamma^2+4q^2\right)4q^2}{\left(\gamma^2-4q^2\right)^2}\right] \\
& =q\gamma^2(p_b-p_a)^2/\left(\gamma^2-4q^2\right) \\
& >0.
\end{aligned}
$$