Mutual Risk Sharing and Fintech: The Case of Xiang Hu Bao*

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Abstract

Unlike standard insurance where an intermediary–the insurance company–collects premiums and pays reimbursements for the enrollees, mutual risk sharing directly shares losses among participants. Meaning 'mutual aid' in Chinese, Xiang Hu Bao (*XHB*) was the largest online mutual risk sharing platform operated by Alibaba's Ant Financial to facilitate risk sharing of critical illness exposures. *XHB* provided restricted coverage to aged individuals, potentially leading to separating equilibrium, à la Rothschild-Stiglitz, where low-risk individuals join mutual aid programs while high-risk individuals purchase insurance. Using *XHB*'s enrollment and claim data, our analysis corroborates this argument and justifies the role of Fintech and advantageous selection in explaining cost advantages of mutual risk sharing.

Keywords: Mutual risk sharing; Fintech; Separating equilibrium; Advantageous selection; Sharing economy
JEL codes: G22; G23; I14; I15

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1 Introduction

Borch's theorem (Borch, 1962), often referred to as the *mutuality principle*, applies Arrow (1953)'s general equilibrium framework to characterize optimal risk sharing in the insurance market. It proposes that participants mutually insure each other to share diversifiable risks while transferring non-diversifiable risks to the more risk-tolerant parties. While the mutuality principle is considered as the cornerstone of the insurance theory and mutual risk sharing, it is barely applied in practice. A major hurdle is the challenge in reaching a sufficiently large pool to diversify the idiosyncratic risks given the presence of myriad regulatory interventions and significant information costs. In the marketplace, rather than participants pooling risks and mutually insuring each other, insurance companies assume a central role, setting premiums with the goal to maximize their own values (Marshall, 1974).

The significant progress in information technologies opens new venues in risk sharing and risk management practices (OECD, 2017). Just like peer-to-peer (P2P) lending platforms connected un- or under-financed borrowers to lenders, emerging Fintech platforms can also be leveraged to reach traditionally un-insured or under-insured customers. This is exemplified by Xiang Hu Bao (abbreviated as *XHB*, literally meaning 'protecting each other' in Chinese), an online mutual risk-sharing platform, also popularly known as a mutual aid product, operated by the Chinese Fintech giant Ant Financial. Launched in late 2018, *XHB* provides indemnity payments to members who are confirmed to have been diagnosed one of the 100 types of covered critical illnesses, such as thyroid cancer, breast cancer, lung cancer, and critical brain injury. Individuals between 30 days and 59 years of age who meet basic health and risk criteria are eligible to become members of *XHB*. The program has been successful: by December 2019, just one year after its inception, *XHB* already had nearly 100 million members, a figure that rivals the total number of traditional critical illness insurance policyholders in China. Although *XHB* achieved widespread market acceptance, it was perceived as a disruptive innovation with possible implications for financial instability. As a result, it failed to secure regulatory approval. *XHB* ceased its operations on January 28, 2022 owing to the substantial pressure to adapt to insurance and financial regulations.[1]

In contrast to the typical practice of pre-defined pricing in traditional insurance, *XHB* operates on an ex-post basis – it distributes losses and expenses among participants after they occur. In a practical term, healthy *XHB* members evenly share the total medical claim payouts within each biweekly claim period, augmented by an 8% markup. In return, upon confirmation of treatment for any covered critical illness, members qualify for a fixed indemnity of CNY 300,000 for individuals under 40 and CNY 100,000 for those aged 40 and above. Remarkably, *XHB*'s participation cost per member is well below the premium of the corresponding critical illness insurance (*CII*) providing the same level of coverage – *XHB* charged between CNY 3 and CNY 6 for coverage of over 100 illnesses in a biweekly claim period while the comparable one-year term *CII* for a 30-year old

[1] *XHB* was not the only mutual aid platform, but it was the largest. Other major mutual aid platforms such as Waterdrop Mutual, Meituan Mutual, and Qingsong Mutual, all ceased operations in 2021 for reasons similar to those that led to the closure of *XHB*. For general information about mutual aids, see the work by Abdikerimova and Feng (2002).

female charged an annual premium between CNY 400 and 600, i.e., between CNY 16 and CNY 25 biweekly. This substantial price difference is unlikely to be solely due to the ex-ante and ex-post arrangements in *XHB* and insurance, especially given *XHB*'s significant scale and its extensive pool size that reduce uncertainty. An intriguing question arises: What factors might contribute to the price gap between these two products?

XHB has several technology-driven advantages over traditional insurance. First, *XHB*'s enrollment process is exclusively operated online and mandates possession of an Alipay account from Ant Financial (by the individual her/himself or her/his immediate family member), coupled with meeting the credit score requirement.[2] Secondly, *XHB* implements an artificial intelligence (*AI*) system designed for processing and settling critical illness claims. This system standardizes the claim procedure, mitigating errors stemming from subjective human biases. This technological approach empowers XHB to establish a competitive edge over traditional insurance firms, which often have less reliance on advanced technology in their claim processes. Moreover, *XHB* publicly discloses approved critical illness cases, ensuring transparency among all participants regarding the claim payments. Remarkably, *XHB* members have the opportunity to contest unfavorable decisions through an appeals process. The details of appealed claims are shared on *XHB*'s public panel, engaging millions of qualified *XHB* members who voluntarily participate in the arbitration process. This offers incentives to the large number of *XHB* members actively involved in the claim process, which is nonexistent in the traditional insurance market. In a seminal article titled *Vox Populi*, meaning 'voice of the people', published in *Nature*, Galton (1907) demonstrates the surprising accuracy of a group's aggregated judgments, namely the 'wisdom of crowds.'

A main insight from this study is that the relatively rigid indemnity amount structure plays a key role in *XHB*'s ability to address the adverse selection problem. *XHB*'s indemnity is below the typical medical cost to treat a critical illness, particularly for elder members who receive a reduced indemnity – the indemnity level to members who are 40 and above is only 1/3 of the indemnity to those below 40. We demonstrate, theoretically, the existence of a separating equilibrium, à la Rothschild-Stiglitz where low-risk individuals choose *XHB* while high-risk individuals purchase traditional critical illness insurance. In our setup, insurance, due to its ex-ante pricing, comes at a higher cost but offers superior protection compared to *XHB*. High-risk individuals value better protection in choosing the coverage amount offered by insurance over the cost benefit under *XHB*. Put differently, the design of *XHB* alleviates the adverse selection problem outlined in Akerlof (1970) and Rothschild and Stiglitz (1976) that high-risk individuals are more likely to purchase protections than low-risk individuals do. We provide empirical support for the separating equilibrium through a comparison between the participation rates of young people and older individuals. The empirical finding is in line with the separating equilibrium hypothesis. For instance, in June 2020, *XHB* boasted 74 million participants below 40 years old and 27 million participants between the ages

[2] As displayed in Figure 1, using the data in June 2020, nearly 40% of Alipay account holders are under 25 years old, far exceeding the representation of this age group in the national population, accounting for just over a quarter. On the other hand, only 9% of Alipay users fall within the 40 and above age range, whereas individuals aged 40 and above constitute nearly 50% of the national population. Alipay users are much younger, thus healthier, than the general public.

of 40 and 59. The age distribution of *XHB* is 2.7:1 for those under 40 to those between 40 and 59, surpassing age distribution of the national population, with a ratio of 1.7:1. These figures suggest that *XHB* holds an advantage in attracting younger individuals, who are often perceived as healthier.

If, in accordance with the prediction of the separating equilibrium, the coexistence of *XHB* and commercial critical illness insurance (*CII*) can separate individuals of different risk types, we would expect a higher likelihood of lower-risk individuals opting for *XHB*. To test this, we conduct a comparative analysis of incidence rates between *XHB* and *CII* that covers the same set of critical illnesses. Our finding presents robust support for the hypothesis. Irrespective of age, the average incidence rate of *XHB* is 1/7 to 1/6 of *CII*'s for the 6 and 25 leading critical illnesses; the same pattern holds for individuals of 10-year age buckets including 3-month to 9-year, 10 to 19, and so on up to the 50 to 59 group. A close look at the incidence rates of the 50 to 59 group reveals that *XHB*'s average critical illness incidence rate is also far below that of the average incidence rates of *CII*; respectively, in terms of the top 6 and 25 critical illnesses, the average incidence rates of *CII* are 7.4 and 7.8 times of those for *XHB*. This unequivocally bolsters the separating equilibrium argument. *XHB*'s low incidence rate cannot be solely attributed to the exclusion of older people. Instead, it reflects the product's ability to attract healthier individuals.

Individuals possess traits beyond their risk profiles. Built on this idea, the advantageous selection argument offers a broader, multi-dimensional framework to understand individuals' decision-making. It indicates that besides risk, factors such as risk aversion, as well as individual attributes like wealth and education play a significant role in shaping individuals' incentives for risk taking (de Meza and Webb, 2001; Cutler, Finkelstein, and McGarry, 2008; Fang, Keane, and Silverman, 2008; Einav, Finkelstein, and Mahoney, 2021). We, therefore, anticipate the design of *XHB* is geared towards attracting individuals with favorable attributes potentially leading to lower claim payments. We examine the advantageous selection argument using a comprehensive mutual aid survey conducted by Ant Financial. The data provides information about survey respondents' participation in mutual aid programs including *XHB*, their income, and their purchase of commercial health insurance. Our first test focuses on the demographic characteristics of individuals inclined to be a member of mutual aid platforms. We find that high-income individuals, either proxied by reported income ranges or by their residing city tiers, are more likely to participate in mutual aid programs than low-income respondents. Given that wealthier people are healthier (as indicated by research such as Ettner, 1996; Lopez, 2004; Deaton, 2008), our result supports the advantageous selection argument.

Moreover, due to its lower cost but more rigid coverage, *XHB* is more suitable for young, healthy individuals who may have less inclination toward costly critical illness insurance. It also serves individuals with lower incomes who might find traditional coverage unaffordable. Conversely, *CII* appeals to high-risk individuals owing to the advantages in risk classification and its ability to cede risks to reinsurance companies. The distinctions prompts us to study individuals' decisions about mutual aid products and insurance using the mutual aid survey data. We have several interesting findings. First, we find that respondents who already have commercial health insurance exhibit a decreased inclination to participate in mutual aid programs. Individuals with insurance might perceive mutual aid programs as redundant or duplicative to the coverage they already possess, leading to a lack of interest in participating. Second, we show that *MA* provides an effective venue for low-income individuals to obtain critical illness protection. Low-income individuals are more inclined to exclusively participate in *MA* programs rather than having insurance or a combination of *MA* and insurance, confirming that mutual aid platforms can reach customers typically not covered by conventional medical insurance and critical illness coverage. Finally, and remarkably, participation in mutual aid programs appears to increase individuals' inclination to purchase commercial health insurance, suggesting heightened risk awareness. This finding aligns with a recent study, Barrios, Hochberg, and Yi (2022), showing that the sharing economy (also known as the gig economy) positively impacts conventional business development due to its flexible nature and low-entry barriers, enabling supplementary income for aspiring entrepreneurs. In summary, *MA* programs nicely complement, rather than replacing, traditional insurance.

In an insightful study, Carbrales, Calvo-Armengol, and Jackson (2003) examine a primitive mutual risk-sharing program, namely 'La Crema', meaning mutual farm insurance, which applies a special way to determine how much a household is reimbursed in the case of a fire and how payments are apportioned among other households - solely relying on households' announced property value. They conclude that as the size of the society becomes large, the benefit from deviating from truthful reporting vanishes, resulting in equilibria of the mechanism being nearly truthful and approximately Pareto efficient. Carbrales et al. (2003) highlight two key features of mutual farm insurance: i) severe penalty in case a member commits fraud, and ii) the arrangement being made in a tight knot society; given that each household is insured by its neighbors, who have the incentive to monitor the behavior of a given household. The contrast between 'La Crema' and *XHB* is striking: while 'La Crema' emphasizes direct connections among its members, *XHB* operates differently. As *XHB* members usually lack direct connections with each other, it is the applications of financial technologies that bring largely independent individuals into the common risk-sharing pool.

XHB exemplifies a fusion of modern financial technologies with classical principles such as mutual risk sharing and advantageous selection in the insurance sector. Our findings indicate a notable similarity with practices observed in capital markets, particularly in areas like asset management and banking (see, e.g., Chen, Wu, and Yang, 2019; Thakor, 2020; Zhu, 2019; Zetzsche, Arner, and Buckley, 2020). By leveraging innovative technologies such as artificial intelligence and blockchain applications, service providers can effectively lower operational costs, improve operational processes (like AI aids in automating tasks), and expand their services to individuals and groups previously hard to reach. The effectiveness of mutual aid practices is highlighted by the significant disparity in incidence rates between *XHB* and *CII*.

We illuminate that the ex-post loss-sharing can outperform traditional insurance in managing diversifiable risks. Our work is broadly related to the extensive literature on household risk sharing. The literature, e.g., Cochrane (1991); Townsend (1994); Cox and Fafchamps (2007); Fafchamps and Gubert (2007); Ambrus, Mobius, and Szeidl (2014), highlight risk sharing among households, i.e., the connection between friends and families, is an important channel to cope with idiosyncratic risks such as illness, unemployment, and bad harvest. These studies focus on the premise of mutual risk sharing - the mutuality principle that an individual's idiosyncratic risk does not matter to her or his consumption while the aggregate risk does. Despite its reliance on personal connections, informal insurance is limited due to transaction costs and information imbalances. Our paper proposes that Fintech presents the potential for more efficient risk-sharing mechanisms, particularly in managing diversifiable risks. One may apply innovative financial technology to address other risks stemming from social networks. For instance, households in less-developed economies pay much more out-of-pocket costs in health expenditures than those in developed economies.[3]

Notably, the closure of *XHB* has underscored the regulatory challenges and political uncertainty in Fintech. With 75 million members compelled to seek alternative coverage or left unprotected following XHB's discontinuation in January 2022 (Feng and Ng, 2021), our paper highlights the significant consumer benefits provided by *XHB*. Despite posing challenges to regulators and potential risks as an ex-post arrangement, it has proven crucial in offering protection to those in need. This case presents a crucial opportunity to assess the efficacy of current regulatory frameworks. An in-depth exploration could illuminate how regulatory adjustments might better adapt to Fintech's evolving landscape (see the relevant discussions in, e.g., Goldstein et al., 2019; Zetzsche et al., 2020), striking a balance between fostering innovation and ensuring robust consumer and business protection.

The remainder of the paper is structured as follows. In Section 2 we describe the institutional background of *XHB*; in Section 3 we present a simple model that contrasts mutual aid against critical illness insurance, and demonstrate the existence of separating equilibrium; in Section 4 we describe the data sets used in our empirical analysis; in Section 5 we present our empirical findings; and finally in Section 6 we conclude.

2 Xiang Hu Bao Overview

Started in October 2018, Xiang Hu Bao was the largest online mutual aid platform sponsored by Alibaba's Ant Financial. The life insurance partner quit shortly after the launch, making *XHB* a pure online mutual aid platform.[4] *XHB* hosts two plans: i) the critical illness plan, abbreviated as *CIP*, for young and middle-aged participants between 30 days and 59 years covering 100 critical illnesses and 5 rare illnesses (see the list provided in Appendix A), and ii) the senior plan, abbreviated as *SP*, for senior participants 60 to 70 covering malignant tumors/cancers only (thus it is also known as the 'senior cancer plan'). All participants of *CIP* stay in the same pool whereas the indemnity to members below 40 is CNY 300,000 while the indemnity to members who are 40 and above is CNY 100,000. Moreover, senior participants between 60 and 70 stay in a different pool

[3] According to the World Bank's worldwide development indicator data, the ratios were 54.78% and 64.39% for India and Cambodia while they were merely 11.31% and 17.07% for the U.S. and U.K. in 2019.

[4] *XHB* was jointly launched in October 2018 by Ant Financial and its life insurance partner, Trust Mutual Life Insurance. It was initially operated as a peer-to-peer risk sharing program with an annual price ceiling of CNY 188. Trust Mutual Life left the platform a month later because the price ceiling was not approved by the Chinese Bank and Insurance Regulatory Commission (*CBIRC*).

and they receive CNY 100,000 once confirmed to have a malignant tumor. The size of *CIP* is far larger than that of *SP* - at the end of 2020, the number of participants in *SP* was 4% of *CIP*'s. Both programs stipulate that members are eligible for a single indemnity payment throughout their lifetime.

Table 1 discusses *XHB*'s critical illness coverages. The first version was effective from October 2018 to April 2019, covering 99 critical illnesses and critical malignant tumors. The indemnity for a young and middle-aged participant diagnosed with critical illness is CNY 300,000 (approximately USD 43,000) and the indemnity is reduced to CNY 100,000 for an ill participant at or above 40. In the second version, *XHB* re-classified two severe critical illnesses to mild critical illnesses with an indemnity of CNY 50,000, for both young and middle-aged participants.[5] Next, in the third version starting in January 2020 and ending in May 2020, *XHB* additionally added coverages for 5 rare illnesses but discontinued its coverage for the two mild illnesses.[6] The latest version of the program offers an alternative reduced indemnity plans which allows CNY 100,000 indemnity for participants below 40 and CNY 50,000 for participants 40 and older. Accordingly, corresponding participation costs are determined on a proportional basis.

Panel A of Figure 2 outlines *XHB*'s enrollment procedure. It begins with a smartphone application where individuals use their authentic identity to apply. To be a member, an applicant needs to be free of any illness listed in Appendix A before joining *XHB*. The first 90 days of enrollment is the *probation period*; if a new member is diagnosed with a critical illness within the probation period, then the membership would be terminated and the paid sharing costs would be fully refunded. The participation in *XHB* is completely voluntary. It is important to note that participants can leave the platform at any time. Nevertheless, in case that a prior member rejoins the program, the 90-day probation period would be applied again. Moreover, individuals are (or directly associated with) account holders of Alipay, the Chinese counterpart of PayPal, the largest online payment platform operated by Ant Financial, to be a *XHB* member. As displayed in Figure 1, Alipay participants are much younger and healthier than the national population. *XHB* requires applicants to have an above-average credit score, a minimum of 600 sesame points out of the maximum of 950 points, to be eligible for *XHB*. Prior works (e.g., Ettner, 1996; Lopez, 2004; Deaton, 2008) show that wealthier people are healthier. Therefore, it is plausible that *XHB* participants are healthier than participants of other insurance products not subject to these requirements.

Panel B of Figure 2 describes *XHB*'s Fintech-empowered claim process. The process starts with online claim submissions that claim documents are required to be submitted through *XHB* mobile phone applications. The platform applies textual analysis to process submitted files and gener-

[5]The two types of illnesses originally categorized as malignant tumors in the first version of *XHB* ('V1') are: i) Papillary thyroid cancer (PTC) or follicular thyroid cancer (FTC) without distal metastases and ii) T2N0M0 prostatic cancer. They are reclassified as mild critical illnesses in *XHB* 'V2', because based on relevant statistics, the per-capita treatment cost of these two types of illnesses is less than CNY 20,000, and the prognosis is good, which will not impose a huge burden on patients.

[6]The five rare illnesses added in *XHB* 'V3' are Gaucher's disease, Fabry disease, mucopolysaccharide storage disease, Pompe disease and Langerhans cell histiocytic hyperplasia. According to *XHB*, these five rare illnesses are relatively common, expensive to treat and have a big impact on normal life, and their inclusion in the coverage will help reduce the burden of families with rare illnesses.

ate digital documents. Important information is extracted from documents and used to generate more than 100 reports used for subsequent analysis. An artificial intelligence (AI) based system conducts a preliminary review involving online video interviews and field visits to hospitals and relevant sites. Internet appendix B provides the design and operational details of AI system.[7] After completing the investigations, *XHB* publicly announces approved claims to members on scheduled announcement dates (the 7th and 21st in each month), ensuring transparency among all participants regarding claim payments. On the other hand, *XHB* privately notify members whose claim requests were rejected, allowing the possibility of appealing rejected claims. On announcement dates, total claim payments within *XHB* are evenly distributed among participants. If a participant intends not to partake in the payment sharing for a given period t, they must exit *XHB* before the claim announcement day. Subsequent to the announcement, a three-day notification period ensues, allowing members to address concerns regarding pending payment claims. Undisputed claims are slated for payment on the 14th and 28th of each month, known as payment dates. However, any claims contested by *XHB* members are removed from the pending payment queue and undergo re-examination by specialized claim handlers. The claim-related data is securely recorded on a tamper-proof blockchain.

XHB members can challenge an unfavorable decision by requesting a second-round review by an appeal panel consisting of members who have joined *XHB* more than 30 days and completing a qualification test on basic knowledge of the product and its coverage. The second-round review is administered by a third party who invites eligible panel members randomly. Invited panel members vote within a 24-hour interval. Each appeal case involved more than 1 million panel member votes. The simple majority rule is utilized to ascertain whether a case succeeds in its appeal. This method aligns with the principle of the 'wisdom of crowds,' where the collective judgment of a majority is relied upon to determine the outcome. There were altogether 12 appeals conducted from October 2018 up to its end in January 2022, among which three were successful. This extremely low number of appeals indicates that second-round investigations are a rare event,[8] while the low appeal winning percentage (3 out of 12 appeals altogether) suggests a low likelihood of false rejections in the first-round claim process.

XHB vs. *CII*

Similar to *XHB*, commercial critical illness insurance *CII* offers lump-sum indemnities to claimants.[9] The same types of illnesses are covered by *CII* and *XHB*. Despite so, there are important differences between these two. First, *XHB* allows members to share losses while *CII* sets a predetermined price for critical illness exposure. As *CII* offers greater certainty to participants, it is expected to be more

[7] It is based on multiple interviewers we had with *XHB* key employees and the researchers from the Research Institute of Ant Financial.

[8] *XHB* handled over 200,000 claims in 2020 and rejected over 50% of these cases. This is discussed in Appendix B.

[9] This is different from other medical insurance policies which typically reimburse actual medical costs up to a certain limit. Critical illness insurance offered by the government, discussed in Internet Appendix C, is reimbursement-based.

costly (this point is elaborated in Section 3.2).[10] Second, distinct from *XHB* offering short-term (bi-weekly) coverage, policies of traditional critical illness insurance have a much longer horizon, e.g., one year, multiple years, or even life-long, namely term critical illness insurance and whole-life critical illness insurance. Third, critical illness insurance offers more flexibility in terms of indemnity amount than *XHB* and other mutual aid products. As such, mutual aid products may be viewed as a supplement to insurance. Finally, different from *XHB* offering a one-time payment to each participant treated for a critical illness, critical illness insurance often allows multiple payments - it breaks down critical illnesses into several categories, and purchasers are eligible to receive one claim payment for each category. In all these aspects, *CII* provides a more comprehensive coverage than *XHB*. At the end of 2019, *CII* covered approximately 100 million people, a comparable size to *XHB*.

3 A Simple Model

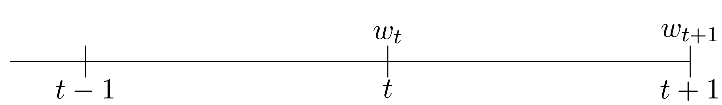
3.1 Risk Sharing in a Large Diverse Pool

XHB has a large diverse pool of participants, thus different from traditional insurance programs classifying heterogeneous participants into different pools. While a larger pool offers a higher level of diversification, heterogeneity across participants (e.g., ages and incidence rates) potentially results in wealth transfer from younger low-risk individuals to older high-risk participants. We model this tradeoff in this section. Using x to denote *XHB*, we express the price, or more precisely the sharing cost, of *XHB*, $\tilde{\pi_t}^x$, as:

$$\tilde{\pi_t}^x = \tilde{p_t}^x k^x (1 + \lambda^x) \tag{1}$$

XHB shares losses ex-post, making its price $\tilde{\pi_t}^x$ is time varying. $\tilde{p_t}^x$ is the incidence rate for *XHB* at time t (which is determined by the proportion of participants being critically ill between $t-1$ and t); k^x is the amount of fixed indemnity to an ill *XHB* participant; λ^x is the markup (to over its operating expenses) charged to *XHB* participants proportional to the indemnity payments.

Note that individuals make their decisions on whether to continue with *XHB* before $\tilde{p_t}^x$ is publicly announced. This is illustrated as the following timeline:



In this two-period setup, the loss occurs between $t-1$ and t but *XHB*'s incidence rate of period t is announced between t and $t+1$. Claim payments are made at $t+1$. To be eligible for the claim payment between t and $t+1$, the individual must be a *XHB* member at $t-1$. As a result, when

[10]In the realms of insurance research and practice, insurers maintain capital reserves to counter potential losses, usually imposing an extra risk charge to manage uncertainties. However, from the capital market standpoint which distinguishes between diversifiable and non-diversifiable risks, only market-correlated risk significantly impacts security prices. As a result, in equilibrium, prices of *CII* align with prices of *XHB*, and higher insurance prices could be interpreted as a form of market friction.

an individual decides whether to stay with *XHB* and commits to pay the price, $\tilde{\pi_t}^x$, she or he does not know $\tilde{p_t}^x$. As such, we express $\tilde{p_t}^x$ as the sum of an expected incidence rate p^x and a residual term ν_t^x, with a mean 0 and a standard deviation of σ. ν_t^x is the idiosyncratic risk, which can be fully diversified away.

$$\tilde{p_t}^x = E(\tilde{p_t}^x) + \nu_t^x = p^x + \nu_t^x \tag{2}$$

We study the optimal *XHB* design concerning the pool size, N (the number of participants of different risks). As outlined above, the participant receives a stream of wealth: w_t at t and w_{t+1} at $t+1$. Participating in *XHB* qualifies the individual to receive the indemnity k^x if diagnosed to be critically ill at t, but it also subjects the individual to price uncertainty since *XHB* shares the losses during period t. Denoting the incidence rate for individual s to be p_s and the amount of losses to be l, the individual's expected utility as an *XHB* member can be expressed as:

$$E[u^x] = \underbrace{E[u(w_t - \tilde{\pi_t}^x)]}_{EU_t} + \underbrace{\beta[(1-p_s)u(w_{t+1}) + p_s u(w_{t+1} - l + k^x)]}_{EU_{t+1}} \tag{3}$$

where β is the discount rate imposed on the utility of period $t+1$.

Given the substantial consequence of critical illnesses, both physically and economically, participating in *XHB* or not (or whether purchasing critical illness insurance) has little impact on the individual's incidence rate. Thus we expect EU_{t+1} to be independent of N (i.e., $\frac{\partial EU_{t+1}}{\partial N} = 0$) and we focus on $\frac{\partial EU_t}{\partial N}$. Applying the Arrow-Pratt approximation (Arrow, 1965; Pratt, 1964), we express EU_t, the expected utility of a *XHB* participant from his wealth at t, as below:

$$\begin{aligned} E[u(w_t - \tilde{\pi_t}^x)] &= u[w_t - E(\tilde{\pi_t}^x) - \Pi_t^x] \\ &= u[w_t - p^x k^x (1+\lambda^x) - \Pi_t^x] \\ &= u[v_t^x - \Pi_t^x] \end{aligned} \tag{4}$$

where

$$\begin{aligned} \Pi_t^x &= 1/2 A_s [k^x(1+\lambda^x)\sigma^x]^2 \\ v_t^x &= w_t - p^x k^x (1+\lambda^x) \end{aligned} \tag{5}$$

A_s is the individual's risk aversion. λ^x is *XHB*'s administrative cost per dollar of claim payment. Π_t^x is the loss to *XHB* participants due to its price uncertainty. σ^x is the standard deviation of *XHB*'s incidence rates.

By taking derivatives of the expected utility, $E[u_t^x]$, against the size of the pool, N, and setting it to zero, we relate individuals' optimal participation decisions to the expected value and standard deviation of *XHB*'s incidence rates. It leads to the following condition:

$$\frac{\partial p^x}{\partial N} + \gamma \frac{\partial \sigma^x}{\partial N} = 0 \tag{6}$$

where $\gamma = A_s k^x (1+\lambda^x)\sigma^x > 0$. See Appendix D.1 for the proof.

The above suggests that the pool size of *XHB* affects a participant's expected utility by influencing i) the pool's incidence rates and ii) the uncertainty of its incidence rates. As *XHB* consists of individuals of varying ages, an increase in pool size might lead to higher incidence rates. Considering this, the importance of a larger pool size leading to a decrease in σ^x emerges as a critical factor for optimizing participants' expected utility. This establishes the first proposition:

Proposition 1 *p^x and σ^x are the expected value and standard deviation of* XHB*'s incidence rates. N denotes the number of participants. The condition to optimize* XHB *participants' expected utility is: $\frac{\partial p^x}{\partial N} + \gamma \frac{\partial \sigma^x}{\partial N} = 0$ where $\gamma = A_s k^x (1 + \lambda^x) \sigma^x$. The amalgamation of individuals with heterogeneous incidence rates necessitates a condition for maximizing expected utility: $\frac{\partial \sigma^x}{\partial N} < 0$.*

Although larger pools likely mitigate uncertainty, this principle doesn't universally apply when dealing with individuals possessing diverse risk profiles. When low-risk individuals and high-risk counterparts share risks, the reduction of uncertainty might not hold true in all cases. In practical terms, *XHB*'s decision to establish 40 years old as the threshold for different lump-sum payments prompts inquiry into its optimality. Is this age cutoff the most effective choice? We address this question in the empirical section.[11]

3.2 Pricing Disparity between *XHB* and *CII*

We compare prices of *XHB* and *CII*: *XHB* sets price ex-post while *CII* sets price ex-ante. *CII*'s price is its expected incidence rate plus an additional risk charge to cover unexpected variations in claims. Using i to denote insurance, we express the insurance price, π_t^i, as below:

$$\pi_t^i = p^i k^i (1 + \lambda^i) \tag{7}$$

where p^i and k^i are the expected incidence rate and the indemnity amount of *CII*; λ^i is the insurance markup (i.e., its operating cost per dollar of claim payment). Different from the variable price for *XHB*, the insurance price is determined by the expected incidence rate. It remains constant in our setup.

The individual's expected utility with an insurance coverage can be expressed as:

$$E[u^i] = E[u(w_t - \tilde{\pi}_t{}^i)] + \beta[(1 - p_s)u(w_{t+1}) + p_s u(w_{t+1} - l + k^i)] \tag{8}$$

Assume that *XHB* and *CII* offer identical coverage, $k^i = k^x$, and have the same expected incidence rates, $p^i = p^x$. The expected utilities under *XHB* and *CII* are equal ($E[u^i] = E[u^x]$) in absence of counterparty risks. This leads to specific relationships in their prices and markups:

$$\begin{aligned} \pi^i - \pi^x &= \Pi^x \\ \lambda^i - \lambda^x &= \frac{\Pi^x}{k^x p^x} \end{aligned} \tag{9}$$

[11] In practice, individuals often lack knowledge of their precise risk types ex-ante, as indicated by Doherty and Thistle (1996); Doherty and Posey (1998), rationalizing *XHB* type of pooling arrangement that blends individuals of diverse risk types.

where $\pi^x = E[\pi_t^x]$ and $\Pi^x = E[\Pi_t^x]$.

Intuitively, *CII* is more expensive because it offers a fixed premium while *XHB* participants face uncertain prices. Since they have the same expected incidence rates, i.e., the same expected losses, the difference in their prices is reflected in the difference in their markups. This is summarized in the following proposition.

Proposition 2 *Given the same indemnity of* XHB *and* CII*, that is,* $k^x = k^i$*, the* CII *price is expected to be higher than the* XHB *price because the insurance premium is set ex-ante while* XHB *participation cost is ex-post. In absence of counterparty risk, the price difference between* CII *and* XHB *is* Π^x $(= 1/2A_s[k^x(1+\lambda^x)\sigma^x]^2)$*, which is the risk premium associated with* XHB*'s price uncertainty; the difference between their markups is* $\frac{\Pi^x}{k^x p^x}$.

Refer to Internet Appendix D.2 for the proof. The *XHB* price is lower than *CII*'s, consistent with the above proposition. The markup of *XHB* is fixed at 8%, well 25% for *CII* reported in the critical illness report published by the China Association of Actuaries (*CAA*).[12]

3.3 Choices between *XHB* and *CII*: A Separating Equilibrium

XHB and *CII* do not offer the same coverage. As we discussed in Section 2, *XHB* offers lower coverage to participants than *CII* does. Its coverage to older individuals is much lower compared to the coverage to younger individuals. We demonstrate that the coverage difference leads to a separating equilibrium – individuals with lower risk or risk sensitivity select *XHB* while individuals of higher risk or risk sensitivity select traditional insurance.

In Figure 3, we utilize a framework resembling the model presented in Rothschild and Stiglitz (1976) to depict individual wealth within a two-state space. This space defines two potential scenarios: either an individual experiences no loss (w_1) during period t, or the individual encounters a loss (w_2). The graph illustrates three points: E represents an individual's payoffs in two states without any protection; X represents individual payoffs in two states after joining *XHB*; I represents individual payoffs with insurance. The specific coordinates for each point are detailed below:

Point	Protection Type	$\mathbf{w}_1$	$\mathbf{w}_2$
E	None	$w_t + w_{t+1}$	$w_t + w_{t+1} - l$
X	*XHB*	$w_t - \pi^x + w_{t+1}$	$w_t - \pi^x + w_{t+1} - l + k^x$
I	*CII*	$w_t - \pi^i + w_{t+1}$	$w_t - \pi^i + w_{t+1} - l + k^i$

E is the individual payoff when she/he has no protection - the individual's total wealth is $w_t + w_{t+1}$ in the no-loss state (w_1) and the total wealth is $w_t + (w_{t+1} - l)$ in the loss state (w_2). At X (*XHB*), the individual's aggregate payoff is $w_t - \pi_t^x + w_{t+1}$ in w_1 while it is $w_t - \pi_t^x + (w_{t+1} -$

[12]This is consistent with the 80-20 rule for medical loss ratio (*MLR*) established in Affordable Care Act for medical insurance, which stipulates that insurers must spend at least 80% of premium dollars on medical claims and healthcare quality improvement, with the remaining 20% for administrative and other non-medical expenses.

$l + k^x$) in w_2. At I (*CII*), the individual's aggregate payoff is $w_t - \pi_t^i + w_{t+1}$ in w_1 while it is $w_t - \pi_t^i + (w_{t+1} - l + k^i)$ in w_2. The individual has a probability of $1 - p_s$ in the no-loss state and a probability of p_s in the loss state.

We present the expected utilities of low- and high-risk individuals under three different scenarios: i) without any protection, ii) with *XHB*, and iii) with *CII*.

$$
\begin{aligned}
E[u_l^e] &= [1-p^l]u(w_l^e) + p^l u(w_2^e); \quad E[u_h^e] = [1-p^h]u(w_l^e) + p^h u(w_2^e) \\
E[u_l^x] &= [1-p^l]u(w_1^x) + p^l u(w_2^x); \quad E[u_h^x] = [1-p^h]u(w_2^x) + p^h u(w_2^x) \\
E[u_l^i] &= [1-p^l]u(w_1^i) + p^l u(w_2^i); \quad E[u_h^i] = [1-p^h]u(w_2^i) + p^h u(w_2^i)
\end{aligned}
\tag{10}
$$

Specifically,

$E[u_l^e]$ and $E[u_h^e]$ are expected utilities of low- and high-risk individuals without protection;

$E[u_l^x]$ and $E[u_h^x]$ are expected utilities of low- and high-risk individuals with *XHB*;

$E[u_l^i]$ and $E[u_h^i]$ are expected utilities of low- and high-risk individuals with *CII*.

A necessary and sufficient condition for distinguishing between low- and high-risk individuals is defined as follows:

$$
E[u_l^x] > E[u_l^i] > E[u_l^e] \text{ and } E[u_h^i] > E[u_h^x] > E[u_h^e] \tag{11}
$$

Detailed proof of this condition is provided in Appendix D.3. The proof centers around the concept that individuals, when selecting their protections, encounter a tradeoff weighing the protect cost (*CII* is more costly than *XHB*) against the difference in uncertainties (having insurance results in a lower uncertainty). Individuals of different risk levels choose their optimal coverage.

Graphically, Figure 3 demonstrates that the aforementioned conditions hold when two individuals exclusively choose between *XHB* and *CII*. Specifically, the figure depicts two sets of indifference curves corresponding to high- and low-risk individuals' expected utilities. It shows that the low-risk individual's indifference curves are steeper than the high-risk individual's. To understand this, consider the slopes of the indifference curves, which are depicted as follows (refer to Internet Appendix D.4 for the proof):

$$
\begin{aligned}
\frac{\Delta u^l(w_2)}{-\Delta u^l(w_1)} &= \frac{1-p^l}{p^l} \\
\frac{\Delta u^h(w_2)}{-\Delta u^h(w_1)} &= \frac{1-p^h}{p^h}
\end{aligned}
\tag{12}
$$

Having protection implies sacrificing consumption in a state where there's no loss (w_1) in exchange for improved consumption in the state where a loss occurs (w_2). Because a high-risk individual prefers consumption in w_2 more than the low-risk individual does since the former is more likely to have a critical illness, the high-risk individual is more willing to sacrifice the consumption in w_1 for the consumption in w_2. Therefore, based on Eq. (12), given that $p^l < p^h$, the slope of the indifference curve for the low-risk individual is steeper than that of the high-risk individual: $\frac{\Delta u^l(w_2)}{-\Delta u^l(w_1)} > \frac{\Delta u^h(w_2)}{-\Delta u^h(w_1)}$.

Separately, Figure 3 shows that the zero-cost budget line of *XHB* (line *EX*) is steeper than the zero-cost budget line of *CII* (line *EI*). To see this, we express the slopes of both lines are specified as follows:

$$\begin{aligned} \frac{\partial w_2}{\partial w_1}|_X &= \tfrac{\pi^x - k^x}{\pi^x} = 1 - \tfrac{1}{p^x(1+\lambda^x)} \\ \frac{\partial w_2}{\partial w_1}|_I &= \tfrac{\pi^i - k^i}{\pi^i} = 1 - \tfrac{1}{p^i(1+\lambda^i)} \end{aligned} \tag{13}$$

where p^x and λ^x are *XHB*'s expected incidence rate and markups; p^i and λ^i are *CII*'s incidence rate and markups. Following Proposition 2, $\lambda^x < \lambda^i$, thus *EX* is expected to be steeper than *EI*.

Since *XHB* is less expensive than *CII*, if *XHB* provides a better protection than *CII*, then everyone would purchase *XHB*. Alternatively, when *XHB* offers a worse coverage than *CII*, the low-risk individual chooses *X* which offers less coverage while the high-risk individual selects *I* offering more coverage, which is graphically presented in Figure 3. This idea is encapsulated in the following proposition.

Proposition 3 XHB *offers a less protection than traditional insurance, high-risk individuals choose* I *and low-risk individuals choose* X*.*

Extending Rothschild and Stiglitz (1976), where individual choices are solely driven by risk, researchers have also explored the concept of 'advantageous selection,' recognizing that multidimensional private information can play a significant role in decision-making. For instance, de Meza and Webb (2001) argue that individuals who are risk averse are more likely to purchase insurance. This line of literature takes a broad perspective on advantageous selection arguing various individual characteristics, including individuals' cognitive abilities such as wealth and education levels, are important determinants of insurance decisions (e.g., Cutler et al., 2008; Fang et al., 2008; Einav et al., 2021). Irrespective of drivers for individual choices, the advantageous selection argument predicts that individuals who are more sensitive to risk would buy insurance. Following this, we expect that individuals who are less risk-sensitive are more likely to participate in *XHB* as it offers limited protections but has a price advantage.

Proposition 4 *When individuals are heterogeneous in their risk preferences, those with a lower risk sensitivity tend to favor enrolling in* XHB *over* CII*.*

In particular, *XHB* is more affordable compared to standard insurance products, thus cost-effective for a extensive array of participants, including individuals with low incomes facing barriers to access conventional insurance markets. Moreover, *XHB* attracts individuals driven by altruism, as they often participate not just for risk mitigation but also to contribute to communal causes. This aspect is underscored in studies such as those by Fehr and Fischbacher (2003); Pingle and Sade (2013). Altruism plays a crucial role in such platforms, fostering a sense of community and shared responsibility, which enhances effectiveness of mutual aid systems. This aspect of altruism, while significant, goes beyond the scope of our study and thus is not elaborated further.

4 Data

Our data include i) *XHB* enrollment, ii) *XHB*'s participation cost (i.e., price), and iii) claim information. The data begins from the inception of *XHB*, October 2018, to December 2020. Since *XHB* has a 90-day probation period for new members (see Section 2 for details), the first claim payment made by *XHB* was on January 28, 2019, i.e., 201901P2 (the second payment period of January 2019), as shown in Table 2. As a result, we begin our sample from the second payment period of January 2019.

Our participant information includes the aggregate number of participants in each payment period. We do not have detailed data about individual participants. We nevertheless have the numbers of *XHB* participants of six age groups provided by Ant Financial's Financial Research Institute: i) 3 months to 9 years old, ii) 10 to 19, iii) 20 to 29, iv) 30 to 39, v) 40 to 49, and vi) 50 to 59 years. Our critical illness claim data are detailed for individual claims which are manually collected from *XHB*'s public claim announcement bulletin board.

We capture screenshots of all claim reports published on *XHB* claim bulletin board and convert them to digital data including payment time, payee's names, names of illnesses, patient age, gender, province, and indemnity amount. To ensure data quality, we identified cases clearly violating *XHB* payment rules: i) critical illness participants below 40 years old receiving an indemnity of CNY 100,000 or CNY 50,000 and ii) participants who are 40 years and above receiving an indemnity of CNY 300,000. We found 149 such cases (out of a total of 68,007 claims of our sample) and made proper adjustments. We also verified digital data against original *XHB* information (the information with initial screenshots) by randomly sampling claim data in three different payment windows, 202003P2, 202006P1, and 202009P1 and confirmed the data is clean.[13]

For comparison, we retrieve information about participation and claims of critical illness insurance (*CII*) from the 2020 Historical Critical Illness Incidence Rate Table published by the China Association of Actuaries (*CAA*), which is referred to as 'the *CAA* table' later. The *CAA* table reports incidence rates for i) the 6 leading critical illnesses (CI6) and ii) the 25 leading illnesses (CI25), which are defined by the Chinese Bank and Insurance Regulatory Commission (*CBIRC*) and listed in Appendix A. These incidence rates are estimated based on a majority group of critical illness insurance in China,[14] and they are specific for ages and for genders. Since our *XHB* claim data contains the specific illness of a claim, we are able to estimate the corresponding incidence rates of the 6 and 25 critical illness for the *XHB* sample. We elaborate the details about *XHB* incidence rates in Section 5.1.

Two important details about the *CAA* table are worth noting. First, despite the fact that critical illness insurance permits multiple illness payments, the incidence rates published in the *CAA* table are calculated based on the first critical illness claim of a policyholder. This aligns the incidence rates reported in the *CAA* table with the incidence rates of *XHB* (which allows only the

[13]We discovered 5 erroneous observations (removed from the sample) in terms of age/payment amount out of 5,558 observations of the randomly selected samples.

[14]These policies are called 'pre-paid' critical illness insurance policies. They account for 85% of critical illness insurance policies in China.

first claim for each individual), making them directly comparable. Second, like *XHB*, *CII* has a probation period (90 or 180 days) over which policyholders would not receive claim indemnity even if one is treated for critical illness treatments.

In Table 2, we report the number of enrollments, claim payments and prices in a bi-weekly payment period from January 2019 to December 2020. On January 28, 2019, the first period that *XHB* has claim payments, the reported number of enrollment is 23,307,500. In that period, the amount of claim payments was CNY 600,000 which was paid to two *XHB* members. The table also shows in that period *XHB*'s participation cost, i.e., the claim cost allocated to each *XHB* member plus the 8% administrative fee, was CNY 0.03. As shown in Table 2, *XHB* enrollments grew rapidly in the early stage. At the end of 2019, just a year after the program was launched, the number of *XHB* participants reached 97,347,400. After the fast growth in the first year, *XHB* no longer grew in 2020. As shown in Figure 4, the aggregate number of enrollments stayed stable in 2020 and the first negative growth rate appeared in May 2020.

Table 2 also shows that *XHB* claim payments experienced exponential growth in the first half year of 2019 and later became stabilized. As September 2019 is a clear switching point shown in Figure 4, we consider payment periods from September 2019 to the sample end as stable claim periods. Our analysis of *XHB*'s claims and incidence rates mainly focuses on the stable period. Claim payments dropped significantly over the period from 202002P2 to 202004P1 when China was locked down to contain the COVID-19 pandemic. The aggregate claim payment dropped from CNY 300 million in January 2020 to CNY 150 million in February 2020 and bounced back to CNY 350 million in April 2020. Even so, the enrollment for *XHB* remained stable throughout the COVID lockdown period.

XHB has a 90-day probation period and participants are not eligible to receive claim payments in their first 90-day membership. The results reported in Table 2 are consistent with this policy. *XHB*'s claim payments were low in the first half of 2019. The total claim payment was CNY 33 million at the end of June 2019 (i.e., 201906P2, the second payment period in June 2019), corresponding to a bi-weekly premium of CNY 0.51. It increased to approximately CNY 4 per payment in August 2020, equivalent to roughly CNY 100 annually.

Moreover, we supplement *XHB* enrollment and claim data with a comprehensive survey of internet-based mutual aid products conducted by the Financial Research Institute of Ant Financial. The survey was distributed to Alipay account holders, including several key questions such as i) whether or not a respondent participates in mutual aid platforms, ii) whether or not a respondent has commercial medical coverage (including critical illness insurance), and iii) whether or not a survey respondent participates in government-sponsored medical and critical illness programs. Additional survey data include participants' ages, gender, city tier of residence, and income levels. The total number of survey respondents is 58,320 including 23,953 participating in at least one type of mutual aid product and 33,128 purchasing commercial health insurance.

5 Empirical Results

In this section, we first address the question of whether *XHB* brings its participants a diversification benefit - by adding participants of heterogeneous incidence rates, does the pooling arrangement make the platform more stable? Next, *XHB* and *CII*, we contrast the enrollment distributions across different age groups and respective incidence rates to test the presence of separating equilibrium of high- and low-risk individuals. Finally, using the mutual aid survey conducted by Ant Financial, we differentiate between the advantageous selection argument and the adverse selection alleviation explanation concerning the large difference in incidence rates between *XHB* and *CII*.

5.1 Analysis of *XHB*'s Pooling Effect

We investigate the potential diversification benefit within the framework of *XHB*'s design. This query is motivated by Proposition 1 outlined in Section 3.1, suggesting that a necessary condition for the platform to generate added value to participants within the utility maximization framework, a prerequisite is a negative pool size effect on the variance of pool incidence rates. To facilitate the empirical examination, we model the critical illness incidence rate using a binomial distribution.

$$p_t = \frac{M_t}{N_t} \tag{14}$$

where M_t denotes the of participants receiving payments at time t and N_t denotes the number of participants in *XHB* at time t.

Consider that M_t follows a binomial distribution: $p(M_t = m_t) = \begin{pmatrix} N_t \\ m_t \end{pmatrix} p_t^{m_t}(1-p_t)^{(N_t-m_t)}$, where m_t is reported number of illness cases. The expected value and variance of M_t are expressed as below:

$$E(M_t) = N_t p_t \;\text{ and }\; \sigma_t^2(M_t) = N_t p_t(1-p_t) \tag{15}$$

We have the variance of the participation pool as:

$$\begin{aligned} \sigma_t^2 &= \sigma^2(p_t) = \sigma^2(\frac{M_t}{N_t}) \\ &= \frac{p_t(1-p_t)}{N_t} \end{aligned} \tag{16}$$

When p_t is invariant to N_t, we have the expression of the standard diversification effect: $\frac{\partial \sigma_t^2}{\partial N_t} < 0$. However, as discussed in Section 3, p_t is expected to be positively related to N_t. Therefore, the relationship between σ_t and N_t, expressed below, is more complicated.

$$\frac{\partial \sigma_t^2}{\partial N_t} = \underbrace{\frac{(1-2p_t)p_t^{'}}{N_t}}_{\text{IR effect}} - \underbrace{\frac{\sigma_t^2}{N_t}}_{\text{diversification}} \tag{17}$$

where $p_t^{'}$ stands for $\frac{\partial p_t}{\partial N_t}$. The sign of the derivative depends on the net of 1) an incidence rate effect and 2) a pure diversification effect. The first term, the incidence rate effect, is expected to be positive since p_t is below 1/2, and thus it takes the same sign as the second term, $\frac{\sigma_t^2}{N_t}$.

We possess enrollment data for *XHB* across various age brackets (< 10; 10∼19; 20∼29; 30∼39; 40∼49; and 50∼60), along with comprehensive individual claim payment information. This rich dataset enables us to conduct a detailed analysis centered around the incidence rates within these specified age groups. Use k to denote a specific age group. Then p_{kt} denotes the incidence rate of a specific age group k at time t. N_{kt} and M_{kt} respectively represent the number of enrollments and paid claims associated with the incidence rate of age group k at time t. Our *XHB* claim data contains the names of illnesses, which allows us to match incidence rates between *XHB* and critical illness insurance.

We define three incidence rates for *XHB* respectively for the 6 leading critical illness (denoted as $p^6_{k,t}$ or $IR6^x_{k,t}$), 25 leading critical illness ($p^{25}_{k,t}$ or $IR25^x_{k,t}$), and all critical illnesses ($p^{100}_{k,t}$ or $IR100^x_{k,t}$). Taking the incidence rate of 6 leading illnesses, $IR6^x_{k,t}$, as an example, we have,

$$p^6_{k,t} = IR6^x_{k,t} = \frac{c6_{k,t}}{e_{k,t-6}} \tag{18}$$

$c6_{k,t}$ and $e_{k,t-6}$, respectively, are the number of paid claims for the 6 leading critical illnesses at time t for age group k and the number of enrollments at $t-6$ for the same age group, as a result of the 90-day (equivalently 6 payment periods) probation period. $IR25^x_{k,t}$ (or $p^{25}_{k,t}$) and $IR100^x_{k,t}$ (or $p^{100}_{k,t}$) are similarly defined. The variance of incidence rates of 6 leading illnesses for age group k is:

$$\sigma^{6\ 2}_{k,t} = \frac{p^6_{k,t}(1-p^6_{k,t})}{N_{k,t}} \tag{19}$$

We conduct an investigation into the pooling effect by pairing each of the six age groups with its neighboring age group. We compare the variance of the combined group with that of the corresponding single age group. The results are reported in Table 3. Panel A shows the results using the full sample spanning from 201901P2 to 202012P2, followed by Panel B presenting the results using stable periods from 201909P2.[15] Among all pairs (single versus combined), the variance of the combined group is *always* lower than that of the single group. Take the stable periods (Panel B) for example, for the test involving 6 leading illnesses, the reported variance of the incidence rate is $14.43{*}10^{-12}$ for the 30∼39 age group and it is reduced to $12.41{*}10^{-12}$ when we combine the 30∼39 and 40∼49 age groups. The results reported in Panel C where we exclude the COVID lockdown period from 202002P2 to 202004P1 yield a quite similar pattern: combining two neighbouring age groups leads to lower variance of incidence rates. Our finding clearly supports the presence of a local diversification benefit when an age group is pooled together with its neighboring group. This is aligned with the first proposition.

The second tests the diversification benefit using a *stacking approach*: starting from the youngest age group (< 10) as the base group, we add the next age group to form a combined group and compare the variance of incidence rates of these two groups; next, the newly formed group is used as the base group and a new age group is added till all six age groups are stacked together. Then

[15]It is important to restrict the analysis to a stable enrollment and incidence rate period because the test is not distribution-free.

we have six age groups: 0∼9, 0∼19, 0∼29, 0∼39, 0∼49, and 0∼59. We use a modified incidence rate to incorporate the fact that participants of 40 and above receive 1/3 indemnity of those below 40. Using the 6 leading illnesses as an example, we express the incidence rates of 0∼49 and 0∼59 as below:

$$IR6^{x^*}_{k,t} = \frac{c6_{k_1,t} + \frac{1}{3}c6_{k_2,t}}{e_{k,t-6}} \tag{20}$$

where k_1 represents a below-40 participant and k_2 represents an above-40 participant. The modified incidence rates are used to calculate the variance of the incidence rate of a combined group.

Figure 5 showcases the impact of diversification on the variance of incidence rates. Across three panels representing 6, 25, and all critical illnesses, it is evident that there's a typically negative association between pool size and the variance of incidence rates. However, an exception emerges when incorporating the 30-39 age group. In general, this outcome suggests that including more age groups within *XHB* confers a diversification benefit, aligning with the first proposition. Furthermore, our analysis reveals that the variance of incidence rates between the 0∼39 age range surpasses that of the 0∼29 category. This suggests that a more suitable threshold for reduced indemnity might be within the age range of 30 to 39, rather than the currently practiced age of 40. This adjustment aligns with the observed variations in incidence rates and could better accommodate the needs and behaviors of participants within this demographic.

In summary, the empirical evidence supports that a larger participant pool helps to reduce the volatility of incidence rates. Recall Eq. (17) suggesting that $\frac{\partial \sigma_t^2}{\partial N_t}$ is jointly determined by a negative incidence rate effect where a larger pool may bring in individuals of heterogeneous risk types involving individuals of higher incidence rates and a favorable diversification benefit. Our results suggest a dominance of the diversification benefits. In the subsequent analysis, we show that a higher enrollment rate of younger individuals potentially contributes to the result. Moreover, it is likely that *XHB*'s involvement in Fintech lowers the information cost to reveal participants' true health state, helping to lower its incidence rates.

5.2 Is There a Separating Equilibrium?

5.2.1 Comparing Enrollment Distributions of *XHB* and *CII* Across Age Groups

To gain insights into the composition of participants in the *XHB* program, Figure 6 illustrates the distributions of *XHB* enrollment in January 2020 alongside reported critical illness insurance by *CAA*. This comparison is made with the 2020 national population distribution across six age groups. The analysis reveals lower *XHB* enrollment among younger individuals (below 20 years old) and those aged 40 years and above. In contrast, the 30∼39 age group exhibits the highest participation rate. Notably, the enrollment rate for *XHB* decreases notably from the 30∼39 group (30.7%) to the 40∼49 group (15.8%). This decline aligns with the significant reduction in indemnity from CNY 300,000 to CNY 100,000, occurring between the ages of 39 and 40. A practical implication of these findings is that a smoother transition in the benefits structure within *XHB* might potentially facilitate increased participation from the 40∼49 age group. By offering a more gradual reduction in indemnity as participants cross the age threshold, *XHB* could attract and retain more individuals in this particular age bracket.

There are significant disparities between *XHB* and *CII* in their enrollment distributions. First, they peak at different age ranges. *CII*'s peak appears at the 40∼49 age group while *XHB* reaches its peak earlier in the 30∼39 age group, suggesting different driving forces for *XHB* participation as opposed to insurance. A primary contributing factor to this discrepancy is the reduced indemnity offered to individuals aged 40 and above. Secondly, *XHB* attracts a larger proportion of younger participants compared to *CII*. Specifically, based on Figure 6, participants below 40 constitute 75% of the total *XHB* enrollment, whereas this fraction is 55% for *CII*. Once again, this is due to *XHB*'s lower indemnity for older participants.

5.2.2 Insights from Incidence Rates

To improve our understanding of the separating equilibrium argument, we compare the incidence rates between *XHB* and *CII* for the same set of critical illnesses. The initial focus is on the counts of critical illness cases covered by *XHB* of different age groups, along with the associated incidence rates. The findings have been detailed in Table 4. The first column reports the total number of claims that *XHB* paid in each biweekly payment period (different from Table 2 reporting the amount of claim payment). As shown in the first column, the first *XHB* claim took place in the second payment cycle of January 2019. At the end of 2019, the cumulative number of resolved claims amounted to 1,953, and this figure witnessed an increase to 2,810 by the end of December 2020. Following this, in Columns two and three, we divide participants into those below 40 and 40+ years old individuals, and report the numbers of cases for both groups. There are more claims for the above-40 group than the below-40 group. As reported in the last row of the third column, the total number of claims for the above-40 group is 30,978, 50% more than the number of the below-40 group, 21,271 (reported in Column 2).

The fourth column reports annual incidence rates of critical illnesses of *XHB*. Denoting the incidence rate of each payment period of all covered illnesses as IR^x, we estimate the annualized incidence rate as $24 * IR^x$. The incidence rate was low in early periods while rising over time. There was a notable surge in incidence rates from 226 per million participants to 540 per million participants between the first and second payment periods in September 2019. Subsequently, these rates stabilized, consistently ranging between 529 and 670 per million participants across bi-weekly payment periods. Notably, during the COVID lockdown period from February 2020 (second payment period) to April 2020 (first payment period), both the number of *XHB* claims and incidence rates experienced a significant decline. This trend aligns with the observed pattern in claim payment amounts outlined in Table 2.

Next, in Table 5, we report our finding when comparing incidence rates between *XHB* and *CII*. Recall that *CII* incidence rate data is from the 2020 *CAA* (the China Association of Actuaries) table, which reports the incidence rates of the 6 and 25 leading critical illnesses for different ages, independently for males and females, but it does not have incidence rates for all kinds of critical illnesses under *CII* coverage. However, our *XHB* data offers detailed insights into individual claim payments, while presenting only generalized enrollment figures across six age brackets (< 10; 10∼19; 20∼29; 30∼39; 40∼49; and 50∼59). As a result, to streamline the comparison process, we derive estimates for *CII*'s incidence rates within these six age groups using the incidence rates extracted from the *CAA* table. For each individual age group k, *CII*'s incidence rates for the 6 leading critical illnesses ($IR6_i^i$) and the 25 leading critical illness ($IR25_k^i$) are respectively expressed as,

$$IR6_k^i = \sum_{j \in k} w_{jk} * IR6_j^{CAA} \text{ and } IR25_k^i \quad = \textstyle\sum_{j \in k} w_{jk} * IR25_k^{CAA} \tag{21}$$

In the above expression, j refers to a specific age, e.g., 35 years. $IR6_j^{CAA}$ and $IR25_j^{CAA}$ denote CAA incidence rates for the 6 leading critical illness and 25 leading critical illnesses for a jth years old individual, respectively. Note that, while the CAA table separately reports incidence rates for females and males, we estimate the average incidence rates based on gender ratios of a specific age j from the CAA data because we do not data of *XHB*'s incidence rates by gender. w_{jk} is the proportion of participants at a specific age j (e.g., 35 years old) in an age group k (30 - 39). Correspondently, *XHB*'s incidence rates of illness groups including the 6 leading critical illnesses and 25 leading critical illnesses: $IR6_{k,t}^x$ and $IR25_{k,t}^x$ are reported.

Panel A of Table 5 presents the results for relatively "stable periods" from 201909P2 to 202012P2 while Panel B shows the results for stable periods excluding COVID lockdown ranging from February 2020 (202002P2) to April 2020 (202004P1).[16] The general message from this table is that *XHB* participants are much healthier than *CII* insurance buyers – the average incidence rate is significantly lower than the rates reported by CAA in each age group. In Panel A, for example, as reported in the first row, when participants across all age groups are pooled together, the average incidence rate of *CII* is 7.34 times that of *XHB* for the top 6 critical illnesses and 7.66 times of that of *XHB* for the 25 leading critical illnesses. Also shown in the first row of Panel A, the average incidence rates of *XHB* are 460 and 478 per million (i.e., 10^{-6}) far below those of critical illness insurance which are 3,192 and 3,459 per million participants. We obtain consistent results based on the analysis when COVID is excluded (as shown in Panels B). This finding is well aligned with the separating equilibrium argument proposed in Proposition 3 that low-risk individuals are inclined to enroll in *XHB* while high-risk individuals prefer insurance offering better coverage.

The comparison of incidence rates within specific age groups for *CII* and *XHB* provides insightful information about these two products. As presented in Panel A, the incidence rate ratios are lowest for the below-10 group (2.46 for the top-6 illnesses and 3.19 for the top-25 illnesses) while it is highest for the 50 to 59 group (6.53 for the top-6 illnesses and 6.85 for the top-25 illnesses). Complementing this result, Figure 7 visually represents incidence rates of *XHB* and those of *CII* of different age groups. Two different panels respectively show the results of the 6- and 25- leading critical illnesses. Remarkably, in every age group, *CII* has a higher average incidence rate than *XHB* does. The enrollment data illustrated in Figure 6 demonstrates that *XHB* is particularly effective in attracting younger consumers. More impressively, the findings presented in Table 5 and

[16] We also perform the analysis using the full sample like we did in Table 3. The result is consistent.

the incidence rate figures further suggest that *XHB* is adept at drawing in healthier individuals, whether they are below or above 40 years of age. The remainder of this paper is dedicated to exploring the underlying factors driving *XHB*'s success in these demographics.

5.3 Evidence of Advantageous Selection

Risk-taking decisions are not just about someone's comfort with risk. Factors like risk tolerance, income, and education also shape how people make these choices. This is well noted under the advantageous selection argument, which suggests that beyond risk, a broader range of individual attributes, including risk aversion, as well as other traits such as wealth and education, significantly shape individuals' risk-taking incentives (de Meza and Webb, 2001; Cutler, Finkelstein, and McGarry, 2008; Fang, Keane, and Silverman, 2008; Einav, Finkelstein, and Mahoney, 2021). In this section, we delve further into whether the advantageous selection argument plays a role in influencing individual choices between *XHB* and *CII*.

We utilize data from the comprehensive mutual aid survey conducted by Ant Financial, the parent company *XHB*, to gain insights about participants' motivations. In March 2020, Ant Financial distributed the survey to two million randomly selected Alipay account holders, yielding 58,719 completed and valid responses. The survey collected information on respondents' ages, genders, economic status of their residing city, and their annual income ranges. The survey encompasses multiple inquiries regarding respondents' participation in mutual aid programs, government-sponsored medical insurance programs (commonly referred to as 'social security'), current involvement in commercial medical insurance programs, and plans for future participation. Further details and specific survey questions are available in Appendix E.

We perform logistic regressions to analyze individual decisions to participate in a *MA* program ($MA = 1$) or not.[17]

$$Ln[\frac{Pr(MA_i = 1)}{1 - Pr(MA_i = 1)}] = \boldsymbol{\beta}' \boldsymbol{X_i} \tag{22}$$

The main independent variables include i) the logarithm of the ages of survey respondents (AGE); ii) AGE^2; iii) *TIER*, taking a value from 1 to 6, with a lower city tier score indicating a better economic development of the city where a survey respondent resides;[18] iv) indicators for individuals' annual income: *INC2* for an annual income range between CNY 50,000 and 100,000, *INC3* for an income range between 100,000 and 200,000, and *INC4* for an income range between 200,000 and 500,000, and *INC5* for income above 500,000;[19] v) an indicator for purchasing commercial insurance (*INS*);[20] vi) whether a respondent participates in a social security health insurance

[17]The analysis corresponds to the responses to Question 3 of Ant Financial's mutual aid survey provided in Appendix E.

[18]See https://www.china-briefing.com/news/chinas-city-tier-classification-defined/ for details of the city tier classifications.

[19]These measures are constructed based on responses to survey Question 4 from Appendix E.

[20]It is based on the responses to survey Question 2 provided in Appendix E.

program (*SS*),[21] and vii) the indicator for female respondents (*FEMALE*).

In Table 6, the first column reports a significant and positive coefficient on *AGE* (= 0.10; *t*-stat = 7.10), inferring that older participants are likely to be *MA* participants. Next, in the second column, we include both *AGE* and AGE^2 in the regression; the reported coefficient on *AGE* is positive while the coefficient on AGE^2 is negative, which suggests a hump-shaped relationship between age and *MA* participation. Moreover, the hump-shaped relation persists after controlling for variables in Columns (3) and (4). Taken together, the positive coefficient on *AGE* suggests that as individuals get older, their participation in *MA* activities tends to increase; converse, the negative coefficient on AGE^2 indicates that the squared effect of age hurts MA participation. This implies that after reaching a certain age, further increases in age decrease participation in *MA* activities. Hence, our survey result aligns with the trend depicted in Figure 6, illustrating a rise in *XHB* participation up to the age of 40 then it declines.

Further note that the third column reports a negative coefficient on *TIER* (= -0.01; *t*-stat = -2.55). Given the inverse relationship between *TIER* and the wealth level of the respondent's city of residence, our survey indicates that respondents from affluent regions are likelier to participate in mutual aid programs than those from less affluent regions. This finding aligns with the perspective presented by Fang et al. (2008), where income is considered a significant source of advantageous selection.

Next, the fourth column shows that dummy variables representing various income ranges (*INC2*, *INC3*, *INC4*, and *INC5*) are added to the regression, with the income group below CNY 50,000 serving as the benchmark. The coefficients reported in Column (3) remain consistent, except that *TIER* is now found to be insignificant. The coefficients on the individual income dummy variables are all significantly positive. The coefficients on income indicators are respectively 0.25 (*t*-stat = 12.52), 0.33 (*t*-stat = 12.49), 0.39 (*t*-stat = 8.37), and 0.24 (*t*-stat = 2.52). Our finding suggests that the probability of joining a mutual aid program for any of the four higher-income groups is greater than the benchmark group.

The following two columns of Table 6 show the result when we separately examine the determinants of mutual aid participation of the young participants and the middle-aged group. The coefficients of the same variable often take opposite signs. Among young participants (shown in Column 5), mutual aid programs are more attractive when age grows and to people from more developed areas. However, in the regression for the middle-aged group (shown in Column 6), the coefficient on *AGE* turns to negative, suggesting that old respondents have less incentive to participate. This evidence is in line with the advantageous selection argument, that more risk-averse individuals seek better health coverage.

Moreover, Table 6 pervasively demonstrates a negative impact of *INS* (indicating possession of commercial medical insurance) on *MA* participation from Columns (3) through (6). This finding suggests that respondents with commercial medical insurance are less willing to participate in mutual aid programs. Mutual aid programs can reach customers typically not covered by conventional

[21] The indicator equals 1 if the response to survey Question 1 provided in Appendix E is 'Employer-sponsored social health insurance', 'Urban resident social insurance' or 'Other public health care'.

medical insurance. This observation lays the ground for a more in-depth analysis of mutual aid participants' preferences and behaviors, with a specific focus on those without insurance coverage relative to individuals having insurance.

5.4 Determinants of Individual Choices

So far, our results indicate that wealthier individuals are more likely to participate in mutual aid programs than those with lower incomes, aligning with the advantageous selection theory. However, theoretically, mutual aid programs should appeal to low-income individuals due to their affordability compared to commercial insurance premiums. We address this question in this subsection. To be specific, our data allows us to categorize survey participants into four groups based on their choices in *MA* and insurance, listed below:

	$INS = 0$	$INS = 1$
$MA = 1$	Exclusively MA	Dual Coverage
$MA = 0$	No Coverage	Exclusively Insurance

This categorization allows us to examine the differences among four distinct groups: individuals exclusively covered by *MA* (Mutual Aid), those solely with insurance, individuals with both insurance and *MA*, and those without any coverage.[22]

The first test is employed to assess the characteristics of survey respondents exclusively enrolled in mutual aid ('exclusively MA') in comparison to those in the 'dual coverage' group, with the results presented in the first column of Table 7. The finding indicates that younger individuals, residents of more prosperous cities, and those with lower income levels are more likely to be exclusive *MA* participants. Specifically, the coefficient for *AGE* is -0.17 which is statistically significant at the 1 percent level. This finding stands in contrast to the results outlined in the first column of Table 6, showing that the coefficient on *AGE* was significantly positive. The shift suggests that holding other factors constant, younger respondents in the survey display a higher tendency to exclusively engage in *MA* rather than opting for dual coverage. This may be understood as that younger people are less inclined to purchase insurance since they are healthier or due to the impact of lower incomes which might deter them from opting for insurance. Moreover, the coefficient for *TIER* is 0.02 (with a t-statistic of 2.01), and the coefficients for the four income categories are consistently negative, with the magnitude increasing for higher income categories. The findings that exclusively *MA* participants tend to have relatively lower incomes, once again, contrast those reported in Table 6 showing on average *MA* participants are more affluent than non-*MA* participants. This contrast yields two significant implications. First, pertaining to advantageous selection, we observe participation in mutual aid among individuals from diverse backgrounds and note significant differences between exclusive mutual aid participants and dual-coverage participants. Second,

[22] In our sample, the number of "exclusively MA" respondents is 14,165 and that of 'exclusively insurance' survey respondents is 12,926. 20,202 have double coverage while 11,027 participants have no coverage.

mutual aid demonstrates inclusivity by involving individuals of lower incomes.

In addition, the first column also reveals a trend where female respondents exhibit a lower inclination toward exclusive participation in mutual aid, possibly linked to a higher tendency for risk aversion among females compared to males. Moreover, individuals without medical coverage from the government's social security program display a higher inclination toward exclusive mutual aid participation, indicating that mutual aid serves as a complementary support to the existing social insurance program.

Next, our second analysis compares the characteristics of individuals in the 'exclusively MA' group with those in the "exclusively insurance" group. This analysis aligns closely with the concept of a separating equilibrium described in the model section. The result is presented in the second column of Table 7. Our finding closely resembles those reported in the first column. It is evident that younger individuals are more likely to opt for exclusive *MA* participation over exclusive insurance participation. Moreover, residents from less economically developed regions and individuals with lower incomes exhibit a higher likelihood of choosing pure *MA* participation instead of opting for pure insurance. While we do not directly test how risk plays a role in shaping preferences for *MA* programs over insurance options, the result, once again, strongly indicates the critical role played by individual attributes in the choices between mutual aid and insurance, rendering further support to the advantageous selection argument. The coverage extended by mutual aid programs provides a safety net for the general public, particularly low-income individuals.

Finally, the third analysis examines the characteristics of individuals in the 'exclusively MA' group in relation to survey respondents who neither participate in any *MA* program nor purchase insurance. The result is displayed in Column (3), Notably, we observe a reversal in the signs compared to the first column. In contrast to individuals without either *MA* or insurance, exclusive *MA* participants are inclined to be older and have higher incomes, This suggests that individuals with lower incomes and younger ages exhibit less willingness to participate in the mutual aid group, opting for neither *MA* nor traditional insurance. This observation hints at potential entry barriers, signaling a necessity for mutual aid programs to implement additional efforts in diversifying their participant demographic.

5.5 *MA* Participation and Insurance Demand

Yet, it remains unclear whether mutual aid protections influence individuals' demand for traditional insurance products. Put differently, does *MA* reduce the demand for traditional insurance or, in contrast, stimulate individual incentives for risk management? We tackle this question using the mutual aid survey data which inquires whether survey participants desire to purchase commercial medical coverage for critical illness in case they have participated in a mutual aid program (see Q5 in Appendix E). We represent the desire to purchase such coverage with the binary variable INS_{t+1}, where 1 indicates a respondent's intent to purchase commercial health insurance in the future and 0 indicates otherwise. We use the binary variable MA_t, where 1 signifies a respondent's participation in a mutual aid program, and 0 indicates non-participation. The results are presented in the following exhibit.

	$MA_t = 0$	$MA_t = 1$	*Total*
$INS_{t+1} = 0$	5,871	3,300	9,171
$INS_{t+1} = 1$	13,793	10,965	24,758
Total	19,664	14,265	33,929

This survey question was responded by 33,929 participants. Among them, the number of respondents not participating in any mutual aid programs is 19,664 and the number of respondents participating in a mutual aid program is 14,265. Interestingly, the survey outcome also reveals that it is more likely for respondents to express an interest in purchasing insurance in the future if they indicate they are current mutual aid participants compared to non-mutual-aid participants. To be Specific,

$$Prob(INS_{t+1} = 1|MA_t = 0) = \frac{13,793}{19,664} = 0.70$$
$$Prob(INS_{t+1} = 1|MA_t = 1) = \frac{10,965}{14,265} = 0.77$$

The probability of purchasing insurance at $t+1$ for individuals who were not mutual aid participants at t is 0.70 while the purchase probability for mutual aid participants is 0.77. These results suggest that participation in mutual aid programs does not diminish the willingness of survey participants to acquire insurance products. On the contrary, it appears that mutual aid participation positively influences the consumption of commercial insurance among households.

We conduct logistic regressions with an indicator for participants' future insurance purchase intentions from the survey as the dependent variable. The purpose is to see whether the positive connection between mutual aid participation and future insurance demand holds after controlling for survey participants' attributes, such as their ages and income. The results are reported in Table 8. In the first columns, we confirm the conditional probability estimations by using *MA* as a univariate regressor. Shown in the first column, the coefficient on *MA* is 0.35, significant at the 1% level, suggesting *MA* participants are more likely to increase their insurance consumption in the subsequent years.The explanation lies in that individuals become more aware of medical risks after they participate in mutual aid programs. Further analysis, not carried out in the current study, is warranted to further look into the positive link between *MA* participation and subsequent insurance demand to better understand the respective dynamics. Our finding here reinforces the complimentary relationship between commercial insurance and mutual aid.

In the next two columns, we present the result when separating respondents below 40 group and those above 40. Confirming the finding from the conditional probability analysis and those reported in the first column, we find that the coefficients on MA from both regressions are significantly positive. In the subsequent three columns (i.e., columns 3 to 5), we include the full set of regressors used in Table 6 respectively for all survey respondents, those below 40, and individuals above 40. The reported coefficients on *MA* remain positive and statistically significant. Moreover, the coefficients on AGE is significantly negative while coefficients on income dummies are all significantly positive, suggesting younger survey respondents are more likely to increase their insurance purchases in subsequent years, so do individuals having higher income.

Finally, in the last three columns (columns 7 to 9) of our report, we present the outcomes of a parallel analysis conducted specifically for respondents who did not have medical insurance at the time of the survey (i.e., $INS = 0$). We find that MA participation are more likely to increase their insurance purchases in subsequent years. Beyond echoing the trends observed in the full sample, this result indicates that individuals currently without insurance are more inclined to obtain commercial medical insurance after enrolling in a MA program.

In conclusion, our analysis reveals that participants in mutual aid programs display a stronger inclination to purchase insurance compared to non-participants. This suggests a complementary relationship between commercial health insurance and mutual aid programs. Notably, our findings align with a recent study, as cited in Barrios, Hochberg, and Yi (2022), which emphasizes the positive role of the sharing economy.[23] With its flexibility and low entry barriers, the sharing economy offers opportunities for potential entrepreneurs to supplement their income, particularly in challenging economic conditions, and provides a safety net in the form of income fallback in case of business failure. Therefore, the introduction of gig opportunities is positively associated with increased new business registrations and greater small business lending in local areas.

6 Conclusions

Xiang Hu Bao (*XHB*) is a novel online platform designed to mutually share individuals' critical illness exposure. It leverages digital technology to lower the cost and improve the efficiency of enrollment and claim processing. Different from insurance products charging a fixed premium upfront, *XHB* simply lets participants share indemnity payments to critically sick members. As a result, it is operated in a much more transparent way than traditional critical illness insurance products do. *XHB* offers restricted coverage amounts to participants and coverage reduction is particularly high for older participants. We demonstrate that such indemnity schedule leads to separating equilibrium where individuals of lower risk or less risk averse enroll in *XHB* while higher-risk or more risk averse individuals purchase critical illness insurance. We also find *XHB* and other mutual aid products to be complementary, rather than substituteable, to existing insurance products.

XHB is a natural experiment on the enforceability of mutual risk sharing. While diversification and the law of large numbers are at the heart of insurance and risk management, the concepts are poorly implemented owing to the presence of transaction costs and potential presence of information asymmetry. Fintech brings huge differences: the technology substantially lowers *XHB*'s operational costs, equips the platform with high operational efficiency, and in the end it offers the incentive for

[23] The sharing economy, also known as the peer economy or gig economy, is characterized by sharing rather than owning. It represents an economic system where participants collaborate in the creation, production, and consumption of goods (Economist, 2013).

sufficient relatively low risk individuals to stay in the pool. As a result, *XHB*'s incidence rate is much lower than comparable critical illness insurance and it holds for different age groups.

This study contributes to the literature in several ways. First, it presents evidence that *XHB* and other mutual aid products make the market more complete. Traditional insurance products might be better in underwriting sophisticated risks that are difficult to be diversified away while mutual aid products are appealing to young and/or healthy individuals or low-incomers who are facing idiosyncratic critical illness exposure but unwilling to purchase commercial coverage as they are often expensive. We present evidence that mutual risk sharing programs empowered by Fintech can reach customers typically not covered by conventional health and critical illness insurance. Our study highlights the role of Fintech in the field of risk management, an important issue largely ignored by existing works. Second, we find that high-incomers, who are more healthy, also have a greater tendency to participate in the mutual aid programs and this phenomenon holds among younger participants in particular. This is consistent with the broad form of advantageous selection (Fang et al., 2008). Third, our paper extends the existing literature on mutual risk sharing for idiosyncratic risks among households (Cochrane, 1991; Townsend, 1994; Cox and Fafchamps, 2007; Fafchamps and Gubert, 2007). Inspired by the finding of this study, Fintech-based platforms may be an effective alternative complimentary to household risk sharing. This is potentially more effective in emerging markets where traditional risk management tools are undeveloped.

We acknowledge that *XHB* is not flawless, particularly concerning platform stability. As a loss-sharing platform, it faces the potential for price surges and subsequent participant exits, a factor that contributed to its closure in early 2022. Moreover, the rapid evolution of Fintech frequently surpasses existing regulatory frameworks, creating disparities between traditional financial institutions and emerging tech-driven firms and sometimes even posing vulnerabilities in the financial system (see, e.g., U.S. Department of The Treasury, 2023). Ongoing discussions focus on formulating effective regulations that encourage innovation while protecting existing businesses. For instance, Goldstein et al. (2019); Zetzsche et al. (2020) propose a regulatory framework centered specifically on functions rather than company types. *XHB* serves as a valuable case study within this context.

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Table 1: Summary Statistics

This table summarizes coverage and modifications of the Xiang Hu Bao program.

Panel A: Program V1 from October 2018 to April 2019

Plan Name	Age	Indemnity (CNY)	Coverage
Critical Illness Plan (CIP)	30 days to 39 years	300,000	99 Critical illnesses
			Critical malignant tumors*
	40 to 59 years	100,000	Same as above

Panel B: Program V2 from May 2019 to December 2019

Plan Name	Age	Indemnity (CNY)	Coverage
Critical Illness Plan (CIP)	30 days to 39 years	300,000	99 Critical illnesses
			plus critical malignant tumors**
	40 to 59 years	100,000	Same as above
	30 days to 59 years	50,000	2 Mild critical illnesses**
Senior Cancer Plan (SP)	60 to 70 years	100,000	Critical malignant tumors
		50,000	2 Mild critical illnesses

Panel C: Program V3 from January 2020 to May 2020

Plan Name	Age	Indemnity (CNY)	Coverage
Critical Illness Plan (CIP)	30 days to 39 years	300,000	Same as V2
			plus 5 rare illnesses
	40 to 59 years	100,000	Same as V2
			plus 5 rare illnesses
Senior Cancer Plan (SP)	60 to 70 years	100,000	Critical malignant tumors only

Panel D: Program V4 since June 2020

Plan Name	Age	Indemnity (CNY)	Coverage
Critical Illness Plan (CIP)	30 days to 39 years	300,000 (Standard)	Same as V3
		100,000 (Reduced)	
	40 to 59 years	100,000 (Standard)	Same as V3
		50,000 (Reduced)	
Senior Cancer Plan (SP)	60 to 70 years	100,000	Critical malignant tumors only

* For the full list of malignant tumors, see https://www.cancer.gov/types. ** Two types of illnesses originally categorized as malignant tumors in *XHB* V1, including i) Papillary thyroid cancer (PTC) or follicular thyroid cancer (FTC) without distal metastases and ii) $T2N_0M_0$ prostatic cancer, are reclassified as mild critical illnesses in *XHB* V2 and are no longer included in coverage since *XHB* V3.

Table 2: Xiang Hu Bao Aggregate Enrollment and Claims Over Time

This table presents i) the number of enrollments to Xiang Hu Bao, ii) aggregate claim payments (in CNY), and iii) prices (i.e., the per-participant bi-weekly sharing cost, in CNY) from January 2019 to December 2020.

Period	Enrollment	Claim Payment (CNY)	Price (CNY)
201901P2	23,307,500	600,000	0.03
201902P1	32,407,600	0	0
201902P2	34,684,900	900,000	0.03
201903P1	37,537,000	300,000	0.01
201903P2	41,185,700	0	0
201904P1	48,624,500	900,000	0.02
201904P2	52,426,700	2,500,000	0.05
201905P1	56,824,200	2,200,000	0.05
201905P2	62,896,200	7,800,000	0.13
201906P1	67,186,700	20,600,000	0.33
201906P2	70,224,600	33,000,000	0.51
201907P1	73,234,000	63,400,000	0.94
201907P2	75,621,800	103,550,000	1.48
201908P1	77,327,200	105,100,000	1.47
201908P2	79,920,300	107,200,000	1.44
201909P1	83,391,000	115,000,000	1.49
201909P2	85,756,600	235,300,000	2.96
201910P1	87,904,100	245,200,000	3.01
201910P2	89,682,000	254,100,000	3.06
201911P1	93,883,800	263,450,000	3.03
201911P2	95,145,600	266,700,000	3.02
201912P1	96,718,200	274,700,000	3.06
201912P2	97,347,400	274,650,000	3.05
202001P1	97,942,100	284,400,000	3.13
202001P2	98,927,100	317,950,000	3.47
202002P1	99,461,300	318,350,000	3.45
202002P2	99,531,100	139,700,000	1.51
202003P1	100,071,800	142,000,000	1.53
202003P2	100,433,700	144,500,000	1.55
202004P1	100,992,000	264,100,000	2.83
202004P2	101,035,200	369,650,000	3.95
202005P1	101,049,100	368,350,000	3.93
202005P2	100,952,900	367,000,000	3.92
202006P1	101,165,600	400,625,776	3.96
202006P2	100,944,200	396,710,705	3.93
202007P1	101,070,800	400,240,368	3.96
202007P2	101,056,300	397,151,259	3.93
202008P1	101,305,000	387,150,000	4.17
202008P2	101,129,000	380,900,000	4.11
202009P1	101,279,021	385,250,000	4.17
202009P2	100,716,367	381,700,000	4.17
202010P1	100,486,662	386,300,000	4.23
202010P2	100,287,800	439,300,000	4.86
202011P1	100,669,825	436,750,000	4.83
202011P2	100,026,526	432,100,000	4.83
202012P1	98,243,639	424,250,000	4.83
202012P2	97,159,970	460,300,000	5.31

Table 3: Effect of Diversification

This table reports the variances of incidence rates (reported as of 10^{-12}) of different age groups and their differences. CI6, CI25, and CI100 respectively represent 6, 25 leading critical illnesses and all critical illnesses covered by *XHB*. σ_i^2 and σ_j^2 in each period are calculated based on Eq. (16) and then averaged over time. t-statistics for the differences are reported in the parentheses. Panel A reports the average results based on the *XHB* claim data during the full sample period. Panel B reports the average results based on 'stable' claim period from 201909P2 to 202012P2. Panel C reports the average results based on the *XHB* claim data during the 'stable' period while excluding COVID-19 lockdown months (202002P2-202004P1).

		CI6				CI25				CI100			
Group i	Group j	σ_i^2	σ_j^2	$\sigma_j^2 - \sigma_i^2$	(t-stats)	σ_i^2	σ_j^2	$\sigma_j^2 - \sigma_i^2$	(t-stats)	σ_i^2	σ_j^2	$\sigma_j^2 - \sigma_i^2$	(t-stats)
Panel A: Full Sample													
<10	0∼19	11.91	5.59	-6.32	(-12.05)	13.39	6.37	-7.03	(-12.70)	19.57	9.24	-10.33	(-13.35)
10∼19	10∼29	8.99	3.91	-5.09	(-7.90)	10.54	4.24	-6.40	(-8.56)	15.08	4.89	-10.20	(-11.30)
20∼29	20∼39	5.12	4.88	-0.24	(-1.41)	5.39	5.08	-0.31	(-1.82)	6.28	5.76	-0.53	(-2.95)
30∼39	30∼49	14.02	12.05	-1.97	(-6.87)	14.54	12.45	-2.09	(-7.14)	16.31	13.78	-2.53	(-8.37)
40∼49	40∼59	51.27	38.98	-12.29	(-7.02)	52.79	40.26	-12.54	(-7.13)	57.63	44.21	-13.42	(-7.18)
Panel B: 'Stable' Periods													
<10	0∼19	12.25	5.75	-6.49	(-12.80)	13.78	6.55	-7.23	(-13.59)	20.14	9.51	-10.63	(-14.43)
10∼19	10∼29	9.27	4.02	-5.25	(-8.12)	10.86	4.26	-6.59	(-8.86)	15.53	5.03	-10.5	(-11.99)
20∼29	20∼39	5.27	5.03	-0.25	(-1.41)	5.56	5.23	-0.32	(-1.82)	6.47	5.93	-0.54	(-2.95)
30∼39	30∼49	14.43	12.41	-2.03	(-6.96)	14.97	12.82	-2.15	(-7.25)	16.79	14.19	-2.6	(-8.57)
40∼49	40∼59	52.83	40.19	-12.64	(-7.12)	54.39	41.51	-12.89	(-7.24)	59.37	45.58	-13.79	(-7.29)
Panel C: Non-COVID19 'Stable' Periods													
<10	0∼19	13.10	6.16	-6.94	(-13.44)	14.75	7.02	-7.73	(-14.59)	21.65	10.20	-11.43	(-16.81)
10∼19	10∼29	9.98	4.25	-5.72	(-8.31)	11.68	4.51	-7.17	(-9.24)	16.58	5.33	-11.25	(-12.60)
20∼29	20∼39	5.57	5.32	-0.25	(-1.22)	5.88	5.55	-0.33	(-1.63)	6.85	6.29	-0.56	(-2.64)
30∼39	30∼49	15.3	13.23	-2.07	(-6.19)	15.88	13.68	-2.21	(-6.49)	17.84	15.16	-2.69	(-7.78)
40∼49	40∼59	56.69	43.11	-13.58	(-6.88)	58.35	44.51	-13.84	(-6.98)	63.76	48.9	-14.85	(-7.08)

Table 4: Number of Paid Claims and Incidence Rates of Xiang Hu Bao

This table reports the number of paid claims made by *XHB* of different age groups and *XHB*'s incidence rates in each payment period. "# Claims (All)" is the total number of paid claims in a specific claim payment period. "# claims <40" and "# claims ≥40)" are the numbers of participants below 40 years (at or above 40 years) receiving claim payments. The incidence rates (*IR*) of a given group is the number of paid claims of a group and scaled by the number of enrollment of 6-period lagged enrollments. This number is annualized, i.e., multiplied by 24, and converted to a per million basis: $IR_t^x = \frac{c_t}{e_{t-6}} * 24 * 1,000,000$, where c_t and e_{t-6}, respectively, are the number of paid claims for all critical illnesses at time t and the number of enrollments at $t-6$, as a result of the 90-day (equivalently 6 payment periods) probation period. The last row reports the aggregate number of cases for different groups and the average incidence rates.

Period	# Claims (All) (1)	# (<40) (2)	# (≥40) (3)	IR_t^x (per million) (4)
201901P2	2	2	0	0
201902P1	1	0	0	0
201902P2	3	3	0	0
201903P1	1	1	0	0
201903P2	1	0	0	0
201904P1	3	3	0	0
201904P2	9	8	1	9
201905P1	10	6	4	7
201905P2	32	23	9	22
201906P1	100	53	47	64
201906P2	150	90	60	87
201907P1	286	178	108	141
201907P2	496	301	195	227
201908P1	500	319	181	211
201908P2	615	347	268	235
201909P1	632	377	255	226
201909P2	1,581	862	719	540
201910P1	1,718	904	814	563
201910P2	1,731	863	868	549
201911P1	1,735	857	878	538
201911P2	1,837	811	1,026	552
201912P1	1,931	860	1,071	556
201912P2	1,953	863	1,090	547
202001P1	2,025	882	1,143	553
202001P2	2,279	982	1,297	610
202002P1	2,381	1,056	1,325	609
202002P2	1,045	459	586	264
202003P1	1,047	462	585	260
202003P2	1,003	440	563	247
202004P1	1,753	709	1,044	430
202004P2	2,559	835	1,724	621
202005P1	2,411	833	1,578	582
202005P2	2,234	851	1,383	539
202006P1	2,219	801	1,418	532
202006P2	2,213	768	1,445	529
202007P1	2,291	751	1,540	544
202007P2	2,275	733	1,542	540
202008P1	2,370	776	1,594	563
202008P2	2,344	757	1,587	557
202009P1	2,336	775	1,561	554
202009P2	2,300	770	1,530	547
202010P1	2,303	785	1,518	547
202010P2	2,660	885	1,775	632
202011P1	2,663	873	1,790	631
202011P2	2,607	869	1,738	619
202012P1	2,554	867	1,687	605
202012P2	2,810	917	1,893	670
Total	52,250	21,272	30,978	430 (Avg)

Table 5: Incidence Rates Comparisons Within Age Groups: *XHB* versus *CII*

This table reports the number of claims, incidence rates of *XHB* and critical illness insurance (*CII*) of across all age groups and within each of the following age groups: <10, 10∼19, 20∼29, 30∼39, 40∼49, and 50∼59. CI6 and CI25 respectively represent 6 and 25 leading critical illnesses. The number of *XHB* enrollment reported in Column (1) is the average of the 6-period trailing enrollments of an age group. The number of paid claims reported in Columns (2) and (3) are the average numbers of reported claims across different payment periods for a specific age group. Columns (4) and (5) report *XHB* incidence rates (IR^x) estimated as the number of paid claims of an individual age group scaled by the aggregate *XHB* enrollment of the corresponding in the lagged 6-periods of the corresponding age range. The reported incidence rates are estimated in each payment period first and then averaged over time. Columns (6) and (7) report *CII* incidence rates (IR^i) estimated as the average critical illness incidence rates of different ages published by the China Association of Actuaries (*CAA*) weighted by the fraction of an individual in total number of participants of a specific age range based on *CAA*. Columns (8) and (9) report the ratios of two incidence rates (IR^i/IR^x) and the associated t-statistics of the ratio minus 1 (reported in the parentheses). Panel A reports the results during the 'stable' claim periods from 201909P2 to 202012P2. Panel B reports the results during the 'stable' periods but excluding COVID-19 lockdown payment periods (202002P2-202004P1).

Group	# *XHB* (6-period lag)	# *XHB* Cases		IR^x (per million)		IR^i (per million)		IR^i/IR^x	
Types of illnesses:		CI6	CI25	CI6	CI25	CI6	CI25	CI6 (t-stats)	CI25 (t-stats)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: 'Stable' Periods									
All Ages	94,039,375	1,804	1,875	460	478	3,192	3,459	7.34 (15.06)	7.66 (15.12)
<10	6,686,520	23	25	81	91	173	254	2.46 (7.47)	3.19 (8.79)
10∼19	4,854,522	9	11	46	54	239	309	6.39 (8.80)	7.21 (7.84)
20∼29	27,647,050	153	162	133	141	1,024	1,132	8.51 (14.50)	8.80 (15.11)
30∼39	28,843,376	475	494	395	411	2,440	2,610	6.45 (17.34)	6.64 (17.38)
40∼49	14,904,129	477	492	768	793	4,910	5,272	6.80 (13.89)	7.07 (14.15)
50∼59	11,103,777	666	690	1,440	1,491	7,986	8,657	6.53 (10.33)	6.85 (10.41)
Panel B: Non-COVID 'Stable' Periods									
All Ages	93,632,114	1,914	1,990	491	510	3,192	3,459	6.53 (64.20)	6.81 (66.74)
<10	6,657,563	24	27	86	98	173	254	2.17 (9.44)	2.81 (11.51)
10∼19	4,833,499	10	12	49	58	239	309	5.54 (11.13)	6.08 (11.60)
20∼29	27,527,318	160	169	139	148	1,024	1,132	8.08 (13.35)	8.30 (14.35)
30∼39	28,718,463	499	519	417	434	2,440	2,610	5.96 (22.83)	6.11 (24.41)
40∼49	14,839,583	509	525	823	849	4,910	5,272	5.98 (52.00)	6.23 (55.72)
50∼59	11,055,689	713	738	1,547	1,603	7,986	8,657	5.72 (12.92)	6.01 (12.71)

Table 6: Logistic Regressions of Mutual Aid and Commercial Insurance Participation

This table presents the logistic regression results based on a survey on mutual aid program participation conducted by Ant Financial. The dependent variable is an indicator of whether a survey participant joined a mutual aid program(*MA*). It reports the regression examining the determinants of mutual aid participation including the following independent variables: i) *AGE* is the natural logarithm of the age of survey participants, ii) AGE^2 is the squared of *AGE*, iii) *TIER* taking a number from 1 to 6; a higher city tier indicates a worse economic development of the city, iv) four indicator variables for respondents' annual income ranges: *INC2* equal to 1 when a respondent's annual income is between CNY50,000 and 100,000 and 0 otherwise, *INC3* equal to 1 when a respondent's annual income is between CNY100,000 and 200,000 and 0 otherwise, *INC4* equal to 1 when a respondent's annual income is between CNY200,000 and 500,000 and 0 otherwise, and *INC5* equal to 1 when a respondent's annual income is more than CNY500,000. v) *INS* equal to 1 if a survey participant purchases a commercial insurance and 0 otherwise. vi) *FEMALE*, 1 for a female respondent and 0 otherwise. vii) whether a respondent participates in a social security health insurance program (*SS*). *t*-statistics are reported in the parentheses. The last two rows report the number of observations and the regression R-squared. Columns (1)-(4) report results for full samples and Columns (5)-(6) report results for subsamples when survey participants are younger than 40 or elder than 40 years old.

	(1) All	(2) All	(3) All	(4) All	(5) <40	(6) ≥40
AGE	0.10***	1.28***	1.24***	1.04***	0.17***	-0.35***
	(7.10)	(15.25)	(14.60)	(12.18)	(9.02)	(-3.05)
AGE^2		-0.24***	-0.23***	-0.20***		
		(-14.38)	(-13.88)	(-11.69)		
TIER			-0.01**	-0.01	-0.02***	0.03***
			(-2.55)	(-0.95)	(-2.68)	(2.94)
INC2				0.25***	0.29***	0.16***
				(12.52)	(12.68)	(3.89)
INC3				0.33***	0.37***	0.22***
				(12.49)	(12.29)	(4.00)
INC4				0.39***	0.45***	0.23**
				(8.37)	(8.23)	(2.40)
INC5				0.24**	0.17	0.45**
				(2.52)	(1.57)	(2.29)
INS			-0.25***	-0.30***	-0.28***	-0.36***
			(-14.28)	(-16.75)	(-14.16)	(-9.59)
FEMALE			-0.08***	0.01	-0.01	0.06
			(-3.92)	(0.01)	(-0.34)	-1.45
SS			0.58***	0.55***	0.57***	0.47***
			(21.37)	(20.26)	(19.06)	(7.35)
INTERCEPT	-0.62***	-1.97***	-2.21***	-2.13***	-1.25***	0.3
	(-16.64)	(-19.17)	(-20.46)	(-19.75)	(-21.68)	-0.76
N	58,320	58,320	58,320	58,320	45,024	13,296
R^2	0.001	0.003	0.01	0.01	0.02	0.01

Table 7: Comparing Exclusively *MA* Participants with Non-exclusively *MA* Participants

This table presents the results of logistic regressions of individuals exclusively participating in *MA* relative to non-exclusively *MA*. The exclusively *MA* group involves mutual aid respondents engaged in mutual aid (*MA*) programs but not purchasing any commercial insurance. Other mutual aid survey respondents include i) the *dual coverage* group involving individuals having *MA* and insurance, ii) the exclusively *INS* group involving individuals purchasing insurance but not engaged in *MA*, and iii) the the *no coverage* group involving individuals neither engaged in *MA* and nor in insurance. The explanatory variables are defined similarly as Table 6. *t*-statistics are reported in the parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The last two rows report the number of observations and the regression R-squared.

	Exclusive MA vs *Dual Coverage* (1)	*Exclusive MA* vs *Exclusive INS* (2)	*Exclusive MA* vs *No Coverage* (3)
AGE	-0.17***	-0.16***	0.14***
	(-7.40)	(-8.21)	(7.01)
TIER	0.02**	0.001	0.01
	(2.01)	(0.21)	(1.02)
INC2	-0.44***	-0.26***	0.38***
	(-14.33)	(-9.30)	(13.15)
INC3	-0.91***	-0.65***	0.50***
	(-22.31)	(-17.11)	(11.39)
INC4	-1.48***	-1.07***	0.30***
	(-18.33)	(-13.63)	(3.09)
INC5	-1.74***	-1.57***	0.17
	(-9.47)	(-8.84)	(0.77)
FEMALE	-0.08**	-0.06*	-0.02
	(-2.37)	(-1.95)	(-0.52)
SS	-0.33***	-0.19***	0.59***
	(-7.24)	(-4.95)	(15.98)
INTERCEPT	0.98***	-0.07	-1.36***
	(12.06)	(-1.08)	(-19.54)
N	23,953	31,229	25,192
R^2	0.03	0.02	0.02

Table 8: Mutual Aid Participation and Future Insurance Purchase

This table presents the logistic regression results based on a survey on mutual aid program participation conducted by Ant Financial. The dependent variable is an indicator of whether a survey participant would plan or continue to buy commercial health insurance after he or she subscribes a mutual aid plan. The key independent variable is *MA*, equal to 1 if a respondent participates in at least 1 mutual aid programs. All other explanatory variables are defined similarly as Table 6. *t*-statistics are reported in the parentheses. The last two rows report the number of observations and the regression R-squared.

	Full Sample						Without Insurance		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All	<40	≥40	All	<40	≥40	All	<40	≥40
MA	0.35***	0.37***	0.25***	0.50***	0.51***	0.49***	0.39***	0.42***	0.21**
	(13.73)	(12.52)	(4.94)	(17.27)	(15.35)	(7.78)	(9.77)	(9.56)	(2.12)
AGE				-0.57***	-0.40***	-1.25***	-0.82***	-0.66***	-1.13***
				(-23.89)	(-12.45)	(-6.65)	(-25.43)	(-15.60)	(-3.65)
TIER				-0.01	-0.02*	0.02	0.001	-0.005	0.028
				(-1.21)	(-1.95)	(1.07)	(0.10)	(-0.35)	(0.91)
INC2				0.38***	0.26***	0.65***	0.36***	0.29***	0.57***
				(11.73)	(7.01)	(9.64)	(8.15)	(5.81)	(5.21)
INC3				0.64***	0.53***	0.86***	0.61***	0.54***	0.72***
				(14.67)	(10.50)	(9.38)	(9.40)	(7.44)	(4.62)
INC4				0.88***	0.74***	1.13***	0.77***	0.70***	0.87***
				(10.58)	(7.64)	(6.90)	(5.58)	(4.47)	(2.97)
INC5				0.70***	0.51***	1.33***	0.59**	0.42	1.36**
				(4.42)	(2.85)	(3.72)	(2.01)	(1.29)	(2.21)
INS				2.14***	1.99***	2.66***			
				(73.37)	(59.96)	(42.43)			
FEMALE				0.37***	0.43***	0.21***	0.38***	0.42***	0.27**
				(10.59)	(10.48)	(2.96)	(7.99)	(7.93)	(2.01)
SS				0.15***	0.21***	-0.13	0.08	0.16***	-0.44***
				(3.67)	(4.50)	(-1.26)	(1.38)	(2.72)	(-3.12)
INTERCEPT	0.85***	0.95***	0.58***	0.61***	0.34***	2.55***	1.36***	0.97***	2.58**
	(54.81)	(51.85)	(19.34)	(7.70)	(3.61)	(3.90)	(12.86)	(8.05)	(2.41)
N	33,929	26,098	7,831	33,929	26,098	7,831	11,274	8,945	2,329
R^2	0.005	0.005	0.003	0.193	0.167	0.274	0.059	0.036	0.026

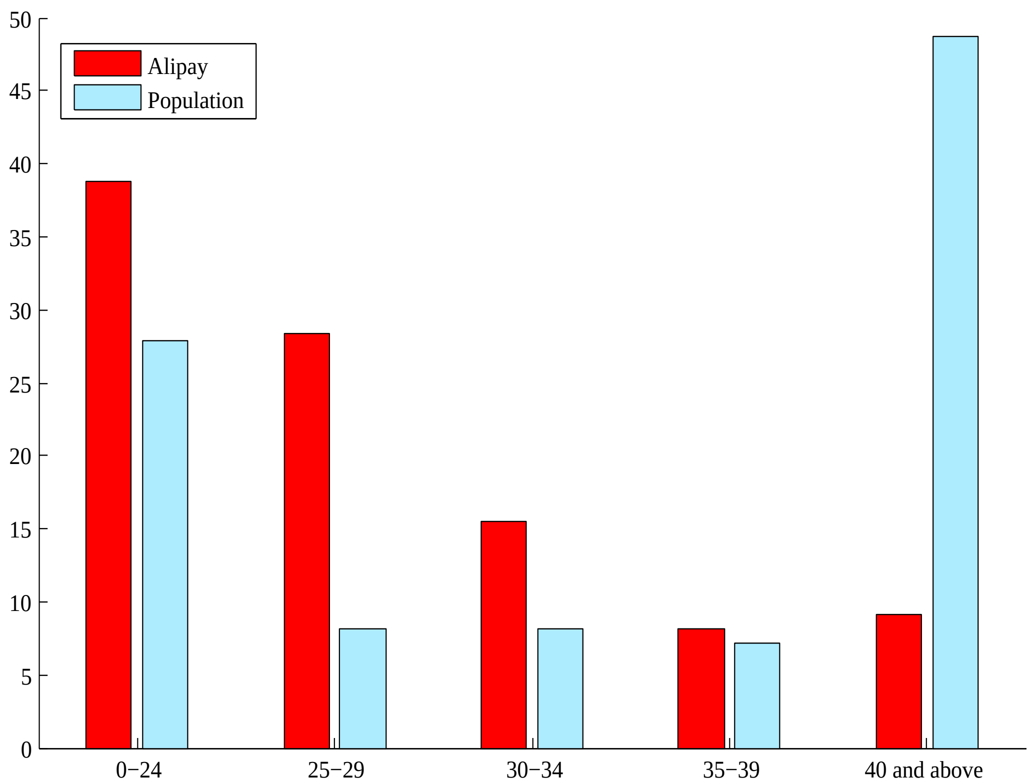


Figure 1: Distributions: Alipay Participants vs. Chinese Population
The figure plots the distribution of Alipay account holders (represented by the red bars) along with the age distribution of the Chinese population (depected by the light blue bars) in various age brackets of June of 2020. Five age brakets are formed: i) below 25, ii) between 25 and 29, iii) between 30 and 34, iv) between 35 and 39, and v) 40 and above. Data sources: the China Mobile Payment Industry Research White Paper and China Population and Employment Statistics Yearbook.

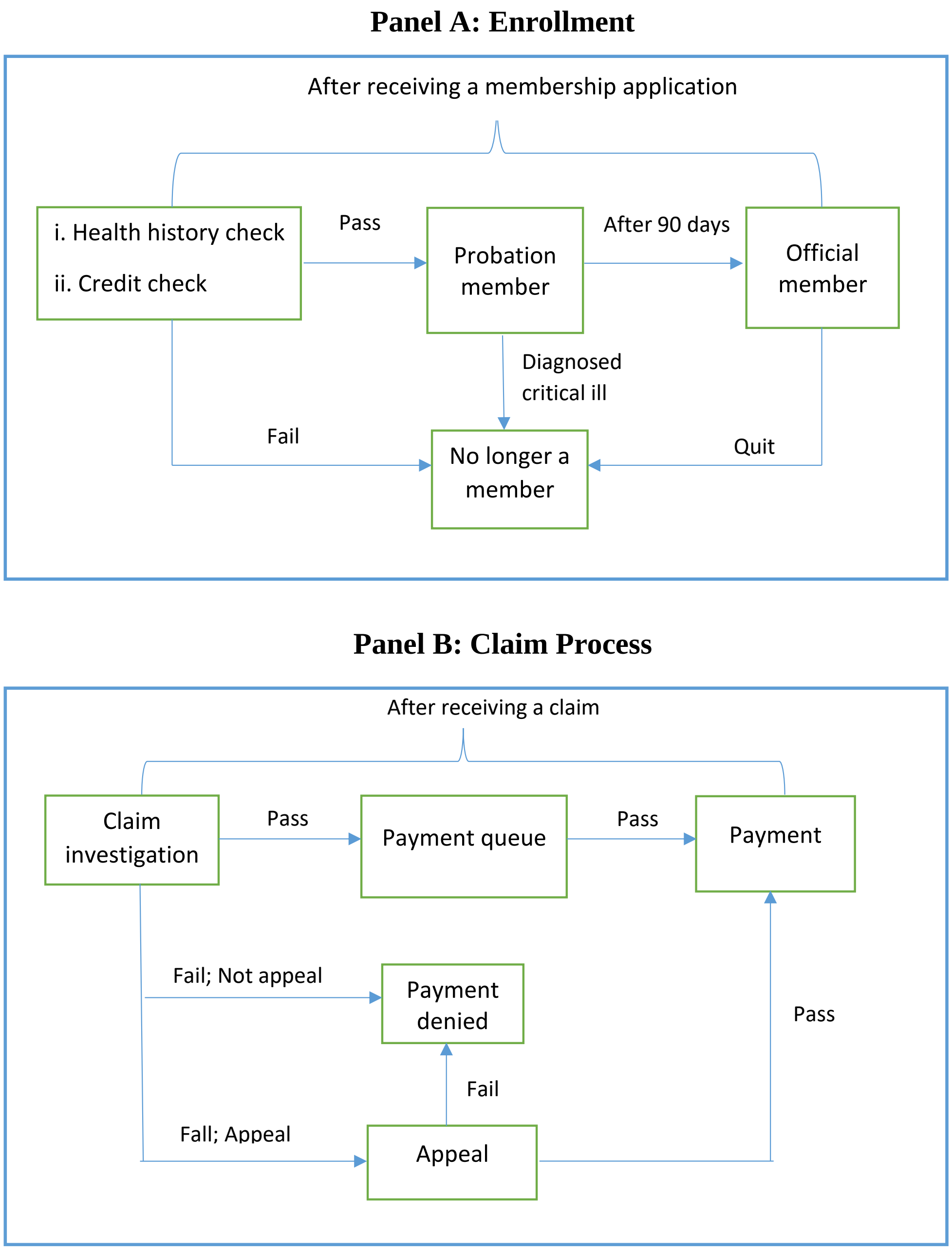


Figure 2: *XHB* Enrollment and Claim Procedures

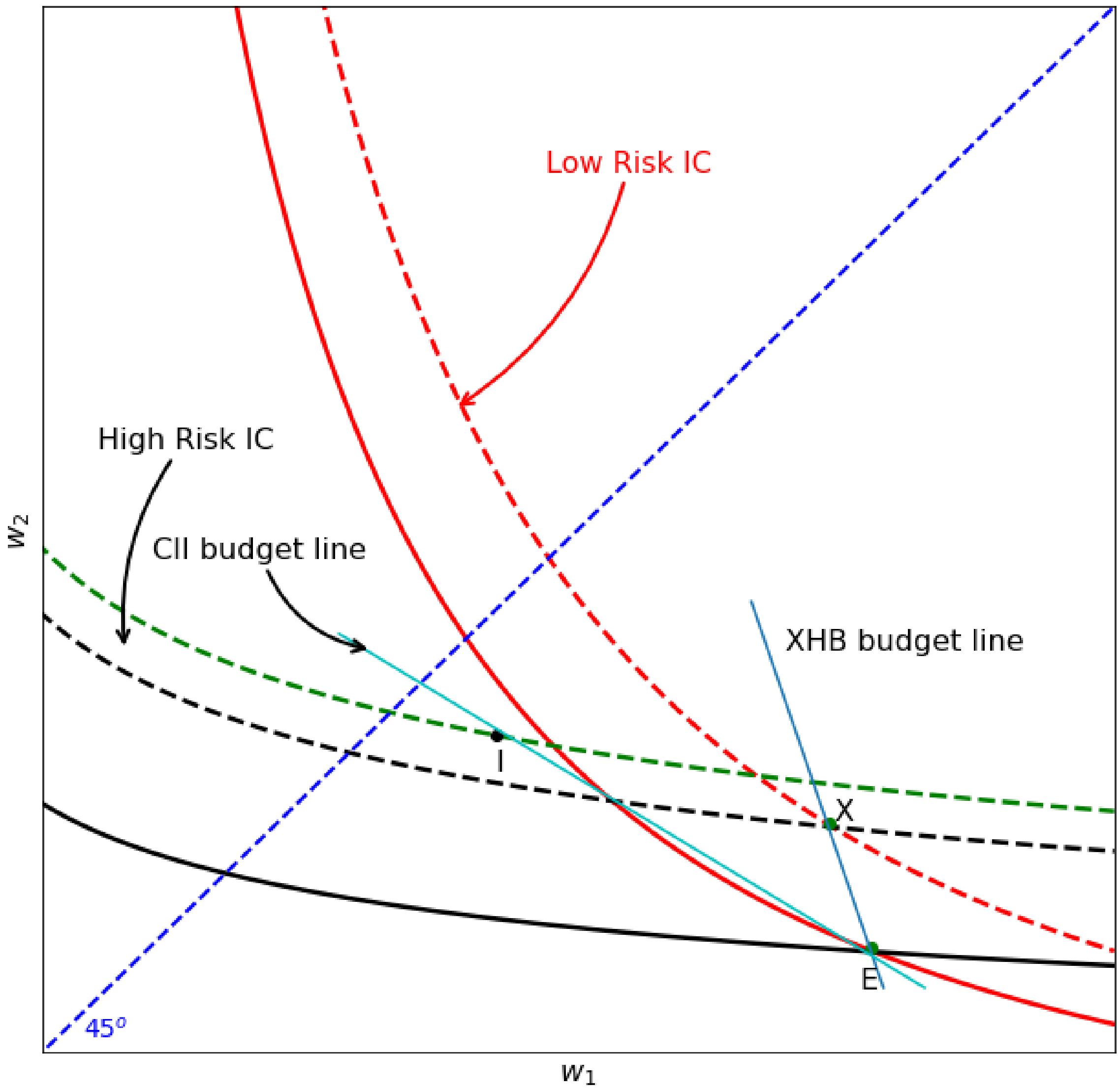


Figure 3: Separating Equilibrium: *XHB* versus Critical Illness Insurance
w_1 represents an individual's aggregate payoff at t and $t+1$ in the no-loss state. w_2 represents the individual's aggregate payoff at t and $t+1$ in the loss state.

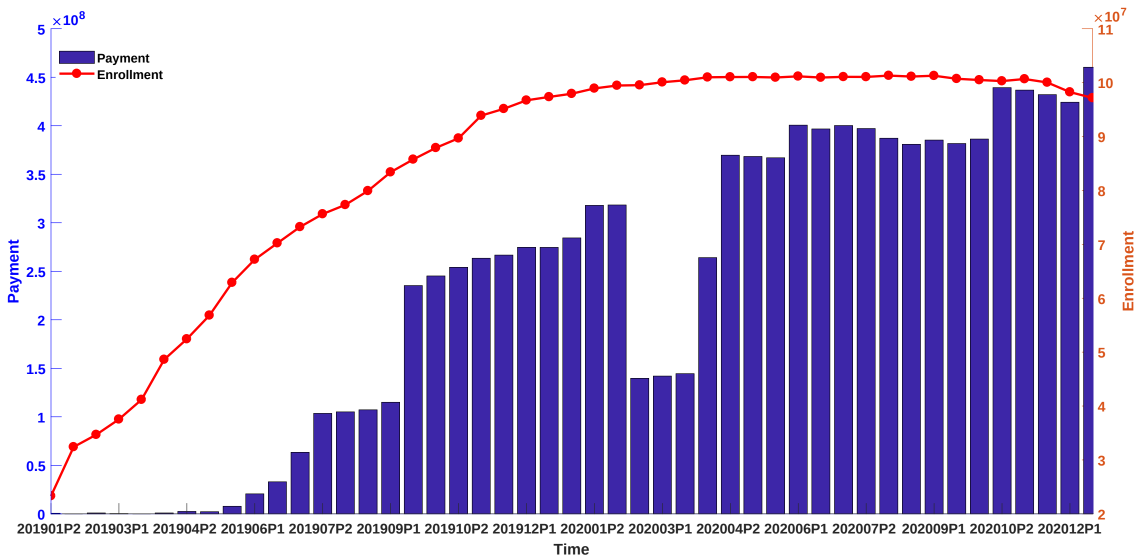


Figure 4: *XHB* Enrollment and Aggregate Claim Payout
This figure plots the number of Xiang Hu Bao enrollments and aggregate claim payouts over time. The curve represents the number of enrollments. Bars represent claim payouts.

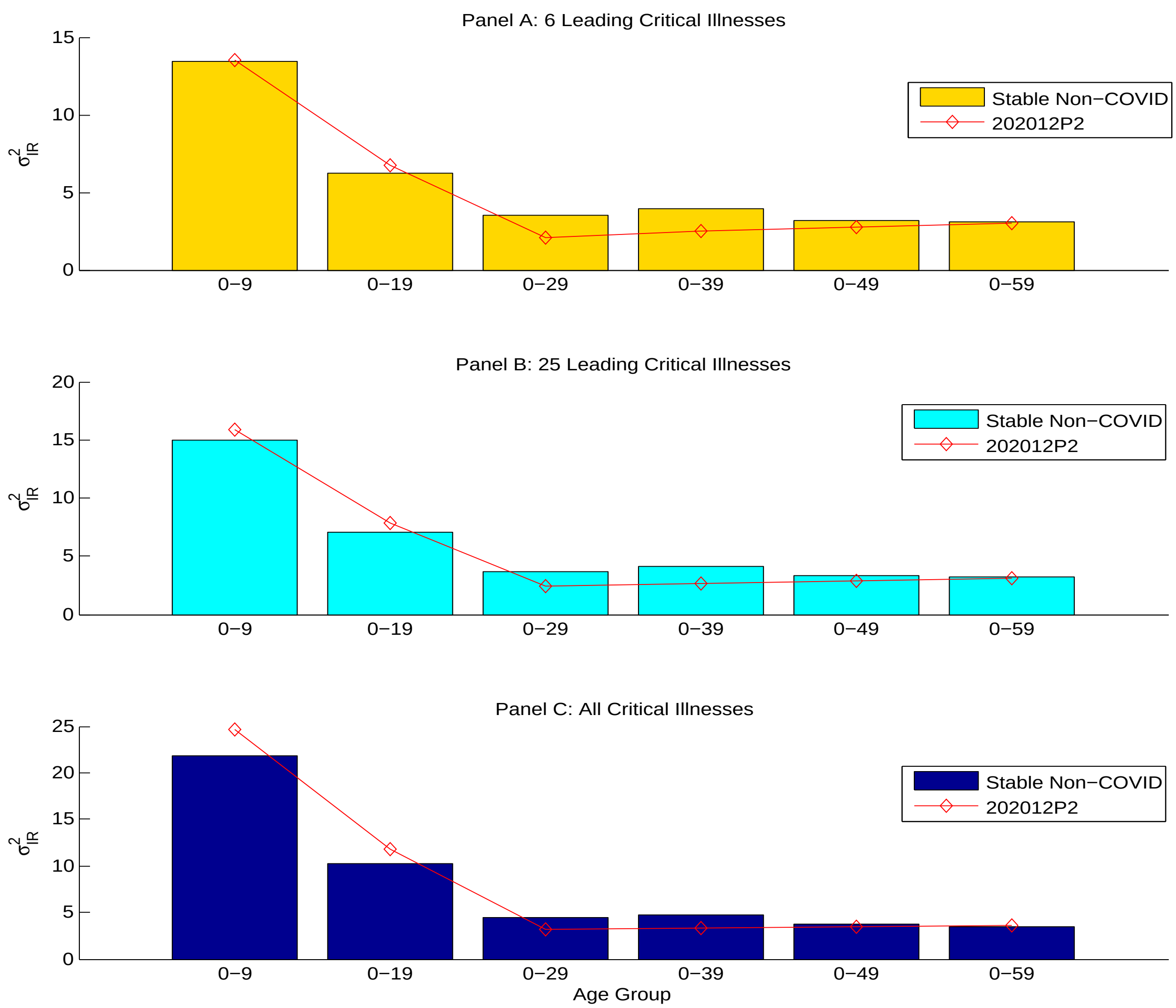


Figure 5: Pooling Effect Across Age Groups

This figure plots the variance of *XHB* incidence rates of different age bandwidths after the adjustment of reduced payment to individuals above 40 years old. Panel A is for the 6 leading critical illnesses; Panel B is for the 25 leading critical illnesses; Panel C is for all critical illnesses. Bars represent the stable non-COVID periods; Curves represent the last payment period of our sample: 202012P2.

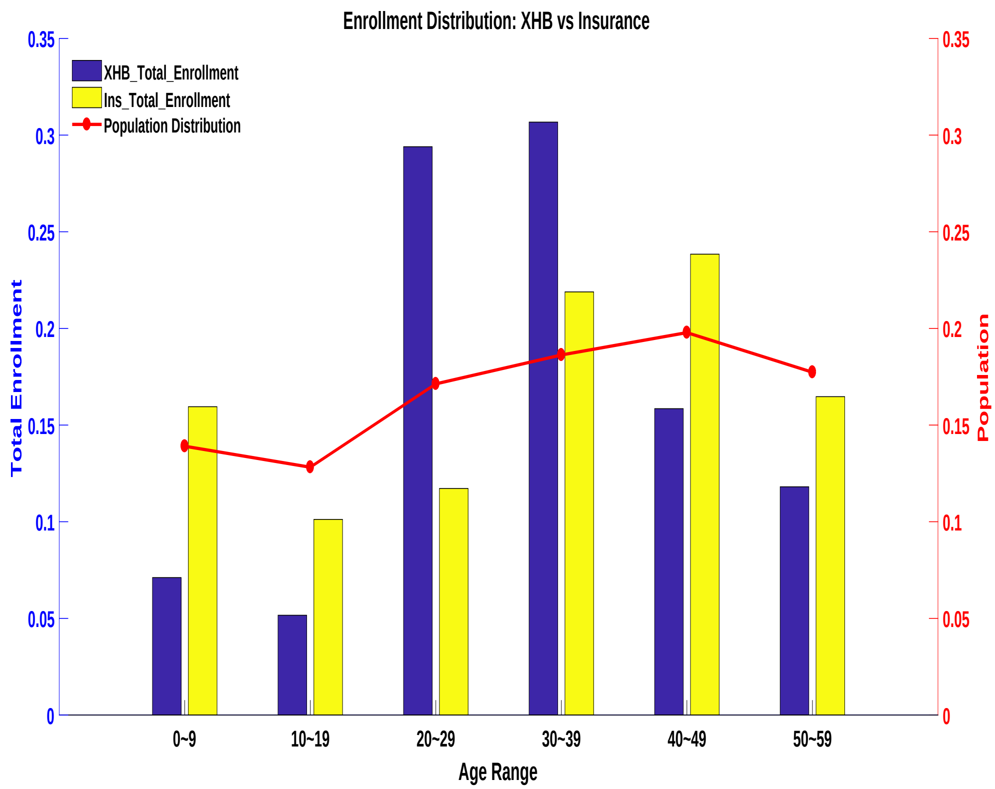


Figure 6: Enrollment Distribution Across Age Groups
This figure plots enrollment distributions of *XHB* (blue bar) and critical illness insurance (yellow bar) across different age groups. The distribution of the population across different ages is also plotted (red curve).

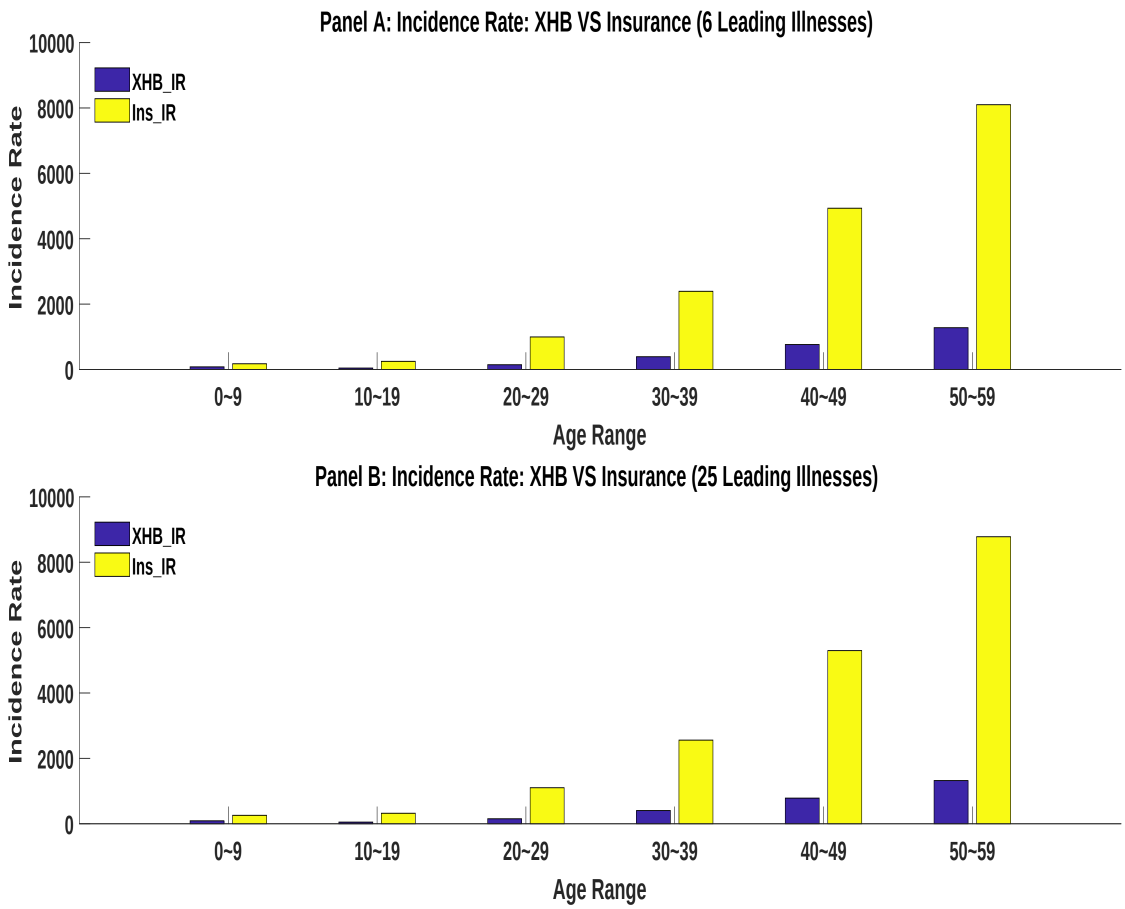


Figure 7: Incidence Rates of *XHB* and Critical Illness Insurance Across Age Groups
This figure plots the incidence rates of age groups for *XHB* and critical illness insurance. The incidence rates for *XHB* are for the stable non-COVID periods.

Internet Appendix

A List of Covered Critical and Rare Illnesses

Panel A: Critical Illnesses

#	Critical illnesses	CI6	CI25
1	Malignant tumor/cancer	Yes	Yes
2	Acute myocardial infarction	Yes	Yes
3	The sequelae of severe stroke	Yes	Yes
4	Major organ transplantation or hematopoietic stem cell transplantation	Yes	Yes
5	Coronary artery bypass surgery (or coronary artery bypass grafting)	Yes	Yes
6	End-stage renal disease (or chronic renal failure uremia period)	Yes	Yes
7	Multiple limbs are missing		Yes
8	Acute or subacute severe hepatitis		Yes
9	Benign brain tumors		Yes
10	Decompensation period of chronic liver failure		Yes
11	Sequelae of severe encephalitis or sequelae of meningitis		Yes
12	Deep coma		Yes
13	Deafness in both ears (no compensation for illness before 3 years old)		Yes
14	Blindness (no compensation for illness before 3 years old)		Yes
15	Paralysis		Yes
16	Heart valve surgery by thoracotomy		Yes
17	Severe Alzheimer's disease		Yes
18	Severe brain damage caused by external forces		Yes
19	Severe Parkinson's disease		Yes
20	Severe degree burns		Yes
21	Severe primary pulmonary hypertension		Yes
22	Severe motor neuron disease		Yes
23	Loss of language ability (no compensation for illness before 3 years old)		Yes
24	Severe aplastic anemia		Yes
25	Aortic surgery with thoracotomy or laparotomy		Yes
26	Severe infective endocarditis		
27	Severe muscular dystrophy		
28	Open surgery for acute hemorrhagic necrotizing pancreatitis		
29	Paralysis caused by polio		
30	Severe progressive supranuclear palsy		
31	Human immunodeficiency virus (HIV) infection caused by blood transfusion		
32	Craniotomy (including ruptured cerebral aneurysm clipping surgery)		
33	Severe heart failure caused by myocarditis		
34	Severe myasthenia gravis		
35	Severe medullary cystic disease		
36	Resection of pheochromocytoma		
37	Idiopathic chronic adrenal insufficiency		
38	Severe elephantiasis		
39	Ebola virus infection		
40	Severe Crohn's disease		
41	Severe chronic recurrent pancreatitis		
42	Severe chronic constrictive pericarditis		
43	Severe systemic scleroderma		
44	Severe primary cardiomyopathy		
45	The third type of osteogenesis imperfecta		
46	Primary sclerosing cholangitis		
47	Aortic dissection aneurysm		
48	Continued vegetative state		
49	Severe necrotizing fasciitis		

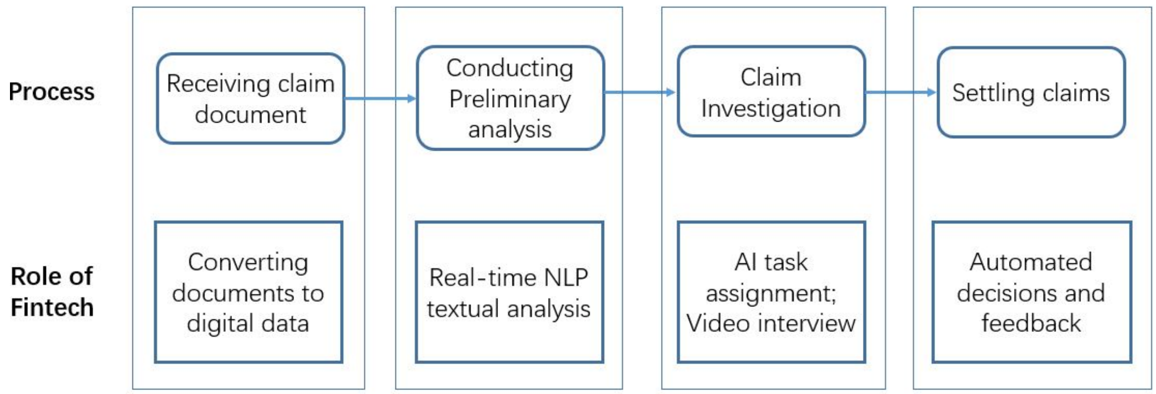
50	Severe hemorrhagic dengue fever
51	Severe Kawasaki disease with coronary aneurysm
52	Severe dementia caused by non-Alzheimer's disease
53	Alveolar proteinosis
54	Severe heart failure caused by pulmonary heart disease
55	Severe autoimmune hepatitis
56	Severe hepatolenticular degeneration
57	Multiple root avulsion of brachial plexus
58	Intellectual disability caused by disease or trauma
59	Severe syringomyelia
60	Tumors in the spinal cord
61	Severe spinal cerebellar degeneration
62	Sequelae of severe spinal vascular disease
63	Progressive multifocal leukoencephalopathy
64	End-stage lung disease
65	Systemic juvenile rheumatoid arthritis
66	Biped amputation due to diabetes complications
67	Autologous hematopoietic stem cell transplantation
68	Aggressive hydatidiform mole (or malignant hydatidiform mole)
69	Hemolytic uremic syndrome
70	Severe cranial fissure meninges or meninges bulging
71	Resection of left ventricular aneurysm
72	Permanent nerve damage caused by bacterial meningococcal meningitis
73	Severe lupus nephritis
74	Pancreas transplantation
75	Severe subacute sclerosing panencephalitis
76	Severe type 1 diabetes
77	Complications of severe intestinal diseases
78	Severe Fanconi syndrome (no compensation for illness before 3 years old)
79	Severe myelodysplastic syndrome
80	Severe spina bifida spinal cord meninges or meninges bulging
81	Human immunodeficiency virus (HIV) infection caused by organ transplantation
82	Severe Eisenmenger syndrome
83	Severe coronary heart disease
84	Severe Creutzfeldt-Jakob disease
85	Fulminant ulcerative colitis
86	Permanent irreversible joint dysfunction caused by rheumatoid arthritis
87	Severe ankylosing spondylitis
88	Severe Reye's syndrome
89	Severe pulmonary lymphangioleiomyomatosis
90	Gangrene caused by hemolytic streptococci
91	Severe facial burns caused by accidents
92	Severe multiple sclerosis
93	Severe hand, foot and mouth disease with complications
94	Thoracotomy for cardiac myxoma
95	Severe acute disseminated intravascular coagulation
96	Severe secondary pulmonary hypertension
97	Severe arthritis
98	Severe Brugada syndrome
99	Severe hemophilia A and B
100	Severe infant progressive spinal muscular atrophy

Panel B: Rare Illnesses

#	Name
1	Gaucher disease
2	Fabry disease
3	Mucopolysaccharidosis
4	Pompe disease

B Fintech-based Claim Process

We conducted several rounds of interviews with *XHB* key individuals and the research team. These communications focused on *XHB*'s financial technology application in its claim process. The following figure outlines the key steps of *XHB*'s claim process and roles played by Fintech.



In the initial step, *XHB* receives claim materials uploaded by through its mobile application. The platform converts documents to digital data via an optical character recognition (*OCR*) system. In case submitted materials are not legible, the system would notify submitters for file replacements. Sorting information based on keywords (e.g., name, age, gender, illnesses, hospitals, payments and etc.), the system generates over 100 reports that will be used in subsequent steps. This results in a more standardized and efficient claim process.

Next, *XHB* performs a preliminary screening on the submitted materials. A claim would be rejected if it does not meet the payment standards. This includes instances where an illness falls outside the coverage list, the patient has a pre-existing condition, or the illness occurred during a probationary period. According to Ant Financial, 50% of submitted claims (100,000 out of 200,000 case submissions in 2020) are rejected in the pre-screening stage. Since this process is entirely managed by the artificial intelligence system, it operates without human intervention. This approach significantly aids *XHB* in reducing its claim adjustment expenses.

In step three, *XHB* launches a thorough investigation on claims passing the first two steps. It includes interviewing claimants and collecting patient documents from hospitals and other third parties, thus it is labor intensive. To improve efficiency, *XHB* develops an artificial intelligence-based dispatching system to arrange claims investigators to tasks optimally, like sending investigators to the nearest hospitals. Investigators update documents and provide their assessment in the online system. Through this method, the AI system assists *XHB* in reducing reliance on human intervention, thereby decreasing labor costs, and enhancing the objectivity of claim settlements.

Finally, *XHB* concludes its decisions and process payments. Claim settlements occur promptly, resulting in three potential outcomes: i) approval with subsequent payments, ii) outright rejection, or iii) classification as disputable claims. The latter are referred to designated specialists, reintroducing the decision stage after receiving specialists' feedback. This process is notably efficient.

In 2020, *XHB* processed payments for 52,682 claims, a figure comparable to the total number of critical illness claims handled by traditional critical illness insurance in China.

C Government Sponsored Critical Illness Insurance Programs

In addition to *XHB* and *CII*, The government also provides critical illness coverage under the 'social security' program. Specifically, these government-provided medical coverage includes the urban employee basic health insurance (*UEBHI*), the urban and rural resident basic health insurance (*URRBHI*), and subsequently combined program for both urban employees and rural residents - urban and rural resident basic health insurance (*URRBHI*) (Zhu, Zhang, Yuan, Zhang, and Zhang, 2017). It extensively covers 95% of the Chinese population (see National Health Security Administration (NHSA): http://www.nhsa.gov.cn/art/2022/3/4/art_7_7927.html.) In 2012, the government-sponsored critical illness insurance was introduced as an extension to the urban and rural combined program (*URRBHI*) to cover critical illness patients' medical expenses (Jiang, Chen, Xin, Wang, Zeng, Zhong, and Xiang, 2019).

Different from *XHB* and commercial *CII* offering fixed amount indemnity, this government-sponsored critical illness insurance reimburses medical expenses, mainly for less expensive drugs and medical treatments on the permitted drug list. Medicines imported from foreign countries are typically not on the drug list, making its coverage quite limited. The government-sponsored critical illness insurance has a low reimbursement rate, lower than 60% of medical expenses. (see National Health Security Administration (NHSA); http://www.nhsa.gov.cn/art/2019/5/13/art_78_3554.html.) For example, in Shanghai, the most economically developed region in China, employer-sponsored critical illness insurance covers merely four types of critical illnesses. According to the Mutual Aid Industry White Paper (2020), the average cost of medical treatment for critical illnesses in China in 2019 was about CNY 330,000, and there was still a gap of about CNY 132,000 to be paid out-of-pocket after 50% reimbursement of medical insurance coverage for critical illnesses.

D Proofs

D.1 Proof of Proposition 1

Taking derivatives of the expected utility specified in Eq. (3) with respect to pool size, N, we have:

$$\begin{aligned}\frac{\partial E[u^x]}{\partial N} &= \frac{\partial E[u(w_t - \pi_t^x)]}{\partial N} \\ &= \frac{\partial u(w_t - p^x k^x(1+\lambda^x) - \Pi_t^x)}{\partial N}\end{aligned}$$

where p^x and λ^x are the expected incidence rate and the administrative cost of *XHB*; Π_t^x is the compensation to *XHB*'s pricing risk.

Π_t^x can be expressed as $1/2A_s[K^x(1+\lambda^x)\sigma^x]^2$. Inserting it to the above expression and setting the expression to be zero to obtain the optimal pool size, we have:

$$\frac{\partial Eu^x}{\partial N} = -c(\frac{\partial p^x}{\partial N} + \gamma\frac{\partial \sigma^x}{\partial N}) = 0$$

where $c = \frac{\partial u}{\partial N}$ and $\gamma = A_s k^x(1+\lambda^x)\sigma^x$. Therefore, $\frac{\partial p^x}{\partial N} + \gamma\frac{\partial \sigma^x}{\partial N} = 0$.
Q.E.D.

D.2 Proof of Proposition 2

The expected utilities of joining *XHB* and *CII* can be expressed as follows:

$$\begin{aligned}E[u^x] &= E[u(w_t - \tilde{\pi}_t{}^x)] + \beta[(1-p_s)u(w_{t+1}) + p_s u(w_{t+1} - l + k^x)] \\ E[u^i] &= u(w_t - \pi^i) + \beta[(1-p_s)u(w_{t+1}) + p_s u(w_{t+1} - l + k^i)]\end{aligned}$$

Setting $E[u^i] = E[u^x]$, we have $E[u(w_t - \tilde{\pi}_t{}^x)] = u(w_t - \pi^i)$.
Following Eq. (4), $E[u(w_t - \tilde{\pi}_t{}^x)] = u[w_t - E(\tilde{\pi}_t{}^x) - E(\tilde{\Pi}_t{}^x)]$. This gives us

$$\pi^i - \pi^x = E(\tilde{\Pi}_t{}^x) = \Pi^x$$

Given that $\pi^x = p^x k^x(1+\lambda^x)$; $\pi^i = p^i k^i(1+\lambda^i)$; $p^x = p^i$; $k^x = k^i$, we have

$$\lambda^i - \lambda^x = \frac{\Pi^x}{k^x p^x}$$

where $\pi^x = E[\pi_t^x]$ and $\Pi^x = E[\Pi_t^x]$. Q.E.D.

D.3 Proof: $E[u_l^x] > E[u_l^i] > E[u_l^e]$; $E[u_h^i] > E[u_h^x] > E[u_h^e]$ is necessary and sufficient for the presence of a separating equilibrium for high- and low-risk individuals

First, we prove that the inequalities $E[u_l^x] > E[u_l^i] > E[u_l^e]$ and $E[u_h^i] > E[u_h^x] > E[u_h^e]$ are a sufficient condition for the existence of a separating equilibrium. In other words, inequalities imply a separating equilibrium among *XHB* and *CII* participants.

As E, not having any coverage, offers the lowest expected utility to both high and low individuals it is not an equilibrium. X offers a higher expected utility to the low-risk individual while I offers a higher expected utility to high-risk individual based on the inequalities. Therefore, a low-risk individual prefers X but a high-risk individual prefers I. This completes the proof of the sufficient conditions.

Subsequently, we prove that $E[u_l^x] > E[u_l^i] > E[u_l^e]$ and $E[u_h^i] > E[u_h^x] > E[u_h^e]$ are a necessary condition for an existence of a separating equilibrium. That is, a separating equilibrium across *XHB* and *CII* participants imply the holding of the inequalities.

We transform the inequalities to two conditions. First, having protection is preferable to being without protection: $E[u^p] > E[u^e]$ (respectively, $E[u^p]$ $E[u^e]$ denote the individual's expected utility with protection and without protection). Second, *XHB* offers a greater expected utility to the low-risk individual while *CII* offers a higher expected utility to the high-risk individual. That is, $E[u_l^x] > E[u_l^i]$ and $E[u_h^i] > E[u_h^x]$.

We start with the proof the first condition. Consider a general case of an individual with an initial wealth w making a choice between having protection offering a coverage of k with a markup of λ or without any protection. The available protection options include *XHB* or a standard insurance policy. We outline the distributions of the individual's payoff both with and without protection below:

State	**Probability**	**Wealth Without Protection**	**Wealth with Protection**
No loss	*1-p*	w	$w - \pi$
loss	p	$w - l$	$w - \pi - l + k$

where π is equal to $(1 + \lambda) * p * k$; w is $w_t + w_{t+1}$ in Section 3.3.

We present the individual's expected utilities with and without a protection as:

$$E[u^e] = [1 - p]u(w) + pu(w - l)$$
$$E[u^p] = (1 - p)u(w - \pi) + pu(w - \pi - l + k)$$

Next, we introduce certainty equivalent of an expected utility function. Consider an individual with a random variable $\tilde{x}$. Then the expected utility of a risk averse agent can be stated as the utility of the certainty equivalent, Γ:

$$E[u(\tilde{x})] = u[\Gamma] = u[E(\tilde{x}) - \Pi]$$

where Π is the risk premium of $\tilde{x}$.

Following the definition, we derive the certainty equivalents for individuals both without protection (e) and with protection (p) as follows:

$$\begin{aligned} \Gamma^e &= w - p * l - \Pi^e \\ \Gamma^p &= w - \pi - p * (l - k) - \Pi^p \end{aligned}$$

Taking the difference of the individual's certainty equivalents, we have:

$$\Gamma^p - \Gamma^e = \underbrace{-\pi + p * k}_{\textbf{Protection Gain}} + \underbrace{\Pi^e - \Pi^p}_{\Delta\Pi}$$

It states that the difference in the certainty equivalents of the individual's wealth with and without a protection is the sum of i) her gain or loss from the protection and ii) the change in risk premium, Π, after having the protection. Given that $\pi = (1+\lambda)*p*k$, we have $-\pi+p*k = -\lambda*p*k$, reflecting the protection's extra expenses. As a result, the choice between having a protection or not depends on the extra cost charged by the protection (since the protection price is not actuarily fair) and the "saving" from a lower risk premium, which is stated below:

$$\Delta\Gamma = -\lambda * p * k + \Delta\Pi$$

That is, $\Gamma > 0$ as long as $\Delta\Pi > \lambda * p * k$. Consider the special case that the uncertainty of $\tilde{x}$ is small, then Π can be expressed as:

$$\Pi = \frac{1}{2} A\sigma^2$$

where A is the individual's risk aversion and σ is the standard deviation of $\tilde{x}$. This is the well-known Arrow (1965)-Pratt (1964) risk premium. We may present certainty equivalents of with protection and without protection as follows:

$$\begin{aligned} \Gamma^e &= w - pl - \tfrac{1}{2}Ap(1-p)l^2 \\ \Gamma^p &= w - \pi - p(l-k) - \tfrac{1}{2}Ap(1-p)(l-k)^2 \end{aligned}$$

Taking the first derivative with respect to k and setting it to be zero, we outline the condition for the optimal indemnity, k^*:

$$k^* = l - \frac{\lambda}{Ap(1-p)}$$

Since $\frac{\lambda}{Ap(1-p)} > 0$, we have $k^* < l$. The expression states that the optimal indemnity is below the loss l. Moreover, as long as the second term above is below l (i.e., the markup, λ, is small relative to the individual's risk average, A, the optimal indemnity is positive. The existence of an optimal protection, either *XHB* or *CII*, indicates that the individual's expected utility with protection exceeds the individual's expected utility without any protection. Thus, we demonstrates the likely existence of a protection dominating no protection, i.e., $E[u^e] < E[u^p]$ for both high- and low-risk individuals. This concludes the proof of the first part of inequality (**??**).

Next, we work on the proof for the second component of inequality (**??**). We first demonstrate that the individual's expected utility with *XHB* is higher than the expected utility with *CII* when the individual's incidence rate, p, is low.

The follow exhibit demonstrates the wealth distribution of the **low-risk individual** with different protections: *XHB* or *CII*.

	(1) Probability	(2) XHB	(3) CII
No loss	1-p^l	$w-\pi^x$	$w-\pi^x-l+k^x$
loss	p^l	$w-\pi^x-l+k^x$	$w-\pi^i-l+k^i$

where p^l is the incidence rate of the low-risk individual; π^x and π^i are the prices of *XHB* and *CII*; k^x and k^i are the indemnity amounts of *XHB* and *CII*: $k^i > k^x$; λ^x and λ^i are the markups of *XHB* and *CII*: $\lambda^i > \lambda^x$.

With *XHB*, the individual's certainty equivalent, Γ_l^x, is:

$$\Gamma_l^x = w - \pi^x - p^l(l-k^x) - \Pi_l^x$$

Alternatively, with *CII*, the individual's certainty equivalent, Γ_l^i, is:

$$\Gamma_l^i = w - \pi^i - p^l(l-k^i) - \Pi_l^i$$

The difference of the low-risk individual's certainty equivalents is:

$$\begin{aligned}\Delta\Gamma_l &= \Gamma_l^x - \Gamma_l^i \\ &= \underbrace{\pi^i - \pi^x}_{\textbf{Price Difference>0}} + \underbrace{p^l[k^x - k^i]}_{\textbf{Protection Difference<0}} + \underbrace{\Pi_l^i - \Pi_l^x}_{\Delta\Pi\textbf{ of low-risk individual<0}}\end{aligned}$$

The first term, the price difference between *CII* and *XHB* (the former minus the later), is positive. The second term, the coverage difference between *CII* and *XHB* (the latter minus the former), is negative. Considering the fact (or assumption) that p^l is low, the impact of the second term on $\Delta\Gamma$ is restricted. The third term, the difference in risk premiums between *CII* and *XHB* (the former minus the latter) of the low-risk individual, is negative, since the individual's uncertainty under *CII* is lower than the uncertainty under *XHB*. Nonetheless, since the low-risk individual concerns less about risk, the impact of the third element on $\Delta\Gamma$ is also limited. Therefore, collectively, $\Delta\Gamma > 0$ is likely to take place for the low-risk individual as long as the magnitude of the first term dominates the effects of the second and third terms.

Finally, we work on the expected utilities of the high-risk individual under *XHB* and *CII*. The wealth distributions of the high-risk individual are specified as below:

	(1) Probability	(2) XHB	(3) CII
No loss	$1-p^h$	$w-\pi^x$	$w-\pi^x-l+k^x$
loss	p^h	$w-\pi^x-l+k^x$	$w-\pi^i-l+k^i$

where p^h is the incidence rate of the high-risk individual.

Like we did for the low-risk individual, the high-risk individual's certainty equivalents with *XHB* and *CII*, are:

$$\begin{aligned}\Gamma_h^x &= w - \pi^x - p^h(l-k^x) - \Pi_h^x \\ \Gamma_h^i &= w - \pi^i - p^h(l-k^i) - \Pi_h^i\end{aligned}$$

The difference of the high-risk individual's certainty equivalents is:

$$\begin{aligned}\Delta\Gamma_h &= \Gamma_h^x - \Gamma_h^i \\ &= \underbrace{\pi^i - \pi^x}_{\textbf{Price Difference>0}} + \underbrace{p^h[k^x - k^i]}_{\textbf{Protection Difference<0}} + \underbrace{\Pi_h^i - \Pi_h^x}_{\Delta\Pi \textbf{ of high-risk individual}}\end{aligned}$$

Once again, the first term on the price difference is positive. The second term associated with the coverage difference (*XHB* - *CII*), is negative. Given p^h is larger than p^i, the impact of the second term on $\Delta\Gamma$ is greater for the high-risk individual. The third term, the difference in risk premiums between *CII* and *XHB* is negative and larger for the high-risk individual since the high-risk individual concerns much more about risk than the low-risk individual. As a result, the impact of the third element on $\Delta\Gamma$ is potentially large. Collectively, $\Delta\Gamma < 0$ is likely to take place for the high-risk individual. It occurs when the magnitude of the first term is dominated by the effects of the second and third terms.

We complete the proof that the second condition is likely.

$$E[u_l^x] > E[u_l^i]$$
$$E[u_h^i] > E[u_h^x]$$

All combined, we have completed the proof that $E[u_l^x] > E[u_l^i] > E[u_l^e]$; $E[u_h^i] > E[u_h^x] > E[u_h^e]$ is a necessary condition for the presence of a separating equilibrium of high- and low-risk individuals. Q.E.D.

D.4 Derivations of individuals' indifference curves

We first derive the indifference curves. Assume there are two individuals, one with a high risk, a high probability of being critically ill (p^h), while the other with a low risk, a low probability of being critically ill (p^h); $p^h > p^l$. Individuals know their loss probabilities while the market does not. The utility functions of the high risk individual and the low-risk individual are follows:

$$E[u^l] = [1 - p^l]u(w - \pi_t) + p^l u(w - \pi_t - l + k)$$
$$E[u^h] = [1 - p^h]u(w - \pi_t) + p^h u(w - \pi_t - l + k)$$

Assume that the original wealth levels in loss and no-loss states are respectively w_1^1 and w_2^1. It is changed to w_1^2 and w_2^2. The indifference curve can be expressed as:

$$[1 - p^j]u(w_1^1) + p^j u(w_2^1) = [1 - p^j]u(w_1^2) + p^j u(w_2^2)\, where\, j = l, h$$

With a slight adjustment, we have the following expression:

$$\frac{\Delta u^j(w_2)}{\Delta u^j(w_1)} = -\frac{1 - p^j}{p^j},\, where\, j = l, h$$

Q.E.D.

D.5 Derivations of slope of budget lines for *XHB* and *CII*

The line EX is the XHB's zero-cost budget line. As plotted in Figure 3, the coordinators of E and X are respectively $(w,\, w - l)$ and $(w - \pi^x,\, w - \pi^x - l + k^x)$. Scaling the difference between the payoffs in loss states (w_2) by the difference between payoffs in no-loss states (w_1), we have the slope of EX to be $\frac{\pi_t^x - k^x}{\pi_t^x}$.

Recall that $\pi_t^x = p_t^x k^x (1 + \lambda^x)$ (Eq. (1)) and insert it in the expression for the slope of EX. This gives us the following result:

$$\frac{\partial w_2}{\partial w_1}|_X = 1 - \frac{1}{p_t^x (1 + \lambda^x)}$$

The slope of the budget line for insurance can be derived in the same way. Q.E.D.

E Ant Financial's Online Survey on Mutual Aid Participation

The original survey contains 12 questions. We include 5 questions directly relevant to this study.

1. Are you currently participating in a social security program?
   - Employer-sponsored social health insurance
   - Urban resident social insurance
   - Other public health care programs
   - Do not participate in any of the above programs

2. Besides social security medical insurance programs, do you currently have other medical insurance?
   - Commercial health insurance
   - Mutual aid program
   - None of the Above

3. How many online mutual aid programs have you participated in?
   - Participating in none
   - Participating in one programs
   - Participating in two programs
   - Participating in three or more programs

4. Select the range of your annual income.
   - CNY 50,000 or less
   - CNY 50,000-100,000
   - CNY 100,000-200,000
   - CNY 200,000-500,000
   - CNY 500,000 or above

5. Do you plan to buy or continue to buy commercial health insurance in the subsequent years?
   - Yes
   - No
   - Uncertain